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CONTROL OF CITRUS INSECTS
AND MITES

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CONTROL OF CITRUS INSECTS AND MITES^{1, 2}

H. J. QUAYLE³

THIS CIRCULAR is intended to give only the more essential facts regarding the control of citrus pests in California. The methods of control directed against such pests are so well organized that details seem unnecessary. To include all the pertinent details, a publication twice the size of this one would be required. For the most part, citrus pest-control work is carried on by associations, coöperative districts, and experienced private organizations, under regulations adopted in the different counties. The owner of a small acreage, who carries on his own pest-control operations, may secure detailed information from local organizations and agricultural officials. Every grower should, of course, be concerned with what materials are applied to his trees, their proper application, and their action on both the trees and the pest.

SCALE INSECTS

The six most important scale insects infesting citrus trees in California are as follows: the red scale, *Aonidiella aurantii* (Mask.); the yellow scale, *A. citrina* (Coq.); the purple scale, *Lepidosaphes beckii* (Newm.); the black scale, *Saissetia oleae* (Bern.); the citricola scale, *Coccus pseudomagnoliarum* (Kuw.); and the soft (brown) scale, *C. hesperidum* Linn. All except the soft scale require more or less regular treatment. This scale is included here because it is frequently found in large numbers on an occasional tree or part of a tree and may be confused in some of its stages with the more injurious citricola scale.

The red, yellow, and purple scales constitute a group having a waxy covering and giving off no honeydew. The injury that these scales cause is due to the feeding alone, which consists of the withdrawal of sap from the tree. The black, citricola, and soft scales, on the other hand, have no waxy covering and give off honeydew. The injury caused by these scales is due not only to the feeding, which is similar to that of the first group, but also to the excreted honeydew, which serves as a medium for the growth of the sooty-mold fungus. This fungus, which may be seen as a black coating on the foliage and fruit, interferes with the normal function of the tree. The red, yellow, and purple scales cause more

¹ Paper no. 431, University of California Citrus Experiment Station, Riverside, California.

² This circular may be considered as a revision of sections relating to control in Bulletin 542, *Biology and Control of Citrus Insects and Mites*, by H. J. Quayle.

³ Professor of Entomology and Entomologist in the Citrus Experiment Station.

direct injury to the tree, as indicated by the greater prevalence of dead twigs and branches, than the black, citricola, and soft scales. The difference is assumed to be due to the more toxic salivary secretion in the first group. The scale insects discussed here may be distinguished by referring to figure 1.

Fig. 1.—Scale insects. *A*, Red scale. (The yellow scale is similar to the red scale in shape, but much more yellowish in color.) *B*, Purple scale. *C*, Black scale. *D*, Citricola scale. *E*, Soft scale.

RED SCALE

Of the different insects that attack citrus trees, the red scale, *Aonidiella aurantii* (Mask.), is one of the most difficult to control. This statement applies particularly to red scale in those districts where fumigation with HCN (hydrocyanic acid) does not give satisfactory results and where spraying as a substitute has not been satisfactory. Until about twenty-five years ago, treatment by fumigation gave good control of the red scale; then poor fumigation results were noted in one or two limited areas. The size and number of such areas have increased considerably up to the present time. Except in these so-called "resistant areas," fumigation is still a satisfactory treatment; and even in these areas it is generally the best single treatment.

Red Scale in Resistant Areas.—The term "resistant red scale" applies to those scales which, while not immune to HCN, require such high dosages for satisfactory results in practical fumigation that the tree is likely to be injured; with ordinary dosages the tree is not likely to be free from scale even for a single year. An area in which this resistant red scale predominates is spoken of as a "resistant area." Such areas are not sharply delimited, however, because different degrees of resistance are recognized in different groves in the same general area, and the phenomenon of resistance appears to be gradually developing in new areas.

In general, it is in the higher foothill areas, particularly where lemons are grown, that difficulty is experienced in obtaining satisfactory fumigation results. These areas include that about Arlington and Corona in Riverside County; most of the foothill lemon area in Orange County; East Whittier, North Whittier Heights, and certain areas around Glendora, Charter Oak, Covina, and elsewhere in Los Angeles County; and parts of western San Bernardino County.

Fumigation for Red Scale in Resistant Areas.—For the resistant red scale, the highest dosage that can be used, with due regard to safety to the tree, should be employed. This dosage will vary according to the locality, the season, and the variety of tree. It is well recognized that the trees in the coastal areas are more susceptible to HCN injury than those in the interior areas; that the trees are usually more tolerant to HCN in the winter season; and that of the citrus tree varieties, the lemon is usually the most tolerant. Lemon trees that have been treated over a period of years with the bordeaux spray for brown rot, may, however, be more or less susceptible to HCN injury even in the winter season.

It is important that any treatment for the red scale should begin before the infestation of the scale is heavy; otherwise, it is difficult to

reduce the population sufficiently to prevent injury before the next treatment. Where infestations are heavy and the scales are particularly difficult to control, it may be desirable to apply two treatments a year for a short time in order to reduce the infestation to such a point that little injury will be done. This program should not be confused with the so-called "double fumigation" practiced in red-scale protective districts.

*Time Interval in Double Fumigation.*⁴—The growers in several districts in California have formed what are known as Red Scale Protective Districts. Such organizations carry on intensive control or attempted eradication of the red scale, and the common treatment is two fumigations separated by a short interval. The object of the interval is to allow the scales that were in the most resistant stages at the time of the first fumigation, and that would be most likely to survive, to develop out of such stages and into more susceptible stages by the time of the next fumigation.

The practical working of such a program depends upon the fact that all the insects except those in but one or, at most, two stages are killed in the first fumigation. The time interval then depends upon the time and uniformity of development of insects in the period between the two fumigations. From the rate of development of the different stages, it may be calculated that where the life cycle requires about 75 days, which may be an average for the summer months, the interval between fumigations will be about 30 days. If several stages of the red scale survive the first fumigation, or if there is great variation in the time of development, it is not possible, from the standpoint of the condition of the insect, to select any one time for the second fumigation that will find all the survivors of the first fumigation in a susceptible state.

Fumigation for Resistant Red Scale on Oranges.—On account of unfavorable weather and the presence of heaters or covercrops, or both, in the groves, only a limited amount of fumigating can be done during the winter season. Nevertheless, in those orange groves where difficulty has previously been experienced in controlling the red scale, winter fumigation should be carried on. A period of cold weather, which usually occurs in the early winter, brings about a greater dormancy of the tree; consequently, higher dosages of HCN may be used and better results secured on the scales at this season than at any other, the season usually extending from the middle of December to the end of February.

The fumigation dosages used in the winter season in the coastal districts are 20 to 24 cc (cubic centimeters), and in the interior districts, 24 to 28 cc HCN.

