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THE CAMPHOR SCALE

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INTRODUCTION

The camphor scale, (*Aspidiotus*) *Pseudaonidia duplex* (Ckll.), is a serious pest of shade and fruit trees, which found its way to southern Louisiana and other Gulf-coast localities about 20 years ago. Although it attacks a large variety of plants, its most important hosts are the camphor-tree, as its name indicates, and the Satsuma orange. The insect is now established in the citrus-growing sections of southern Louisiana, where it threatens to become an addition to the list of major pests.

Shortly after the discovery of the camphor scale in New Orleans in 1920, the insect was found in Alvin, Tex., in the vicinity of Mobile. Ala., and in several places in Mississippi. Later, infestations were found in Houston and Arcadia, Tex. The infestations in Mississippi were thought to have been eradicated, but in 1932 the scale was discovered at Logtown and Bay St. Louis.[2] Originally rather heavy infestations occurred in the Satsuma orange district near Mobile, Ala., but inspections in 1931 revealed only a few scales, and these were in one Satsuma grove and on an abandoned plantation.

There is evidence that New Orleans, La., Alvin, Tex., and Mobile, Ala., represent three separate points of introduction from Japan, for Japanese nurseries were located at Alvin and Mobile, and nursery stock from Japan had also been imported into New Orleans.

Although the finding of the camphor scale along the Gulf coast in 1920 apparently represented the first permanent establishment of the insect in the United States, it appears to have reached this country in earlier years without gaining a permanent foothold. The first

[1] Most of the studies upon which the information contained in this circular is based were conducted at the laboratory formerly maintained by the Division of Tropical, Subtropical, and Ornamental Plant Insects at New Orleans, La.

[2] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ENTOMOLOGY. CAMPHOR SCALE (PSEUDAONIDIA DUPLEX CKLL.) U. S. Dept. Agr., Bur. Ent. Insect Pest Survey 12 : 20. 1932. [Mimeographed.]

report of its occurrence in the United States was in 1895 (*3*),[3] in California. In 1897 Cockerell (*4, p. 20*) mentioned its occurrence on azalea in Washington, D. C., and in 1909 it was again noted in greenhouses in California (*10*). Apparently these early infestations were eradicated, and there were no further reports of this scale until it was discovered in New Orleans.

Although since 1925 there has been little extension of the outer limits of the area infested by the camphor scale, the insect has become more generally disseminated through the south-central part of Louisiana. Its distribution in Louisiana in the spring of 1934 is shown in figure 1.

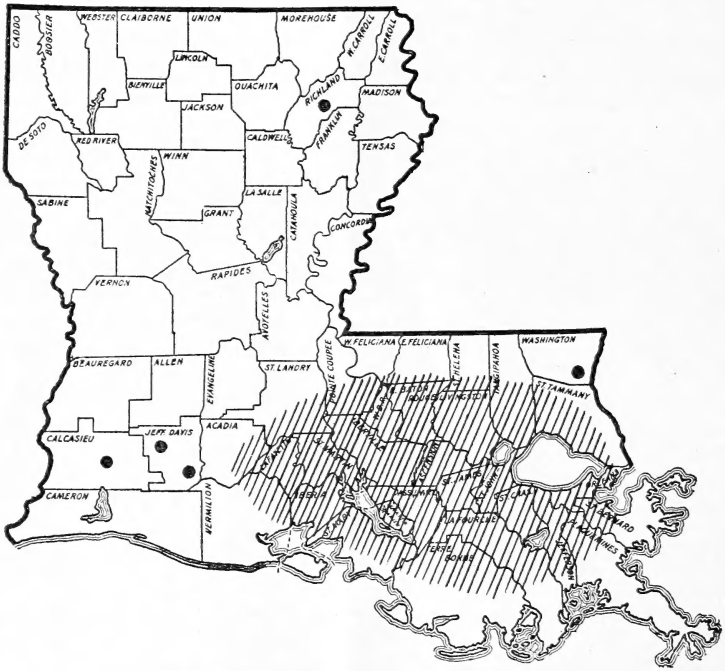

FIGURE 1.—Camphor scale infestations in Louisiana, May 1, 1934. The shaded area represents a section of general infestation. The solid circles outside this area are localities where the scale is found at the present time. Infestations that have been eradicated are not shown.

Because of its relative resistance to low temperatures, it is possible for the insect to become a pest considerably north of its present distribution. It has survived temperatures of 10° F. in northern Louisiana, and at New Orleans a minimum of 19° F. in 1924 killed only about 16 percent of the scales (*2*). The scale could probably thrive under greenhouse conditions anywhere in the United States.

This circular summarizes the information about the scale that will be of interest and value to entomologists, nursery inspectors, and growers who are faced with the problem of its control. More technical data have appeared in other publications (*1, 7, 8*).

[3] Italic numbers in parentheses refer to Literature Cited, p. 19.

POSSIBLE MEANS OF DISSEMINATION

It seems likely that most, if not all, of the infestations mentioned above and shown in figure 1 have arisen from the setting out of infested plants from other areas, as many of them have been traced to shipments from New Orleans nurseries. It is improbable, however, that the scale is being distributed by movement of citrus fruits, since there are few young beneath the parent scale at the time oranges from the Gulf coast are picked and shipped. A limited dissemination may take place through the movements of the insect itself, since the newly hatched young may crawl for 24 hours or more after emerging from beneath the scale covering, and thus become established on adjacent plants. Strong winds are also a factor in the local spread of the insect, and undoubtedly there is some accidental transfer by birds, insects, and other animals. The camphor scale does not secrete honeydew and consequently is not attended by ants, although the writers have seen Argentine ants carrying the newly hatched young after the scale covering had been removed.

HOST PLANTS AND INJURY

In Louisiana nearly 200 host plants have been found, many of which are seriously injured by the scale. Because of its general use for ornamental and shade purposes and the severity with which it is attacked by the scale, the camphor-tree is probably the most important host. Although trees are seldom killed by the scale, a continued infestation may kill back many of the twigs and devitalize the tree. In such cases water sprouts usually arise near the base and, together with the dead branches, give the tree an unsightly appearance (fig. 2). The females are found in the greatest numbers on the younger wood, while the majority of the males go to the leaves. The tendency of the crawlers to move towards the light and to the outer portions of the tree, where the bark is more suitable for feeding, probably accounts for the fact that the most injury is noted on the younger branches and twigs.