⁴Quayle, H. J. Time interval in double fumigation. California Citrograph 26:4. 1940.

The next best season for fumigation is during midsummer and very early fall, or from the latter part of July until October. The orange tree is not so susceptible to injury at this time as it is later in the fall, particularly during the month of October of most years. The midsummer season permits treating heavy infestations of red scale that would cause much more injury if allowed to go until winter. Where the spray-fumigation treatment is employed, the fumigation may follow the spray in from one to two weeks, the preferable time to spray oranges being in August or early September. The summer fumigation season may start a week or two earlier on navels than on Valencias because there is less likelihood of injury to the larger-sized fruits on the navel tree. The old Valencias should be picked before the treatment, but it is not always possible to have this done. If black scale (see "Spraying for Black Scale," p. 11) is also present, as it often is, the summer treatment may be delayed somewhat in certain years because the hatch of the black has not been sufficiently completed.

The summer fumigation dosages in the coastal areas are from 16 to 20 cc, and in the interior, from 20 to 24 cc HCN.

Fumigation for Resistant Red Scale on Lemons.—The problem of the resistant red scale on lemons is rather more serious than that of the red scale on oranges. A greater proportion of lemons are on the higher, warmer locations, and the build-up of population of the insect is more rapid under these conditions. Also, lemon fruits are present on the tree the year round, and it is on the fruit that the red scale is most likely to survive the fumigation. The factors favoring the case of the lemon include the longer winter and spring fumigation season, when the best results may be expected, and the fact that in the spray-fumigation treatment (see "Spray-Fumigation Treatment for Red Scale on Lemons and Oranges," p. 9) a heavier and consequently more effective type of oil may be applied to the tree.⁵

The winter and spring fumigation season for the lemon extends from December to, usually, the end of April. During some years, treatment toward the end of this season may burn the new growth, but if the young fruits are not affected, the injury to the growth alone is not considered serious.

The fumigation dosages in the coastal areas are 22 to 24 cc, and in the interior, 24 to 28 cc HCN.

Fumigation for Nonresistant Red Scale.—In those areas where fumigation for the red scale need not be repeated oftener than every second

⁵ Recent developments involving the incorporation of rotenone extractives, (p. 9) make the use of lighter oils more effective on the red scale although such oils are less lasting on the citrus red mite.

year, or where a heavy infestation may be cleaned to such a point that no damage occurs for a single year, red scale may be considered non-resistant. The fumigation treatment described for resistant red scale will apply in general for the nonresistant scale, except that lower dosages may be used, winter fumigation is less important, and the spray-fumigation treatment need not be considered unless there are other pests, such as the citrus red mite, or red spider.

When it is well established that the red scale is easy to kill, or non-resistant, a greatly reduced dosage will give a high degree of control.⁶ But because nonresistant areas cannot generally be positively and sharply defined and because of the danger of too great a reduction in dosage, only a reasonable reduction or the avoidance of the extremely high dosages is recommended.

On oranges in the coastal areas, the dosages for the nonresistant red scale are 16 to 20 cc, and in the interior, 20 to 24 cc HCN. The same or slightly higher dosages may be used on lemons.

Spraying for Red Scale on Lemons.—Because of the greater likelihood of injury to trees during hot weather, the spraying of lemon trees is better deferred until October and November. In the case of heavy infestations of red scale or of red scale and red mite, earlier spraying may be necessary, followed by fumigation. Medium or heavy-medium oil is used at a strength of 2 per cent as an emulsion or $1\frac{2}{3}$ per cent as an emulsive.⁷ Where the infestation of red scale is light and the red mite is prevalent, this spray may be sufficient to take care of both pests. (Such a situation may occur in the eastern part of Los Angeles County and the western part of San Bernardino County.)

Spraying of lemons may also be carried on in the spring, in April and May, where preferably the old crop of fruit has been picked. This treatment will take care of the red mite, which may be present at this time, until fall.

The picking of the lemons should take place before the spraying or should be delayed as long as possible after the spraying to avoid difficulties in the coloring of the fruit in the packing-house.

Extractives of rotenone-bearing plants, when properly incorporated

⁶ Lindgren, D. L. Factors influencing the results of fumigation of the California red scale. *Hilgardia* 13(9):491-511. 1941.

⁷ The term *emulsive*, or *emulsive spray oil*, refers to a spray oil in which the emulsifier is soluble in the oil itself, and the solution contains 98 or 99 per cent oil. In an *emulsion* the emulsifier is dissolved in water, and the mixture contains but 80 or 85 per cent oil; hence the difference in strength of the two types of spray. The tank-mix spray, developed by Dr. R. H. Smith, consisted of straight oil plus blood-albumin spreader; which, with proper spray-tank agitation, produced a quick-breaking emulsion. This represented an important contribution in the development of petroleum oil sprays and was the forerunner of the emulsive-oil spray, which has at the present time largely replaced the tank-mix spray, and which is used at the same strength.

in oil by means of certain mutual solvents, add to the effectiveness of oil sprays on the red scale.⁸

Spraying for Red Scale on Oranges.—Since the orange tree is more susceptible to oil-spray injury than the lemon, particularly in the interior districts, the heavier oils necessary for the control of red scale on lemons are likely to affect the orange tree adversely. For this reason a medium oil is as heavy as should be used on oranges, and even this grade is too heavy for use in certain districts, especially in the interior. Sprays recently tested at the Citrus Experiment Station, in which such a toxicant as rotenone is incorporated in oil, may make possible the more effective use of oils of even lighter grades than those in use at the present time.

August and September are probably the best months for spraying oranges. In October there may be more detrimental tree reaction, particularly with reference to the set of crop the following year, than later, in November, when spraying of Valencias may be warranted if a light-medium oil is used. Spraying as late as November may interfere with the proper coloring of navels. In the past year a considerable amount of spraying has been done during the winter and spring with a light-medium oil and toxicant for the red scale on both lemons and oranges, particularly on navel oranges after the fruit has been picked.

Spray-Fumigation Treatment for Red Scale on Lemons and Oranges.—Where heavy infestations of the red scale persist in spite of repeated treatments, either on lemons or on oranges, both spraying and fumigating may be necessary, and this program is generally relied upon to give the best results.⁹ It will, at the same time, control the red mite.

On lemons, a medium or heavy-medium oil, at a strength of 2 per cent as an emulsion or $1\frac{2}{3}$ per cent as an emulsive, is used in September, October, or November, or in April or May if the old fruit has been removed (see "Spraying for Red scale on Lemons," p. 8). The fumigation may follow in a week or two, may be postponed for a few months, or may precede the spraying. (See "Fumigation for Resistant Red Scale on Lemons," p. 7.)

On oranges, a light-medium or medium oil, at a strength of 2 per cent as an emulsion or $1\frac{2}{3}$ per cent as an emulsive, may be applied in August or September and followed by fumigation in a week or two or after four or five months (see "Fumigation for Resistant Red Scale on Oranges," p. 6, and "Spraying for Red Scale on Oranges," above).

Where the red scale tends to increase in spite of past treatments, it is necessary to resort to repeated treatments at short intervals for a year

⁸ Ebeling, Walter. Toxicants and solids added to spray oil in control of California red scale. Jour. Econ. Ent. 33:92-102. 1940.

⁹ Quayle, H. J., and Walter Ebeling. Spray-fumigation treatment for resistant red scale of lemons. California Agr. Exp. Sta. Bul. 583:1-22. 1934.

or two. If these treatments consist of fumigation only, a high dosage should be used at least once during the year, in the winter months. If a spray-fumigation treatment is used, the spray should be applied thoroughly and then followed, preferably, by winter fumigation with a high dosage.

BLACK SCALE

For the control of the black scale, *Saissetia oleae* (Bern.), two principal methods are available, namely, fumigation and spraying. Two conditions relating to the insect itself influence the choice of treatment and time of application; these conditions are the increased resistance of the insect in some areas to HCN and whether there is one life cycle or two in a year.

The black scale in the interior areas has a single life cycle in a year, while that in the coastal areas may have two life cycles overlapping more or less. Where there is considerable uniformity in development, as is the case with the black scale, the time of treatment is influenced by the presence of susceptible stages of the insect. In the warmer, interior areas, the younger or susceptible stages are present from midsummer through the fall months. The time for beginning treatment in these areas is when most of the eggs have hatched (late July or early August) and the fruits, in the case of the orange, are sufficiently sized. Treatments may then be given any time during the succeeding two or three months. In the coastal areas, the younger stages may be present in midsummer and again in midwinter. In both intermediate and coastal areas, the time of treatment is governed more closely by the presence of the younger stages.

Fumigation for Black Scale.—In parts of eastern Los Angeles and western San Bernardino counties, the black scale has been known for a good many years to be difficult to kill by fumigation. Some indication of fumigation tolerance seems to be appearing in this scale in a few other restricted areas. Except in these areas, fumigation is a satisfactory method of control, which may be relied upon to clean a heavy infestation and to make further treatment usually unnecessary for a couple of years.

The dosage in the coastal areas is from 16 to 18 cc, and in the interior, from 18 to 22 cc HCN. The presence of a few red or purple scales may make it desirable to raise these dosages somewhat, particularly on lemons. Fumigation should be carried on as soon as possible after the appearance of the young or most susceptible stage of the insect, especially in the case of Valencias that have the old fruit still on the trees. As previously stated, there are two seasons for treating for black scale in the coastal areas.

Spraying for Black Scale.—The black scale, which lacks the firm waxy covering that protects such scales as the red, yellow, and purple, may be satisfactorily controlled by oil sprays and yields to oil sprays of the lighter grades, which are not so detrimental to the tree. These sprays are also valuable for the control of the red mite, which may be present in much of the black-scale area. A light-medium oil is used at a strength of 2 per cent as an emulsion or $1\frac{2}{3}$ per cent as an emulsive.

Recent work¹⁰ has shown that the oil content of the spray may be reduced to $\frac{1}{2}$ to 1 per cent when rotenone is added.¹¹ The reduction in the amount of oil is important where there may be unfavorable tree reaction on account of the locality or season and where water spot is likely to occur in conjunction with winter rains, as in the San Gabriel Valley, on navel oranges.

The most favorable season for spraying oranges is usually from the middle of July to the middle of September. Lemons may be sprayed later (October and November) if the scales are not too far advanced. The picking of lemons should occur before, or be delayed as long as possible after, oil spraying. Where some red scale is present, a medium oil may be used in both intermediate and coastal districts on oranges as well as on lemons; but because of the tree reaction, the use of this grade of oil would not be warranted in the interior districts. In the intermediate area (eastern Los Angeles County), the water spot on navels is a hazard, also, with the heavier grades of oil and even with light-medium oil at full dosage.

Sulfur Dusting for Black Scale.—Sulfur dusting for the citrus thrips has value in some sections in keeping the black scale down to such a point that the interval between the more effective treatments of fumigating or spraying may be prolonged. Sulfur also has value in that it evens the hatch by killing the young that appear early and thus makes the later treatment of fumigation or spraying more effective. It also tends to free the tree of the sooty-mold fungus, which grows in the honeydew given off by the black scale.

Sulfur dusting must be avoided in hot weather and on this account cannot be used safely later than June; it should be used with due caution even in that month or earlier. Since black scale may continue hatching until after midsummer, sulfur applications cannot be continued long

¹⁰ Boyce, A. M., J. F. Kagy, G. L. McCall, and J. P. LaDue. Black scale control. Summary of studies with low dosages of oil with rotenone-bearing materials. California Citrograph 25:314, 342-44. 1940.

¹¹ The amount of extractives of rotenone-bearing plants (extractives 34 per cent rotenone) commonly used is 11 per cent in $\frac{1}{16}$ per cent of solvent to 100 gallons of spray. Powdered rotenone-bearing materials incorporated in oil sprays have been in use in the coastal areas for the past few years, but such sprays are less effective than those in which extractives have been used as indicated here.

enough to be relied upon as a general method of control. In the cooler sections, sulfur is of no value.

PURPLE SCALE

The purple scale, *Lepidosaphes beckii* (Newm.), occurs only in the coastal areas of southern California; hence control measures are influenced less by variations in climatic conditions than is the case with the other scales thus far discussed.

The time for treatment for the purple scale is during the summer and fall. While the appearance of the younger and more susceptible stages of this scale is less uniform than that of the black scale, it is rather more uniform than that of the red scale. The time of hatch of the purple scale is therefore one of the factors that influence the time of treatment, which may be as early as July and as late as November, although August and September are usually the preferred months. Since the black scale is often associated with the purple, the time of treatment will be influenced also by the hatch of the black scale. Winter fumigation has not proved satisfactory for control of the purple scale; this is generally attributed to the difficulty of killing the eggs in the colder weather.

The best single treatment for purple scale is fumigation with a dosage of from 18 to 20 cc HCN, if possible. It is often necessary to spray also with light-medium or medium oil at 2 per cent as an emulsion or 1 $\frac{2}{3}$ per cent as an emulsive before or after fumigation. In cases where the grove is generally sprayed, the trees infested with the purple scale may in addition be spot-fumigated; and where the grove is generally fumigated, the trees with purple scale may be spot-sprayed. The reason for such a program is that the purple scale is not so generally distributed in a grove as is the case with some of the other scales, yet the double treatment is often necessary to secure satisfactory results.

A scale insect closely related to the purple scale is Glover's scale, *Lepidosaphes gloverii* (Pack.), which occurs in a restricted area in Orange County. It has occurred there since the early days of the citrus industry but seems not to have spread to other sections. The control measures suggested for the purple scale apply also to this species.