Satsuma orange is another favored host of the camphor scale. The females attack all parts of this plant, settling readily on the fruit. Since the infestation tends to reach its height about the time the fruit matures, large numbers of mature scales are present on the ripe fruit, and this reduces its market value. The scale may also kill back some of the younger twigs unless it is brought under control.

On fig trees (*Ficus carica* var.) a large number of the females go to the leaves, and since these are shed in the fall there is a natural reduction of the population each year. When no control measures are taken, however, the scale population on the branches may continue to increase. During 1930 and 1931 severe injury to figs was observed on several trees that had never been sprayed. It seems likely that one thorough spraying will protect the trees from injury for several years.

Other plants that are severely attacked include Japanese privet, glossy privet, common camellia, sweet osmanthus, roses, confederate-jasmine, and Kaki persimmon.

Tests were made on a number of plants to determine whether they would serve as hosts for this scale. Eggs and crawlers were scratched from heavily infested camphor-tree twigs into small pasteboard boxes, which were then fastened to the twigs of the plant

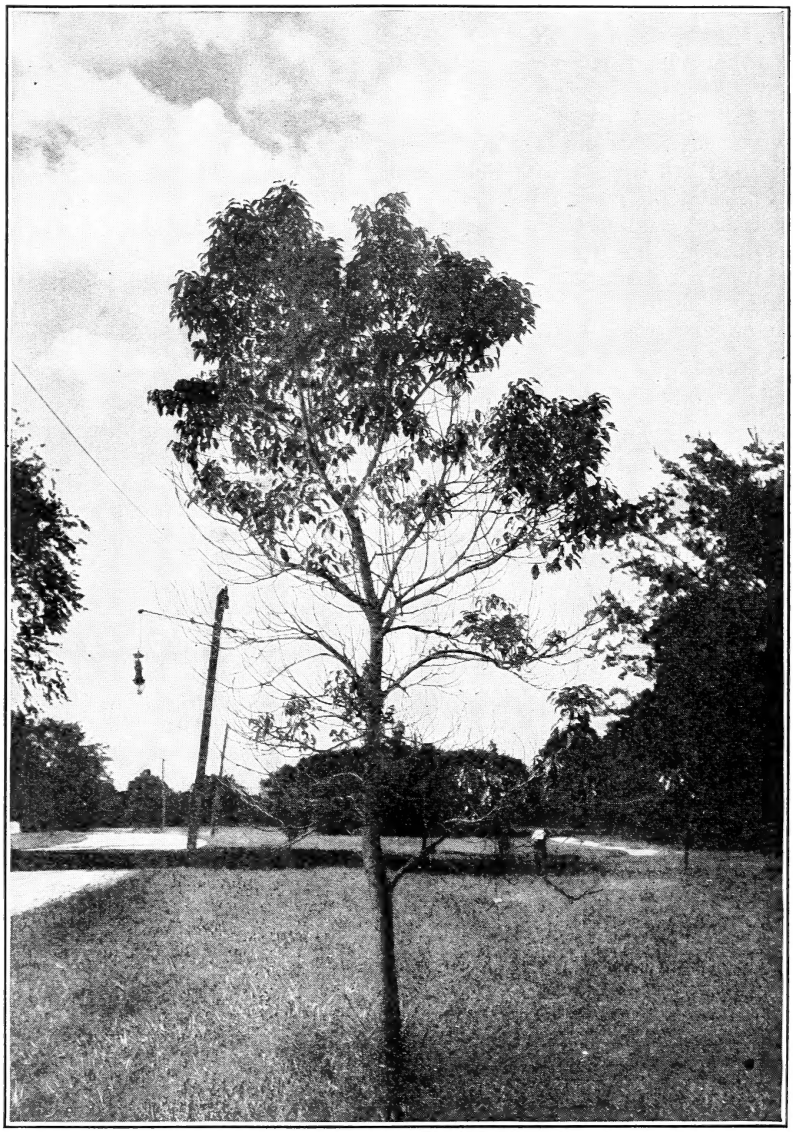

FIGURE 2.—Typical injury to camphor-tree from severe scale infestations.

under observation and allowed to remain for 24 to 48 hours. Infestations started in this way on two young apple trees developed, in less than 3 years, to the point where the younger twigs were being killed back. Muscat grapes showed numerous dead twigs within 1

year after infestation. The scale carried over on quince and plum, although during the 3 years these trees were under test they did not become heavily infested. On peach the scale never reproduced, although several attempts were made to establish an infestation.

A list of the plants on which the camphor scale has been found in the New Orleans area is given below.[4] In the different classes they are arranged in the order of susceptibility to the scale; those plants that have been observed to be heavily infested are marked with an asterisk (*).

Small fruits:
- Muscadine grape (*Vitis rotundifolia*)
- Concord × Moore Early grape (*Vitis* sp.)

Orchard fruits:
- *Kaki persimmon (*Diospyros kaki*)
- *Satsuma orange (*Citrus nobilis unshiu*)
- *Seville orange (*Citrus aurantium*)
- *Celeste fig (*Ficus carica* hort. var.)
- *Pecan (*Hicoria pecan*)
- Ponderosa lemon (*Citrus limonia* hort. var.)
- Orange (*Citrus sinensis* hort. var.)
- Grapefruit (*Citrus grandis*)
- Kumquat (*Fortunella japonica*)
- Common pear (*Pyrus communis*)
- Loquat (*Eriobotrya japonica*)
- Mandarin orange (*Citrus nobilis deliciosa*)
- Peach (*Amygdalus persica*)
- Sand pear (*Pyrus serotina*)
- Brunswick fig (*Ficus carica* hort. var.)
- Mission fig (*Ficus carica* var.)
- Brown Turkey fig (*Ficus carica* var.)
- Myrobalan plum (*Prunus cerasifera*)
- Avocado (*Persea americana*)
- Filbert (*Corylus avellana*)

Truck crops:
- Common string bean (*Phaseolus vulgaris*)
- Okra (*Hibiscus esculentus*)
- Lima bean (*Phaseolus lunatus macrocarpus*)