CITRICOLA SCALE

The citricola scale, *Coccus pseudomagnoliarum* (Kuw.), is another of the scale insects of citrus in California whose distribution is rather sharply restricted by climatic conditions. Unlike the purple scale, which thrives best in a coastal climate, the citricola scale thrives best in such interior conditions as are represented by Riverside and San Bernardino counties in southern California and by the San Joaquin and Sacramento

valleys in central and northern California. This scale has but one life cycle in a year, and the time of treatment is consequently governed chiefly by the time of appearance of the younger stages, in July, August, and September.

Fumigation was formerly relied upon very generally for the control of the citricola scale, but in recent years the insect has developed such a tolerance to fumigation that the method is no longer applicable over most of the area south of the Tehachapi Mountain Range. In this area, spraying with a light-medium oil at a strength of 2 per cent as an emulsion or $1\frac{2}{3}$ per cent as an emulsive, in August or September, is now the recommended practice. In areas where the citricola scale occurs and the black scale is not a pest of citrus, as in Tulare County and in the Moreno Valley in Riverside County, the strength of the light-medium oil may be reduced to $1\frac{2}{3}$ per cent as an emulsion or $1\frac{1}{2}$ per cent as an emulsive, or rotenone may be incorporated in a $\frac{1}{2}$ per cent light-medium oil (see p. 11). Fumigation, particularly in conjunction with the yellow scale, may be desirable in central California.

Where citricola scale and citrus thrips occur together and two or three applications of sulfur as a dust are applied for the control of the latter (see "Sulfur Dust for Thrips," p. 20), infestations of the scale may be kept in check. Hatching of the eggs of the citricola scale is completed earlier in the season than is the case with the black scale; hence sulfur dusting is more applicable as a control for the citricola scale, the hazard of injury to the fruit by late treatments being avoided.

YELLOW SCALE

The yellow scale, *Aonidiella citrina* (Coq.), thrives in the warmer interior sections of southern California and in the citrus areas of the San Joaquin and Sacramento valleys, as well as in some of the coastal areas. In many respects it is similar to the red scale, although it is more restricted and somewhat different in its distribution. Because of the difference in distribution and the fact that the yellow scale does not occur to any extent on the branches or old wood, control measures for the two scales are usually considered separately.

Fumigation with a dosage of 20 to 24 cc HCN in the summer months or 22 to 24 cc in the winter is recommended for control of the yellow scale in the interior areas. Where possible, with due regard to tree safety, a dosage of at least 18 cc should be used in the coastal areas.

Somewhat better results may be expected from spraying for the yellow than for the red scale, because the yellow scale, unlike the red, does not occur on the old wood, where the spray is least effective. A medium or light-medium oil at 2 per cent as an emulsion or $1\frac{1}{2}$ per cent as an

emulsive, or the same oils with rotenone added,¹² may be used on oranges in midsummer or early fall. A heavy-medium oil at the same strength may be used on lemons in October and November.

Sulfur dusting seems to keep light infestations of the yellow scale in check to some extent in the Highland district of San Bernardino County, but is not to be relied upon elsewhere.

SOFT (BROWN) SCALE

As previously stated, the soft (brown) scale, *Coccus hesperidum* Linn., may be confused with the more important citricola scale. Instead of occurring generally over a planting, however, as does the citricola, the soft scale is usually restricted to an occasional tree or even to a small part of a tree. On this part of the tree, the infestation may be very heavy, but since it ordinarily soon disappears, direct control measures are rarely necessary. The lack of widespread infestations or the failure of an infestation to persist is attributed to the work of parasites, of which there are a number that attack this scale. When warranted, treatment therefore consists first in controlling the ants which are likely to be present and which interfere with the work of the parasites. (For the control of ants, see "Argentine Ant," p. 28.)

MEALYBUGS

Four common species of mealybugs are known to attack citrus trees: the citrophilus mealybug, *Pseudococcus gahani* Green; the citrus mealybug, *P. citri* (Risso); the long-tailed mealybug, *P. longispinus* (Targ.); and the grape mealybug, *P. maritimus* (Ehrh.). Mealybugs do injury in much the same way as the scale insects that have no waxy covering; that is, they extract sap from the trees and give off honeydew in which the sooty-mold fungus grows. When abundant, mealybugs may also cluster around the pedicels of fruits and cause young fruits and sometimes old fruits to drop. The distinguishing character of mealybugs is the white mealy or waxy covering over their bodies. Mealybugs are sometimes confused with the cottony cushion scale, but the latter may be distinguished by the compact, white, fluted or ridged egg sac. The four species of mealybugs discussed here are shown in figure 2.

The citrophilus mealybug was formerly a serious pest over a large acreage of citrus, but the work of parasites introduced from Australia¹³ has, in recent years, kept the populations of this insect below the point of causing economic damage.

¹² See footnote 11, p. 11.

¹³ Compere, Harold, and Harry S. Smith. The control of the citrophilus mealybug, *Pseudococcus gahani*, by Australian parasites. *Hilgardia* 6:585-618. 1932.

The citrus mealybug, the most important species on citrus before the appearance of the citrophilus species in 1913, has, in recent years, been of little importance.

Fig. 2.—Mealybugs. Top row, long-tailed mealybug; second row, citrophilus mealybug; third row, grape mealybug; bottom row, citrus mealybug.

The long-tailed mealybug has never been a very important pest on citrus except in an occasional instance in a restricted area.

The grape mealybug occurs only sparingly on citrus trees and is probably the least important of the four species mentioned.

Mechanical measures, such as spraying and fumigating, have not been satisfactory against mealybugs (with the possible exception of fumigation in the case of the long-tailed species); hence none are here prescribed. The biological method for the control of mealybugs on citrus in California has been successful, utilizing either predators or parasites. When occasional outbreaks occur, this is the method employed.

MITES

There are four species of mites that are pests of citrus trees in California: the citrus red mite, or red spider, *Paratetranychus citri* (McG.); the six-spotted mite, *Tetranychus sexmaculatus* Riley; the citrus rust or silver mite, *Phyllocoptruta oleivorus* (Ashm.); and the citrus bud mite, *Eriophyes sheldoni* Ewing. In general, the coastal areas are more favorable for these pests, although one species, the citrus red mite, occurs as a pest as far inland as Riverside and Redlands. The injuries caused by the four species differ considerably (fig. 3)

The citrus red mite causes the green leaves (fig. 3, *A*) and fruit to assume a pale grayish color and the mature oranges or yellow lemons to become a pale straw yellow. Continued infestation results in leaf drop and sometimes fruit drop, particularly when the injury occurs in the late fall during the period of dry north winds.

The six-spotted mite feeds in restricted areas on the underside of the leaves (fig. 3, *B*). Such feeding causes a distinct depression on the lower leaf surface and a corresponding yellow or yellowish-white raised portion on the upper surface.

Lemon fruits attacked by the citrus rust (silver) mite become white or silvery (fig. 3, *C*).

The injury caused by the citrus bud mite differs from that of the other mites in that it results in deformities of the leaves, fruit, and flowers, and in multiple bud formation (fig. 3, *D*, *E*, *F*).

CITRUS RED MITE

Sulfur, either dry or incorporated in some form in a spray, was formerly the material commonly used for the control of the citrus red mite, or red spider, *Paratetranychus citri* (McG.). Except to a limited extent in certain areas that have weather conditions favorable for the use of sulfur, this material is no longer depended upon.

Oil sprays, such as those employed for scale insects on citrus trees, are effective for control of red mite. One advantage of these sprays is that the mite and some of the scale insects may be controlled at the same

time. Light-medium, medium, or heavy-medium oils are applicable, but the heavier the oil, the more lasting is the effect. The particular grade of oil used depends upon the kind desirable for application for the associated scale insect. If oil is applied for the red mite alone, as is sometimes the case in the spring, the lighter oils are used, especially on the orange, because of their less unfavorable tree reaction at this season.

Fig. 3.—Injury caused by mites. *A*, Pale square in center of leaf caused by feeding of the citrus red mite. *B*, Work of six-spotted mite shown in particular areas on underside of leaf. *C*, Silvery effect due to work of citrus rust mite on lemon. *D*, Deformed lemons and *E*, deformed blossoms caused by the citrus bud mite; *F*, at left, bunchy twig growth caused by the citrus bud mite and, at right, normal twig growth.

Because of the undesirability of applying oil to citrus in some sections, as well as at some seasons when the citrus red mite requires treatment, there has been need for other control material for this pest. This need has been satisfactorily met by the development of a material commonly known as DN-Dust,¹⁴ applied by a dust machine of a particular design developed by the University of California. The amount of DN-Dust used per tree varies somewhat according to size and kind of tree (whether

¹⁴ Boyce, A. M., and J. F. Kagy. Control of the citrus red mite. California Citrograph 26:154, 170-72. 1941.

orange or lemon) and according to the amount of fruit on the tree, but ordinarily from 1 to 1½ pounds is sufficient. The time of application is dependent upon the appearance of the mites in numbers, which is generally in the spring, late summer, and fall. One treatment of DN-Dust usually affords satisfactory control for from two to six months, according to conditions. Two treatments of DN-Dust applied from 10 to 14 days apart may be necessary where a longer period of control is desired.

SIX-SPOTTED MITE

The six-spotted mite, *Tetranychus sexmaculatus* Riley, does sufficient injury to citrus trees in certain areas close to the coast to warrant treatment. The treatment described for the citrus red mite applies also to this species.

CITRUS RUST MITE

The citrus rust or silver mite, *Phyllocoptruta oleivorus* (Ashm.), occurs as a pest in a limited area in San Diego County. It is satisfactorily controlled by sulfur dust, which should be applied before the mites become abundant and before too much injury is done.

CITRUS BUD MITE

The citrus bud mite, *Eriophes sheldoni* Ewing, is a species of mite that has been known to be a pest of lemons in Ventura and Santa Barbara counties only during the last few years. Of the numerous treatments tried, the regular oil sprays¹⁵ used for the black scale, that is, light-medium or medium oil at 2 per cent as an emulsion or 1⅔ per cent as an emulsive in the summer and fall, and ¾ per cent oil with rotenone in March and April, are the most generally satisfactory.

An "inverted" oil-sulfur mixture, consisting of ½ per cent emulsive oil plus 4 pounds of dusting sulfur and a suitable stabilizer per 100 gallons, has also been used in the late winter and early spring. While the results on the mite have been satisfactory with this treatment, there is danger to the fruit and foliage in hot weather, and the application should therefore not be delayed later than March. This spray will also check the citrus red mite.

THRIPS

Two species of thrips, the citrus thrips (*Scirtothrips citri* [Moult.]) and the greenhouse thrips (*Heliothrips haemorrhoidalis* [Bouché]), occur as pests on citrus in California. Two other species, the flower thrips (*Frankliniella occidentalis* [Perg.]) and the bean thrips (*Hercothrips*

¹⁵ Boyce, A. M., and K. E. Maxwell. The new citrus bud mite. California Citrograph 23:109, 152. 1938.

fasciatus Perg.), are found on citrus but do little or no direct injury. The flower thrips occurs commonly in the flowers of citrus trees; it often occurs on the same tree at about the same season as the citrus thrips, but the latter does not occur, except incidentally, in such flowers. The bean thrips is found particularly in the navel of navel oranges, seeking pro-

Fig. 4.—Injury caused by thrips: *A*, work of citrus thrips on lemons; *B*, work of greenhouse thrips on oranges.

tection for hibernation in the late fall and winter. Oranges carrying bean thrips are required to be fumigated before shipment to Hawaii.

The citrus thrips causes a characteristic scarring in the form of a uniform ring around the button, as well as irregular scarring on other portions of the orange. Distorted younger leaves with silvery streaks are indications of the work of these thrips. On lemons, they cause scarring of the fruit (fig. 4, *A*) and also the formation of multiple buds. Severe infestations result in the checking of the new growth of both lemons and oranges.

The greenhouse thrips injures chiefly the older, mature oranges, particularly those that form a cluster. No ring-marking occurs, as with citrus thrips; but the entire surface of the fruit, or a large portion of it, may be of a pale color and roughened texture (fig. 4, *B*).

CITRUS THRIPS

The citrus thrips, *Scirtothrips citri* (Moult.), has been known as a pest, particularly of the navel orange, for many years and has been found chiefly in the citrus areas of central and northern California and the interior areas of southern California. During the last few years it has extended its range, however, farther toward the coast, in Los Angeles and Orange counties, and into the warmer, drier Coachella Valley. It has also become an important pest of the lemon in several sections.

Sulfur, applied either as a dust or as a spray, has until recently been relied upon for control of citrus thrips, and this material is still applicable for oranges.

Sulfur Dust for Thrips.—The sulfur-dusting program, as adapted especially for Tulare County, is as follows:¹⁰

1. One pound of sulfur per tree for average-sized trees, applied during the first warm weather of spring, which is usually between March 20 and April 10.
2. Three-fourths pound sulfur per tree for average-sized trees, applied when the trees are in full bloom, that is, usually, between April 20 and May 1.
3. One-half pound sulfur per tree for average-sized trees, applied during the last week of May or the first week of June, largely to the north side of the tree, to avoid injury in case of warm weather.

In southern California, the early dusting treatment (March 20 to April 10) may be omitted most years because of the cool weather and the scarcity of thrips at that time.