Field crops:
- Kudzu-bean (*Pueraria thunbergiana*)
- Flax (*Linum* sp.)
- Johnson grass (*Sorghum halepensis*)

Ornamental plants:
- * Sweet osmanthus (*Osmanthus fragrans*)

Ornamental plants—Continued.
- Confederate-jasmine (*Trachelospermum jasminoides*)
- Common camellia (*Camellia japonica*)
- Japanese honeysuckle (*Lonicera japonica*)
- Rose (*Rosa* sp.) (Infestations have been found on 25 varieties.)
- Green rose (*Rosa chinensis viridiflora*)
- Banksian rose (*Rosa banksiae*)
- Japanese privet (*Ligustrum japonicum*)
- Hardy orange (*Poncirus trifoliata*)
- India azalea (*Azalea simsi*)
- Arabian jasmine (*Jasminum sambac*)
- Common crapemyrtle (*Lagerstroemia indica*)
- Chinese privet (*Ligustrum sinense*)
- Grecian laurel (*Laurus nobilis*)
- Southern waxmyrtle (*Myrica cerifera*)
- Roughleaf dogwood (*Cornus asperifolia*)
- Flowering quince (*Chaenomeles lagenaria*)
- Golden California privet (*Ligustrum ovalifolium* hort. var.)
- Chinese lilac (*Syringa chinensis*)
- Climbing fig (*Ficus pumila*)
- Windmill palm (*Trachycarpus excelsa*)
- Canary hair palm (*Chamaerops humilis* hort. var.)
- Moreton bay fig (*Ficus macrophylla*)
- Saucer magnolia (*Magnolia soulangeana*)
- Fiddleleaf fig (*Ficus pandurata*)
- Sprenger asparagus (*Asparagus sprengeri*)
- American beautyberry (*Callicarpa americana*)
- Primrose jasmine (*Jasminum primulinum*)
- American wisteria (*Kraunhia frutescens*)

[4] The writers acknowledge the assistance of R. S. Cocks, late Richardson professor of botany at Tulane University, in the determination of these plants.

Ornamental plants—Continued.
- American redbud (*Cercis canadensis*)
- Willow (*Salix interior*)
- Parkinsonia (*Parkinsonia aculeata*)
- Italian jasmine (*Jasminum humile*)
- Buckwheat-vine (*Brunnichia cirrhosa*)
- Nightblooming cestrum (*Cestrum nocturnum*)
- Sago cycas (*Cycas revoluta*)
- Fern asparagus (*Asparagus plumosus*)
- Oregon hollygrape (*Berberis aquifolium*)
- English ivy (*Hedera helix*)
- Shrub-althea (*Hibiscus syriacus*)
- Carriere(?) hawthorn (*Crataegus carrierei?*)
- Chinese Ixora (*Ixora chinensis*)
- Purpleleaf myrobalan(?) plum (*Prunus cerasifera* hort. var.?)
- Butchersbroom (*Ruscus aculeatus*)
- Chinese wisteria (*Kraunhia sinensis*)
- Roebelin palm (*Phoenix roebelinii*)
- Indigobush (*Amorpha fruticosa*)
- Banana-shrub (*Michelia fuscata*)
- Poinsettia (*Euphorbia pulcherrima*)
- Manihot (*Manihot carthaginensis*)
- Oxeye butterflybush (*Buddleia davidii* hort. var.)
- French tamarix (*Tamarix gallica*)
- Common aspidistra (*Aspidistra lurida*)
- Common oleander (*Nerium oleander*)
- Common box (*Buxus sempervirens*)
- Glossy abelia (*Abelia grandiflora*)
- Common banana (*Musa sapientum* var.?)
- Sweet viburnum (*Viburnum odoratissimum*)
- Laland firethorn (*Pyracantha coccinea lalandi*)
- Mescalbean (*Sophora secundiflora*)
- Three-seed hornbeam (*Acalypha ostryaefolia*)
- Fiveleaf akebia (*Akebia quinata*)
- Crossvine (*Anisostichus capreolatus*)
- Chilean cestrum (*Cestrum parqui*)
- Sweet autumn clematis (*Clematis paniculata*)
- Elephants-ear (*Colocasia esculenta*)
- Parsley hawthorn (*Crataegus apiifolia*)
- Deutzia (*Deutzia* sp.)
- Bush-honeysuckle (*Diervilla* sp.)
- Dracena (*Dracaena* sp.)

Ornamental plants—Continued.
- Coraltree (*Erythrina crista-galli*)
- Montevideo escallonia (*Escallonia montevidensis*)
- Euonymus (*Euonymus* sp.)
- Fatsia (*Fatsia japonica*)
- Japanese anisetree (*Illicium anisatum*)
- Nepal privet (*Ligustrum nepalense*)
- True myrtle (*Myrtus communis*)
- Redbay (*Persea borbonia*)
- Pomegranate (*Punica granatum*)
- Jerusalem-cherry (*Solanum pseudocapsicum*)
- Vanhoutte spiraea (*Spiraea vanhouttei*)
- Arborvitae (*Thuja* sp.)
- Lilac chaste-tree (*Vitex agnus-castus*)
- Spanish-dagger (*Yucca aloifolia*)
- Hercules-club (*Zanthoxylum clava-herculis*)

Flowering garden plants:
- *Weeping lantana (*Lantana sellowiana*)
- Bergamot mint (*Mentha citrata*)
- Old garden dahlia (*Dahlia rosea*)
- Snapdragon (*Antirrhinum* sp.)
- Canna (*Canna* sp.)
- Eupatorium (*Eupatorium aromaticum*)
- Waterlily (*Nymphaea* sp.)
- Cape plumbago (*Plumbago capensis*)
- Primrose (*Primula* sp.)
- Common periwinkle (*Vinca minor*)
- Violet (*Viola* sp.)

Shade and timber trees:
- *Camphor-tree (*Cinnamomum camphora*)
- *Glossy privet (*Ligustrum lucidum*)
- *Sugarberry (*Celtis mississippiensis*)
- *Common persimmon (*Diospyros virginiana*)
- *Paper-mulberry (*Papyrius papyrifera*)
- *Chinese tallowtree (*Sapium sebiferum*)
- American elm (*Ulmus americana*)
- Water oak (*Quercus nigra*)
- Western catalpa (*Catalpa speciosa*)
- Laurel oak (*Quercus laurifolia*)
- Common catalpa (*Catalpa bignonioides*)
- Sweetgum (*Liquidambar styraciflua*)
- Southern cottonwood (*Populus deltoides*)
- Red mulberry (*Morus rubra*)
- White mulberry (*Morus alba*)
- Cassiabark-tree (*Cinnamomum cassia*)

Ornamental plants—Continued.
- Oak (*Quercus laurifolia rhombica*)
- Live oak (*Quercus virginiana*)
- American linden (*Tilia americana*)
- Possumhaw (*Ilex decidua*)
- Common locust (*Robinia pseudoacacia*)
- Tuliptree (*Liriodendron tulipifera*)
- Chinese parasoltree (*Firmiana simplex*)
- Black walnut (*Juglans nigra*)
- Black willow (*Salix nigra*)
- Winged elm (*Ulmus alata*)
- Drummond maple (*Acer rubrum drummondii*)
- Red maple (*Acer rubrum*)
- Southern magnolia (*Magnolia grandiflora*)
- Chinaberry (*Melia azedarach*)
- American planetree (*Platanus occidentalis*)
- Lombardy poplar (*Populus nigra italica*)
- Shumard oak (*Quercus shumardii*)
- Maidenhair-tree (*Ginkgo biloba*)

Weeds:
- *Groundselbush (*Baccharis halimifolia*)
- *Morning-glory (*Ipomoea lacunosa* and *I. trichocarpa*)
- *Canada goldenrod (*Solidago canadensis*)
- Texas sage (*Salvia coccinea*)
- Wild aster (*Aster* sp.)
- Florida lettuce (*Sonchus mulgedium*)
- Tall ironweed (*Vernonia altissima*)
- Verbena (*Verbena bonariensis*)

Weeds—Continued.
- Inkberry (*Ilex glabra*)
- Prickly sowthistle (*Sonchus asper*)
- Big ragweed (*Ambrosia trifida*)
- Beardgrass (*Andropogon* sp.)
- Creeping dayflower (*Commelina nudiflora*)
- Tickclover (*Meibomia* sp.)
- Mock-strawberry (*Duchesnea indica*)

Wild flowers, vines, shrubs, and trees other than timber trees:
- *Peppervine (*Ampelopsis arborea*)
- *Heartleaf ampelopsis (*Ampelopsis cordata*)
- *Poison-ivy (*Toxicodendron radicans*)
- Carolina cherry-laurel (*Prunus caroliniana*)
- Frost grape (*Vitis cordifolia*)
- American holly (*Ilex opaca*)
- Dogwood (*Cornus stricta*)
- Summer grape (*Vitis aestivalis*)
- American elder (*Sambucus canadensis*)
- Chickasaw plum (*Prunus angustifolia*)
- Black cherry (*Prunus serotina*)
- Texas boxelder (*Acer negundo texanum*)
- Oakleaf poison-ivy (*Toxicodendron pubescens*)
- Trumpetcreeper (*Bignonia radicans*)
- Wild calla (*Calla palustris*)
- Oxeye daisy (*Chrysanthemum leucanthemum*)
- Florida anisebush (*Illicium floridanum*)
- Wild grape (*Vitis palmata*?)
- Wild plum (*Prunus mexicana*)

In addition to these hosts, the scale has been reported on the following plants from other countries:

Azalea spp	Japan (*5, 14*).
Eurya ochracea	Japan (*11, 12*), Hawaiian Islands, India (*12*).
Gardenia	Argentina (*14*).
"Kioku"	Japan, Hawaiian Islands, India (*12*).
"Mokkoku"	Japan (*15*).
Myrica rubra	Japan (*6, 12*), Hawaiian Islands, India (*12*).
Peony	Japan (*6, 14*).
Purple gumamela	Philippine Islands (*16*).
Rhododendron spp	Japan (*6, 12, 14*), Hawaiian Islands, India (*12*).
Rhus succedanea	Japan (*11, 12*), Hawaiian Islands, India (*12*).
Tea	Japan (*5, 11, 12*), Hawaiian Islands, India (*12*).
"Umame"	Japan, Hawaiian Islands, India (*12*).

DESCRIPTION OF STAGES AND HABITS

The eggs, which are found beneath the covering of the female, are oval in shape, with a lilac to purple coloring. The newly hatched nymphs, or crawlers, are also oval in outline, nearly flat, and similar to the eggs in color. When a crawler emerges from beneath the covering, it wanders over the plant for a short time before it

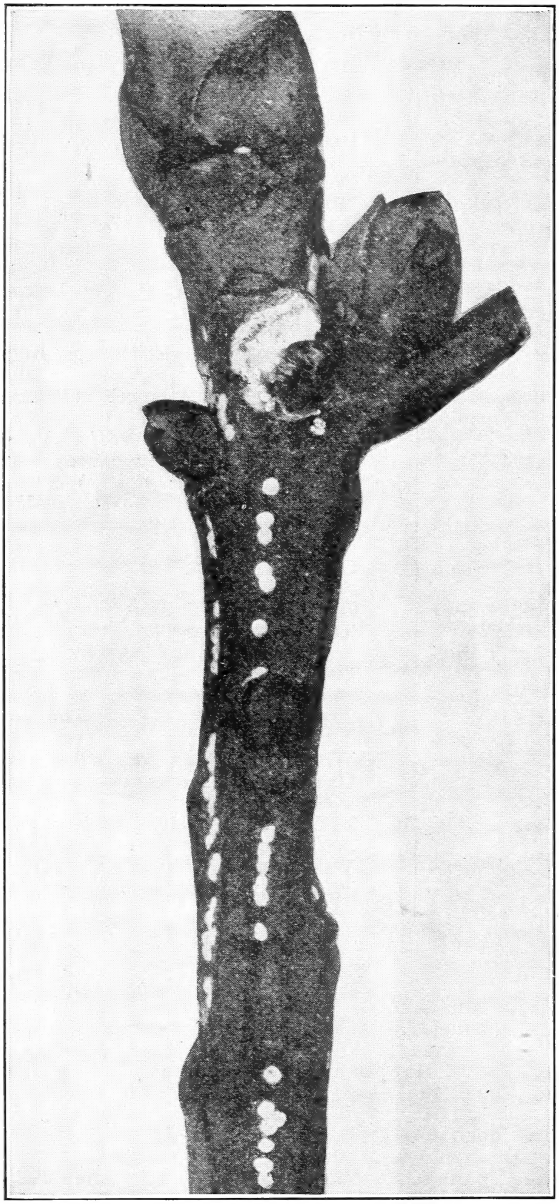

FIGURE 3.—Newly settled scales on a camphor-tree twig. The covering has been raised from the reproducing female, giving a dorsal view of the scale. Enlarged 9 times.