The sulfur-dust program also aids in the control of the citricola scale (see "Combined Treatment for Thrips and Citricola Scale," p. 23).

Sulfur Spray for Thrips.—The sulfur spray for thrips consists of commercial lime-sulfur at a strength of 1½ to 2 gallons per 100 gallons of water. Wettable sulfur is usually added to this spray, using 3 to 5 pounds to 100 gallons of the diluted lime-sulfur. Dry sulfur may be made wettable by mixing 1 ounce of calcium caseinate with each pound of dry sulfur, or by the use of 2 ounces of a preparation of sodium oleyl sulfate plus synthetic resins per 100 gallons of spray. Such a spray is applied immediately after the petals fall. This spray is also of some value against the citrus red mite.

Tartar-Emetic Spray for Thrips.—A new treatment for thrips has

¹⁰ McGregor, E. A. Progress report on sulphur dusting in central California. California Citrograph 15:202, 252. 1930.

been developed, consisting in the use of tartar emetic.¹⁷ This treatment is in many respects superior to the sulfur treatment and is particularly

Fig. 5.—*A*, Boom sprayer. Nozzles are attached to pipes which are fixed vertically but which may be manually operated horizontally to direct the spray to the tree while the spray-rig keeps moving. *B*, Broom guns with eight nozzles, used for sweeping the tree as the spray-rig passes along. These sprayers are adapted to treatment for such pests as thrips and red mite, but are not recommended for general use against scale insects.

adaptable to summer use on lemons, as well as on oranges and grapefruit.

For oranges and grapefruit where the application of the spray is by

¹⁷ Persing, C. O., and A. M. Boyce. Citrus thrips control. Present recommendations for the use of tartar emetic. California Citrograph 26:118, 144-45. 1941.

means of a boom sprayer or with broom guns (fig. 5), the amount is $2\frac{1}{2}$ gallons per average-sized tree, and the formula is as follows:

Tartar emetic	1 pound
Sugar	1 pound
Water	100 gallons

For oranges and grapefruit where the application of the spray is by

Fig. 6.—*A*, Spray-duster built by the Experiment Station and used for applying tartar emetic for citrus thrips. Note the nozzles in the fishtail outlet of the duster. This machine may apply dust alone, liquid alone, or dust and liquid in combination. *B*, Rear view of same machine shown applying but 20 gallons of tartar-emetic spray per acre, the spray being well distributed by the blast of air from the fishtails.

means of a spray-duster (fig. 6), the amount is 20 gallons per acre of average-sized trees, and the formula is as follows:

Tartar emetic	7½ pounds
Sugar	7½ pounds
Water	100 gallons

The time for application of the sprays for oranges and grapefruit is just after the petals have fallen. To protect the fall growth, a second application may be desirable in August.

For lemons where the application of the spray is by means of a boom sprayer or with broom guns, the amount is 2½ gallons per average-sized tree, and the formula is as follows:

Tartar emetic	2 pounds
Sugar	2 pounds
Water	100 gallons

For lemons where the application of the spray is by means of a spray-duster, the amount is 20 gallons per acre of average-sized trees, and the formula is as follows:

Tartar emetic	15 pounds
Sugar	15 pounds
Water	100 gallons

The time for application of the spray for lemons is when the thrips first appear in numbers in the spring, which is usually in May or June. The later this application is made, the longer it is effective. A second application should be made during the last of July or in August. A third application may be desirable some years, later in the fall.

When citrus thrips is injurious in the citrus nursery, the formula given for lemons, where the application is by means of a boom sprayer or broom guns, may be used.

Combined Treatment for Thrips and Citricola Scale.—Heretofore, the control of citrus thrips in Tulare County by means of sulfur has at the same time generally kept the citricola scale in check. If tartar emetic, which has no value against the citricola scale, is to be substituted for sulfur dust for thrips, some provision for the control of the scale will be necessary. The following tentative program, retaining the use of sulfur dust, is suggested.

The first application of sulfur dust, recommended for March or early April (see "Sulfur Dust for Thrips," p. 20), may be omitted. In this program, the time for applying the first sulfur dust (that is, application 2 of p. 20) would coincide with that for the application of the tartar-emetic spray. If broom guns or boom sprayers are used for applying the tartar emetic, sulfur dusting should follow the tartar-emetic spray;

for if the spray is applied after the dusting, it may remove or disturb the deposit of sulfur. If the spray-duster is used, the small volume of liquid applied will probably not interfere with the sulfur deposit, and sprays of tartar emetic can probably be applied over sulfur dust in this manner.

It may be possible, through the use of the spray-duster, to apply sulfur and tartar emetic in the same operation. In this case, a combined program of thrips and scale control would consist of a simultaneous application of sulfur dust and tartar-emetic spray after the petals have fallen, followed by an application of sulfur dust, directed against the citricola scale, two or three weeks later. The thrips would thus be controlled by the tartar emetic, and the citricola scale would have about the same treatment with sulfur as heretofore, because the first dusting in the old program was applied before any young scales were present.

If necessary for better scale control, a third light application of sulfur dust may be made two or three weeks after the second.

GREENHOUSE THRIPS

The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), has, for many years, been known to occur abundantly on an occasional orange tree in the near-coastal sections, but only recently has it become a more or less general pest in a portion of San Diego County. A number of different treatments for control have been tried; the best recommendation that can be made at present is a summer or fall application of a spray consisting of oil and pyrethrum.¹⁸ This treatment is effective against black scale as well as thrips.

The spray consists of a light-medium or medium oil at 2 per cent as an emulsion or $1\frac{2}{3}$ per cent as an emulsive, to which is added $\frac{1}{4}$ to $\frac{1}{2}$ pint of pyrethrum extract to each 100 gallons of spray. The pyrethrum extract contains the equivalent of 20 pounds of pyrethrum flowers, containing 0.9 to 1.0 per cent pyrethrins, in 1 gallon of kerosene.

It may be desirable to supplement the fall spray with another in the spring, using $\frac{1}{2}$ to $\frac{3}{4}$ per cent of light-medium emulsive oil plus $\frac{1}{4}$ to $\frac{1}{2}$ pint of the pyrethrum extract to each 100 gallons of spray. If aphids are present, as may be the case in the spring, $\frac{3}{4}$ pint of nicotine sulfate should be substituted for the pyrethrum.

Where the thrips are abundant and persistent, it may be necessary to follow the regular fall spraying, within 20 to 30 days, with a spray containing $\frac{3}{4}$ pint of pyrethrum extract plus 8 ounces of blood-albumin spreader per 100 gallons.

¹⁸ Boyce, A. M., and Janet Mabry. The greenhouse thrips on oranges. California Citrograph 23:19-20, 28-29. 1937.