settles, or inserts its beak and begins feeding. After settling, the nymph secretes over its body a waxy substance in the form of delicate white threads, which coalesce into a solid white covering (fig. 3). In a few days this covering takes on a yellowish color, which darkens as the scale ages, until, in the case of the reproducing female, it assumes a characteristic chocolate-brown hue, although in the latter part of the summer it is sometimes slate gray. When not crowded by other scales, the covering of the female is nearly circular and distinctly arched, with a subcentral apex or nipple (fig. 4). At its maximum size it is one-eighth to one-sixth inch in diameter. There is also a fragile layer of white wax underneath the female, and this usually adheres to the bark of the plant when the insect is removed, forming the so-called white "scars."

After settling, the nymph becomes rounded and gradually loses its purple hue, becoming white to flesh-colored. In the course of her growth the female molts twice, fertilization taking place after the second molt. Preceding each molt, her body becomes swollen and its contents fluid, and for a few days the dorsal integument adheres to the covering, with which it is incorporated when the skin is shed. As the adult female ages, she becomes pink, then purple, often with developing eggs

plainly visible. The reproducing scale shows a purple-brown color, and has two characteristic white patches on the ventral side (fig. 5).

In the first instar the male is indistinguishable from the female, but during the second instar the male becomes elongated and the

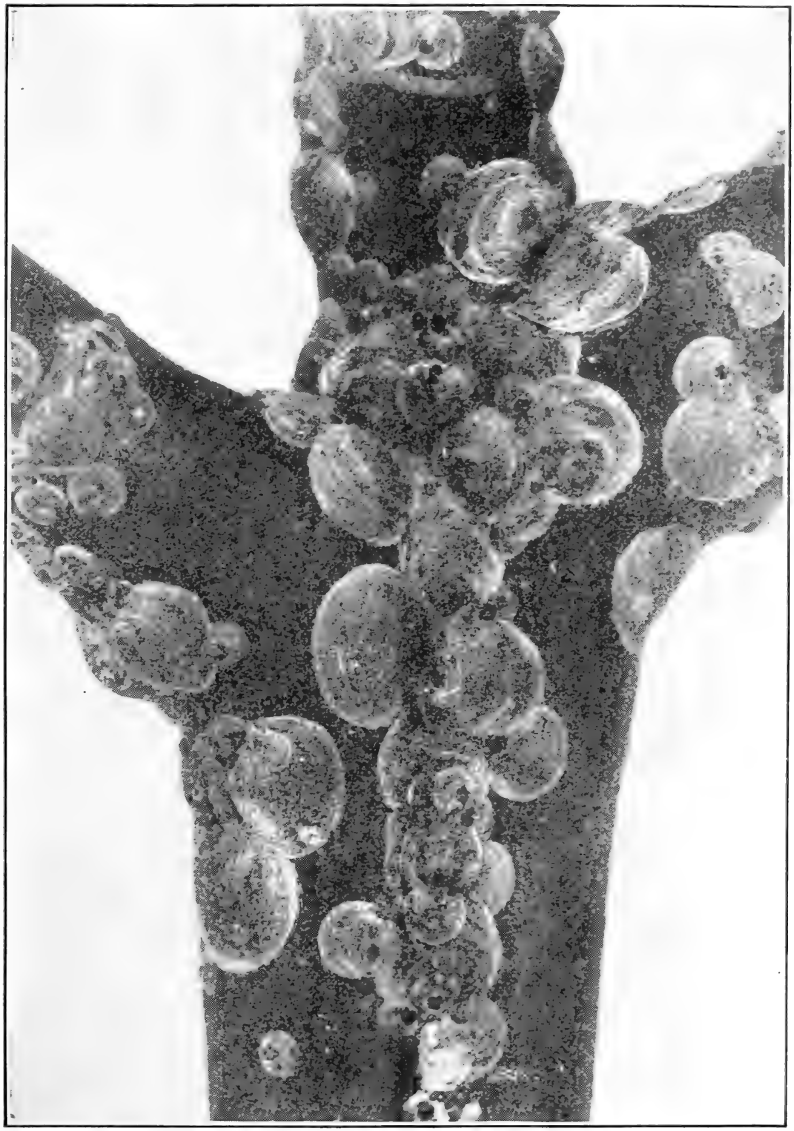

FIGURE 4.—Detailed view of camphor-tree twig heavily infested with the camphor scale. Enlarged 9 times.

covering oblong-elliptical. The covering does not increase in size after the second molt, although the male makes four molts in all. The adult male (fig. 6) is a small two-winged insect rarely noticed by the casual observer.

SEASONAL HISTORY

The length of each stage depends largely upon climatic conditions, development being more rapid in warm weather. Insectary breeding experiments and field observations have shown that in summer the following average periods are required to complete each stage of the female:

	Days
First instar	10–11
Second instar	15–17
Preoviposition period	17–20
First egg to emergence of crawlers	9–11
Total period	51–59

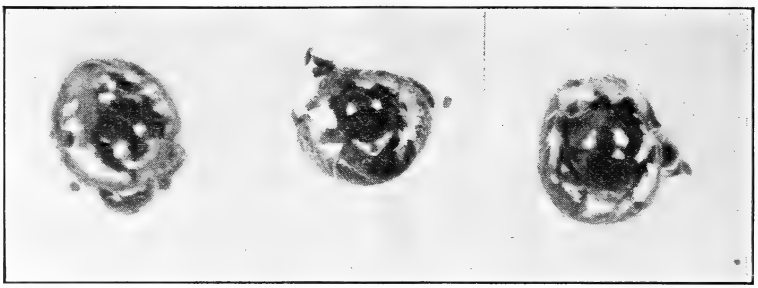

FIGURE 5.—Ventral view of producing female scales in coverings. These have been lifted from the twigs to show the underside of the females, with the characteristic white patches. Enlarged 9 times.