In the control of the greenhouse thrips on Valencia oranges, it is important to pick old and off-bloom fruits prior to the fall treatment. Such fruits, unless removed from the grove, should be picked a week before the treatment and thrown in the center of the rows in the sun, to destroy the thrips that may be present. Windbreaks, such as eucalyptus and cypress, and ornamental plants that are also infested and in close proximity should be treated along with the orange trees.

APHIDS

Aphids occur in injurious numbers in the coastal areas and sometimes in the intermediate areas, chiefly during the spring or early summer. The main effect of their feeding is to be noted in the curling of the younger leaves and the resulting stunted growth of the twigs. Young trees suffer more than old ones because the proportion of young growth is larger in the younger trees.

The four species of aphids commonly attacking citrus trees in California are the green citrus aphid (*Aphis spiraeicola* Patch), the cotton or melon aphid (*A. gossypii* Glover), the black citrus aphid (*Toxoptera aurantii* [Boyer]), and the green peach aphid (*Myzus persicae* [Sulz.]). The species and their relative numbers vary considerably with the locality and season.

Treatment should be applied before the young leaves are too badly curled; otherwise it is difficult to get coverage on the aphids in the curled leaves. When the citrus red mite is present at the same time as the aphids, the same spray may be used to check both pests. Formulas for control treatments are as follows:

SPRAY FOR APHIDS ALONE

Nicotine sulfate (40 per cent).....	1 pint
Calcium caseinate	½ pound
Water	100 gallons

SPRAY FOR APHIDS AND RED MITE

Nicotine sulfate (40 per cent).....	¾ pint
Lime-sulfur (commercial).....	1½ to 2 gallons
Calcium caseinate	½ pound
Water	100 gallons

DUST FOR APHIDS

A no. 10 commercial nicotine sulfate and hydrated lime dust

or

Nicotine sulfate	10 pounds
Hydrated lime	90 pounds

The addition of 1 or 2 pounds of ammonium sulfate to 100 pounds of dust increases the effectiveness of the treatment by activating the nicotine. If a home-mixed dust is to be used, a special equipment is necessary to insure a uniform mixing of the nicotine sulfate with the hydrated lime. When such a mixture is made shortly before it is used, it has the advantage of assured freshness.

For the combined control of aphids, red mite, and black scale, a spray consisting of light-medium oil, $\frac{1}{2}$ to $\frac{3}{4}$ per cent, with rotenone¹⁹ may be employed.

ORANGE TORTRIX

Three different species of what are commonly known as "orange worms" nibble or burrow into the rind of the orange. Of the three species,

Fig. 7.—A, Orange showing tortrix moth and burrow of orange tortrix in the rind. B, Work of Fuller's rose beetle on orange foliage.

the only one of importance is the orange tortrix, *Argyrotaenia citrana* (Fern.). The same control measures may be used for the three.

The program recommended for control²⁰ includes the application of cryolite dust in the spring and a cryolite spray, when necessary, in the late summer or fall. The tortrix may do considerable damage in the late spring and summer to the old fruit on Valencia trees (fig. 7, A). To prevent such damage, dusting with cryolite in May or June is recommended, using 1 pound of the following formula per average-sized tree:

DUST FOR ORANGE TORTRIX

Cryolite	50 per cent
Frianite or talc.....	50 per cent

In the interior sections where the tortrix and citrus thrips, or the

¹⁹ See footnote 11, p. 11.

²⁰ Boyce, A. M., and C. O. Persing. Present recommendations for control of orange tortrix. California Citrograph 24:278, 312. 1939.

tortrix, citrus thrips, and red mite may be present at the same time, the following dusts may be used at the rate of $1\frac{1}{4}$ pounds per tree :

DUST FOR ORANGE TORTRIX AND CITRUS THRIPS

Cryolite	40 per cent
Sulfur	60 per cent

DUST FOR ORANGE TORTRIX, CITRUS THRIPS, AND RED MITE

Cryolite	40 per cent
Proprietary DN-Sulfur Dust mixture.....	60 per cent
(Where thrips is not a factor, the standard DN-Dust is used.)	

SPRAY FOR ORANGE TORTRIX

Cryolite	3 pounds
Water	100 gallons
(If aphids are present and require treatment, 1 pint of nicotine sulfate may be added to this spray.)	

Where tortrix persists in considerable numbers year after year on Valencias in the coastal areas, cryolite may be used as a dust in the spring and may be incorporated in an oil employed for scale insects in the summer and fall. This double treatment is recommended only for use on Valencias and only where the infestation is heavy.

One pound of cryolite is used in 100 gallons of the oil-spray mixture, where the gallonage of the spray per tree is for scale insects. Cryolite should not be combined with oil sprays, however, without the sanction of the dealer of the particular oil spray to be used. The extra cost of the cryolite in the oil spray is from 2 to 4 cents per tree, and this may be considered somewhat in the nature of insurance.

For the tortrix on navel oranges, the application of the combination of oil spray and cryolite is sufficient, and the dust treatment need not be used in the spring unless the scarring around the buttons of the young fruit is considered serious. If oil sprays are not to be applied for scale insects, either the straight cryolite spray or dust may be employed as described.

FULLER'S ROSE BEETLE

The work of Fuller's rose beetle, *Pantomorus godmani* (Crotch), shows on the leaves as portions eaten away around the edges (fig. 7, *B*). Such injury generally occurs on leaves in the lower part of the tree and is done during the summer and fall months by the adult beetle. Only rarely is the injury to old trees sufficient to warrant treatment, but it may be severe on recently budded trees or on interplants. More or less injury is done also to the roots of citrus trees by the larvae of this beetle.

When the injury to old trees is sufficient to warrant treatment, the

portion of the trees where the beetles feed may be dusted with cryolite (50 per cent cryolite and 50 per cent Friarite or talc) or may be sprayed (3 pounds of cryolite to 100 gallons of water).

For rebudded trees or young interplants, the aforementioned cryolite dust or spray is satisfactory, or a barrier may be placed around the trunk to prevent the beetles from ascending the tree. The success of the latter method is due to the fact that the beetles cannot fly, but those that may be already on the trees should first be shaken off. The barrier may consist of a sticky banding material, which should not be applied to the tree directly, but over a coating of such material as grafting wax. Or a 4-inch band of cotton batting may be placed around the trunk and tied with a string around the bottom edge. The upper part of the band is then pulled down over the string, a space being left between the cotton and the tree to form a trap in which the beetles become enmeshed. Cotton bands are ineffective when the part of the cotton next to the tree becomes matted.

ARGENTINE ANT

The Argentine ant, *Iridomyrmex humilis* Mayr., is associated with certain scale insects, with mealybugs, and with aphids on citrus trees, because it feeds on the honeydew given off by these insects.

Where the control of such citrus pests as the mealybug and the soft scale depends upon the work of parasites, it is important that interference by the Argentine ant be prevented.