The majority of the scales pass the winter in the adult stage, but there is no well-defined hibernation period. The number of eggs beneath the coverings begins to increase in January, and emergence of young may commence in February or March, depending on the temperature.

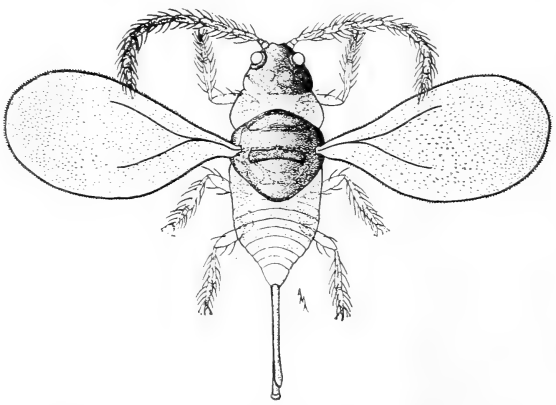

FIGURE 6.—The adult male amphor scale. Greatly enlarged.

In the New Orleans district there are usually three complete generations each year, but in years when the temperatures are higher than normal a partial fourth generation may develop. In 1926, 1927, and 1928, respectively, the dates of first appearance of crawlers of each brood were as follows: First brood, March 30, February 21, and March 19; second brood, June 22, May 26, and June 20; third brood, August 17, July 23, and August 16.

Because the developmental rates are largely dependent on temperature, it is possible to predict accurately the time of appearance

of each stage from a consideration of the average temperature. The method of prediction (*7*) offers a means of correctly timing the applications of summer sprays, and will be discussed in a later section.

NATURAL ENEMIES

The following hymenopterous parasites of the camphor scale have been found in southern Louisiana: *Aphelinus fuscipennis* Howard, *Aspidiotiphagus citrinus* (Craw), *Prospaltella aurantii* (Howard), *Prospaltella fasciata* Malenotti, *Aphelinus diaspidis* Howard, and *Signiphora flavopalliata* Ashmead. Of these, *A. citrinus* and *P. fasciata* were the most frequently encountered, but none has yet given any appreciable control. *Metalaptus torquatus* Malenotti has also been taken from cages in which camphor scales were confined, but this may be a parasite of psocid eggs.

In limited areas a considerable decrease in infestation has occasionally been caused by predators, the most effective being the orange bagworm (*Platoeceticus gloverii* Pack.) (*13*), the twice-stabbed lady beetle (*Chilocorus bivulnerus* Muls.) (fig. 7), and the pitiful lady beetle (*Microweisea misella* Lec.).

Two fungous parasites of the scale have been discovered. These were determined by Vera K. Charles, of the Bureau of Plant Industry, as *Microcera coccophila* Desm. and *Cladosporium* sp., with the following note: "Ordinarily the latter fungus is not truly parasitic, its injury being more mechanical in effect, that is, by interference with respiration and locomotion of the scales." These, however, have never been found to give permanently effective results over any general area, and so direct, or artificial, methods must be used to combat this pest.

ARTIFICIAL CONTROL

OIL EMULSIONS

METHODS OF PREPARATION

The most effective sprays for controlling the camphor scale are emulsions of petroleum oil in water. There are a number of ways in which such emulsions can be prepared, and three of the most suitable methods are given below.

Formula 1.—The hot-pumped, or boiled, emulsion is made up as follows:

Oil	gallons	2
Water	do	1
Potassium fish-oil soap	pounds	2
or		
Hard soap	do	1

The soap is dissolved in water, which should be heated if hard soap is used, and the oil is added. The mixture is placed in a metal container over a covered fire and heated until it begins to boil. It is then removed from the fire and immediately pumped into another vessel with a bucket pump or, for large quantities, with a power outfit that is equipped with metal valves. The mixture should be pumped once more while it is still hot to obtain a moderately thick,

creamy emulsion. When the mixture is heated and pumped as here directed, no free oil should come to the top on cooling. This makes

FIGURE 7.—Characteristic feeding of the larvae of the twice-stabbed lady beetle on female camphor scales on camphor-tree twigs. Note two empty pupa cases on twig at left. Enlarged 2 times.

a stock mixture containing about 60 percent of oil by volume, and is diluted for use according to the concentration desired.

Formula 2.—When a power sprayer developing 300 to 400 pounds' pressure is available, a soap emulsion can be more easily prepared according to the following formula:

Oil	gallons	10
Water	do	5
Fish-oil soap	pounds	3

The ingredients should be combined unheated in the spray tank and the mixture pumped at 300 to 400 pounds' pressure for 10 minutes. On account of the increase in volume of the emulsion during preparation, not more than half the capacity of the spray tank should be made up at one time.

The toxic effect of oil emulsions is due largely to the oil component, the proportion of scales killed increasing with the quantity of oil left upon the sprayed plant. The quantity of oil deposited, and hence the scale mortality, can be increased by decreasing the quantity of soap used for emulsification. Emulsions made by the second method have been used extensively in New Orleans, and the proportion of soap given is the minimum that can be used without danger of plant injury. It is best to test emulsions of this type by diluting them in the spray tank and observing if there is any surface accumulation of free oil when the agitator is running. If so, the quantity of soap should be increased in order to avoid applying a heavy concentration of oil to the trees as the last of the spray liquid from the tank goes through the nozzle. Any emulsion of oil in water, emulsified with soap, tends to break down when diluted with hard water, but the boiled emulsions made by the first formula should be satisfactory for any fresh waters encountered in southern Louisiana. The soap emulsions keep better than those made with casein-lime spreader, and stock mixtures for the season's spraying can be prepared in advance. Such mixtures, however, should always be well agitated before any is withdrawn for dilution, so that the final sprays will be uniform in quality.

Formula 3.—Emulsions that are not affected by hard waters may be prepared with certain nonsoap emulsifiers, such as casein-lime spreader. An emulsion may be prepared as follows:

Lubricating oil	gallons	8
Water	do	4
Casein-lime	pound	1

The casein-lime should be dissolved in a small quantity of the water, the remainder of the water then added, and the oil-water mixture pumped back upon itself until emulsified. These emulsions do not keep well and should be prepared only as needed for use.

TYPE OF OIL TO BE USED

Mineral oils of the cheaper lubricating type make the most satisfactory sprays from the standpoints of cost of materials and toxicity to the camphor scale. A number of physical and chemical characteristics are listed by the manufacturers of such oils, but most of these specifications indicate their value as lubricants and may have little bearing upon their insecticidal value. Only volatility, viscosity, and unsulphonatable residue will be considered here.

The volatility is usually expressed as a percentage showing the proportion of oil evaporating in a given time under standard conditions. As given by the oil companies this has little meaning in insecticidal practice, because the volatility is measured at much higher temperatures than those prevailing when oils are used for sprays (*9*). Oils of the kerosene type evaporate too quickly to make efficient insecticides, but if lubricating oils, which evaporate comparatively slowly, are used it is probable that volatility can be disregarded.

The viscosity of an oil is a measure of the rate of flow under specified conditions. With soap emulsions, it has been found that the more viscous oils give a greater oil deposit and better insect kill than oils of lower viscosity. Against the camphor scale, oils within the range of approximately 100 to 220 seconds Saybolt have given satisfactory results, oils in the upper part of this range showing a somewhat better kill than those in the lower part.

The unsulphonatable-residue value expresses the percentage of oil by volume that is not affected by treatment with concentrated sulphuric acid, and is an index of the degree of refinement of the oil. A high unsulphonatable residue indicates that the oil has been highly refined and that the more chemically active constituents have been removed. Oils ranging from 67 to 95 percent unsulphonatable residue have shown no difference in their effect upon the camphor scale, but the refined oils are less toxic to plants than oils showing a low unsulphonatable residue. In spite of the higher cost, therefore, their greater safety to the plant may justify the use of the refined oils for the more susceptible host plants.

TIME OF APPLICATION AND OIL CONCENTRATIONS

The best time to spray the infested camphor-trees and most other trees and ornamental plants (except citrus) is during the dormant season, from about November 15 until the buds begin to burst in the spring. All the scales are in the adult stage at this time, but the plants will stand heavier concentrations of oil than during the growing season.

The oil concentration to be used will depend upon the type of emulsion. For a boiled emulsion prepared according to formula 1, 3 percent of oil should be used in the dilute spray. Since the concentrated emulsion contains approximately 60 percent of oil, 1 part of emulsion should be mixed with 19 parts of water to give a 3-percent spray. The cold-pumped emulsion made according to formula 2 will deposit more oil than the boiled emulsion and should be used at the rate of 2.5 percent of oil, or approximately 1 part of oil in 23 parts of water. The oil-depositing qualities of the casein-lime spreader and soap emulsions have never been compared, but some investigators have found that the casein-lime gives a kill equal to that obtained with the boiled emulsions.

When only a few gallons of emulsion are needed, the grower will probably find it more satisfactory to purchase one of the commercial emulsions. These are ready for use when diluted with water, and should be applied in the strength given in the manufacturer's directions.

The proportion of camphor scales killed by a given quantity of oil depends largely on the intensity of the infestation. The scales are most easily killed on the lightly infested plants. In one spray test in which the branches were marked off in units 1 cm long and these units were classified according to the percentage of twig area covered by scales, the units having less than 10 percent of the twig area covered by scales showed a mortality of approximately 90 percent, whereas on those having 90 percent or more of the surface covered less than 15 percent of the scales were killed. Because of the effect of excessive quantities of oil on the plant, it is impossible to use enough oil to secure control in one application when plants are heavily infested. In such cases additional sprays must be applied during the growing season, but oil sprays for fig trees should be confined to dormant applications.

In selecting the time to apply spring or summer sprays, it should be kept in mind that the younger the scales the more susceptible they are to oils. Practically all the exposed scales of the first and second instars, and those of the third instar that are not more than 1 week past the second molt, can be killed with sprays containing 1 percent of oil. As the time of appearance of these stages depends on the temperature, no definite dates for best results can be given, but the most favorable time for application can be determined from the time of emergence of the young of each brood, which can be fairly easily observed. The newly settled scales are white, about the size of a pinhead, and conspicuous on the plant (fig. 3). The range of dates within which their appearance may be expected is given on page 10. Those who wish to get the maximum benefit from summer sprays should keep the infested plants under observation and determine the date of appearance of the new brood. Summer temperatures in New Orleans are usually so uniform that sprays can be properly applied at a constant time after the emergence of the first instar of each brood. In 1926, 1927, and 1928, the best time for summer sprays was found to be at the intervals shown in table 1 after the first appearance of the young of the first and second broods.

TABLE 1.—*Period from the emergence of the first instar of the camphor scale to the best time for summer-spray applications, 1926, 1927, and 1928*

Brood	Period after emergence		
	1926	1927	1928
	Days	*Days*	*Days*
First	56	58	58
Second	38	38	35

At the times shown in table 1 not more than 3 to 5 percent of the scales were reproducing, and nearly all the others were in stages capable of being killed by summer sprays. Tests have proved that the oil remaining after plants have been sprayed with 1 percent of oil is sufficient to destroy most of the crawlers emerging for a period of 2 weeks after application. Consequently, when sprays are ap-

plied at the times recommended in table 1, few scales can develop from the small numbers of reproducing females present. For such sprays it is recommended that emulsions prepared by formula 1 be diluted at the rate of 1 part to 50 parts of water, and that the cold-pumped emulsions (formula 2) be diluted 1 to 60.

After the infestation of the camphor scale has been reduced to a point where it can be controlled by dormant applications, one thorough spraying each winter should be sufficient to hold it in check. The New Orleans Parkway Commission has kept the scale generally under control on city property in recent years by one dormant application each year.

Citrus trees present a different spraying problem than do ornamental and shade trees, because of the possibility of injury if freezing weather follows within several weeks of winter applications. Although some defoliation of shade trees may take place under these conditions, they quickly recover when the spring growth puts out; but if a freeze follows the application of an oil spray to citrus trees it may cause a severe reduction in the crop the following season. In the short time since the camphor scale has invaded the commercial citrus-growing district of Louisiana, there has been no opportunity to work out spray schedules for this district. Probably reliance will have to be placed on summer applications. There were some heavily infested groves in the Satsuma orange district of Alabama, but intensive control measures have either eradicated these infestations or reduced the scale to negligible numbers.