The most satisfactory control for the Argentine ant consists of a poisoned bait placed in containers attached to the tree trunk. Special containers are available for such purpose. The poisoned bait may be made according to the following formula:

Water	11 pints
Tartaric acid	$\frac{1}{4}$ ounce
Benzoate of soda.....	$\frac{1}{3}$ ounce
Granulated sugar	12 pounds
Sodium arsenite (chemically pure).....	$\frac{3}{4}$ ounce
Strained honey	2 pounds

The water is heated until lukewarm; tartaric acid is then added and stirred until dissolved. Benzoate of soda is added and stirred until dissolved. The sugar is added slowly and stirred constantly until dissolved. The height of the liquid in the container is noted, then the container is covered and the mixture boiled slowly for 40 minutes. At the end of each 20-minute period water to equal that evaporated is added. The sodium arsenite is added to 1 pint of lukewarm water and stirred until completely dissolved; this is added to the sirup and stirred thoroughly. Finally the honey is stirred in.

POTATO LEAFHOPPER

During the last few years, the potato leafhopper, *Empoasca fabae* (Harris), has appeared as a pest on citrus trees. This insect begins to feed on the fruit in October and causes irregular spots characterized by collapsed tissue between the oil cells, which becomes grayish and, in the case of old Valencia fruits, later turns brown.

"Potato leafhopper" is the official common name of this insect, but by citrus growers in California it is appropriately called the "green leafhopper," to distinguish it from other noninjurious species that may be present. It occurs most abundantly in Tulare County, but some injury is found occasionally in the interior citrus areas of southern California.

For the control of this pest, the following spray is recommended:²¹

Hydrated lime.....	50 to 100 pounds
Zinc sulfate	15 pounds
Water, to make 300 gallons	

The smaller amount of lime is used on navels, while on Valencias, where longer protection is needed, the amount of lime is increased. This spray acts as a repellent and should be applied only in those groves where the leafhoppers appear in considerable numbers (usually in October in navel groves and somewhat later in Valencia groves). The zinc is added as a corrective for mottle-leaf and probably adds somewhat to the adhesive properties of the spray.

SNAILS

In a few localities in California, snails cause injury to citrus trees by feeding on the fruit and leaves. Two species are involved: the brown snail, or European brown snail, *Helix aspersa* Müller, and the white snail, *H. pisana* Müller. They are most effectively controlled by a bait²² (originated by A. J. Basinger) consisting of calcium arsenate (1 pound) and coarse bran (16 pounds) mixed dry, with enough water added to make the mixture very slightly moist. This may be distributed at the rate of $\frac{1}{2}$ pound per tree into the tree and on the ground beneath by means of a blower or by hand, preferably during the winter and spring months. More than one application may be necessary.

Another bait, in which metaldehyde is the active ingredient, may be purchased in the market. This bait should not be broadcast, but about

²¹ Woglum, R. S., and H. C. Lewis. Whitewash to control potato leafhopper on citrus. Jour. Econ. Ent. 33:83-85. 1940.

²² Lewis, H. C., and J. R. LaFollette. Snail control in orchards. California Citrograph 26:117, 132. 1941.

$\frac{1}{3}$ pound per tree should be distributed in three or four piles beneath the skirt; this may conveniently be done by means of a small cup attached to a 3-foot stick, preferably during the summer and fall months.

COMBINED CONTROL OF TWO OR MORE PESTS

Throughout this discussion attention has been directed to the possibility of controlling two or more pests by the application of a single material. Where practicable, this is very desirable from the standpoint of economy. Some of the examples that have been indicated or that may be inferred are as follows:

- Fumigation for two or more scale insects, pages 5, 6, 7, 8, 10, 12, 13.
- Oil sprays for two or more scale insects, pages 8, 9, 11, 12, 13, 16.
- Oil sprays for scale insects and mites, pages 8, 9, 11, 12, 13, 16.
- Sulfur dust for certain scale insects, for mites, and for citrus thrips, pages 11, 13, 14, 20, 23.
- Poisoned bait for control of ants and, indirectly, the soft scale, pages 14, 28.

Certain combinations of materials may also be applied for the control of two or more pests at the same time:

- Cryolite and nicotine sulfate, for tortrix and aphids, page 27.
- Cryolite and oil, for scale insects and tortrix, page 27.
- Cryolite and sulfur dust, for tortrix, and citrus thrips, page 27.
- Cryolite and DN-Sulfur Dust, for tortrix, red mite, and citrus thrips, page 27.
- Cryolite and DN-Dust, for tortrix and red mite, page 27.
- Hydrated lime and zinc sulfate, for leafhopper and mottle-leaf, page 29.
- Lime-sulfur and wettable sulfur, for red mite and thrips, page 20.
- Lime-sulfur and nicotine sulfate, for red mite and aphids, page 25.
- Lime-sulfur and zinc, for mottle-leaf, red mite, and thrips, page 31.
- Oil-rotenone, for scale insects, red mite, and aphids, page 26.
- Oil and pyrethrum, for greenhouse thrips and scale insects, page 24.
- Oil and sulfur, for citrus bud mite, and red mite, page 18.
- Oil and nicotine sulfate, for aphids and greenhouse thrips, page 24.
- Oil and zinc, for scale insects and mottle-leaf, page 31.
- Tartar emetic and sulfur, for thrips and citricola scale, page 23.

A spray-fumigation treatment (see "Spray-Fumigation Treatment for Red Scale on Lemons and Oranges," p. 9) may be used for the control of certain scale insects and for the red mite and possibly other pests at the same time, but these treatments are applied with an interval of from one week to several months between spraying and fumigating.

The zinc treatment for mottle-leaf, a common citrus-tree ailment not

related to insects or mites, is often combined with the application of insecticides (see p. 30). Elemental zinc (from metallic zinc dust, zinc oxide, and zinc sulfate plus soda ash) has been found to be compatible with oil sprays²³ and is used at the rate of $\frac{1}{3}$ pound to 100 gallons of spray. (Zinc should not be combined with oil spray, however, without the recommendation of the dealer in such spray.) After the mottle-leaf has once been corrected, the spray described above should be sufficient for control, when applied annually at the gallonage used per tree for scale insects.

Lime-sulfur spray is sometimes used in the spring for thrips and red mite, and zinc may be incorporated in this spray to correct the mottle-leaf at the same time. The addition of $\frac{1}{4}$ to $1\frac{1}{2}$ pounds of metallic zinc or zinc oxide to 100 gallons of $1\frac{1}{2}$ per cent lime-sulfur solution is usually sufficient. The range in the amount of zinc is to meet the requirements in accordance with the severity of the mottle-leaf.

²³ Boyce, A. M., C. O. Persing, and E. R. Parker. Combination of cryolite and zinc materials with oil sprays on oranges. Univ. California Div. Entom. News Letter 14:1-2. 1939. (Mimeo.)