In spraying camphor-trees an effort should be made to cover the branches and twigs thoroughly, without applying an excess of oil to the leaves. Most of the females are on the wood, and these are the scales that must be killed. Moreover, most of the oil taken up by the plant is absorbed through the leaves, and this method of spraying will give maximum effectiveness against insects and minimum danger to the tree. In the case of citrus trees, the females develop on leaves, fruit, and stems, and all parts should be given equal coverage.

SUMMARY OF SPRAYING RECOMMENDATIONS

The recommendations as to sprays for controlling the camphor scale with oil emulsions are summarized in table 2.

TABLE 2.—*Oil-emulsion sprays recommended for controlling the camphor scale*

Type of emulsion	Dormant application		Summer application	
	Oil concentration	Dilution	Oil concentration	Dilution
	Percent	*Parts* [1]	*Percent*	*Parts* [1]
Hot-pumped	3.0	19	1.2	50
Cold-pumped	2.5	23	1.0	60
Casein-lime spreader	3.0	19	1.2	50

[1] Parts of water to 1 part of emulsion.

One dormant application should be sufficient to control the scale except in cases of severe infestation. This may be applied between November 15 and the time the buds burst in the spring.

When spring or summer sprays are necessary, the best results will be obtained if applications are made about 57 days after the appearance of the first newly settled nymphs in the spring or about 36 days after the beginning of emergence of the second-brood crawlers. Emergence of the second brood begins in June in years when normal temperatures have prevailed.

Cheap lubricating oils of 100 to 200 seconds Saybolt viscosity may be used in preparing the emulsions, or one of the commercial emulsions on the market may be purchased. In the latter case the manufacturer's directions for use should be followed.

FUMIGATION

The best means of controlling the camphor scale on nursery stock or other plants that are to be shipped is by fumigation with hydrocyanic acid gas. For this purpose a double-walled box or other suitable container should be provided. This box should be large enough to allow ample room for the plant material and pot or other earthen vessel in which the gas is to be generated, as nearly gastight as possible, and fitted with a door that can be quickly and tightly closed.

The foliage and tender twigs of all plants should be thoroughly dry before fumigation is started, to avoid undue risk of burning, and the plants should not be exposed to direct sunlight for several hours before and after treatment. All boxes or other containers of plant material should be open to enable the gas to reach all surfaces of the stem and leaves in full strength.

An exposure of 1 hour is recommended at the following temperatures and dosages (per 1,000 cubic feet):

At 80° F. and above:		Below 80° F.:	
Water——fluid ounces——	2¼	Water——fluid ounces——	3
Sulphuric acid——do————	1⅛	Sulphuric acid——do————	1½
Sodium cyanide ounce avoirdupois——	¾	Sodium cyanide ounce avoirdupois——	1

The acid should be poured slowly into the water, in an earthen pot or jar, the cyanide, previously weighed, gently dropped into this solution, and the door of the fumigating box immediately closed. (Do not pour water into the acid, or the violent reaction may spatter the mixture and cause dangerous burns.) Commercial sulphuric acid that tests at least 65° Baumé, or 1.84 specific gravity, should be used. The sodium cyanide should be practically free from chlorine and should contain not less than 51 percent of cyanogen. These dosages will kill practically all the scales, but at temperatures below 80° F. even the increased quantity of cyanide has failed to kill all the eggs. Neither can the 1-ounce dosage be used with all plants, since some will be injured by this concentration of gas.

In greenhouse fumigation it is difficult to give a general dosage schedule because of the variation in susceptibility between different plants, and the loss of gas through leakage. When only a few plants are to be treated, the use of a fumigating box avoids these difficulties. If it is desired to fumigate the entire greenhouse, the proper strength to use will depend on the tightness of the house and the susceptibility of the plants to be treated.

It is better to use a low concentration of gas and repeat the fumigation in a week or 10 days than to risk burning the plants.

The procedure for fumigating greenhouses and nurseries is given in more detail in a Farmers' Bulletin (*17*).

SUMMARY

The camphor scale was first discovered in injurious numbers in Louisiana in 1920, probably having been introduced into the United States from Japan. It is now generally distributed in southern Louisiana, and isolated infestations exist in Mississippi, Alabama, and Texas.

The scale has been found on nearly 200 host plants. Camphor-tree, Satsuma orange, Japanese privet, glossy privet, common camellia, sweet osmanthus, roses, confederate-jasmine, and Kaki persimmon are important host plants that may be heavily infested in Louisiana. Apple trees were severely attacked when artificially infested.

The minimum time required to complete a generation is 51 days, but this period is considerably lengthened by low temperatures. There are three complete generations each year, and in some years a partial fourth generation may develop. The majority of the scales pass the winter in the adult stage, but there is no well-defined hibernation period. The number of eggs beneath the coverings begins to increase in January, and emergence of young may commence in February or March, depending on the temperature.

Although natural enemies may appreciably reduce the infestation in limited areas, they cannot be relied upon to control the scale.

Emulsions of petroleum oil make the most effective sprays. Several formulas are given for preparing such emulsions.

Highly refined oils are less toxic to plants than the less refined oils, and they are fully as toxic to the camphor scale. They are somewhat more expensive than oils that have been given less refinement. The efficiency of an oil emulsion against the scale increases with the viscosity of the oil, an oil having a viscosity falling within the range of 100 to 200 seconds Saybolt being recommended. The volatility of petroleum oils is not an important specification for insecticidal purposes.

The most important spray is a winter application using 2.5 to 3 percent of oil. Heavy infestations of the scale cannot be controlled by one spraying, and the winter application must be supplemented with sprays during the spring or summer.

The emulsions used in summer sprays should be diluted at the rate of 1 part of emulsion to 50 or 60 parts of water. A table is given to show the best time to make these applications.

Fumigation with hydrocyanic acid gas is also an effective means of control for nursery stock and for many greenhouse plants. A dosage schedule is given for this treatment. The maximum dosage recommended for growing plants will not kill all the eggs at temperatures below 80° F.

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