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SCALE INSECTS AND MITES ON CITRUS TREES.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., April 17, 1903.

SIR: I have the honor to transmit herewith for publication an account of the more important scale insect and mite enemies of citrus trees, prepared by Mr. C. L. Marlatt, entomologist in charge of experimental field work. This bulletin is a somewhat condensed revision of the article under the same title published in the Yearbook of this Department for 1900. The classes of insects mentioned are the most important enemies of the citrus fruits, and this Office is in receipt almost daily of inquiries concerning them. To meet the need for more widespread dissemination of information on the subject, this paper is recommended for publication in the Farmers' Bulletin series. The information conveyed will be of special service in California, throughout the Gulf region, including Florida, and in our new subtropical possessions.

Respectfully,

L. O. HOWARD,
Entomologist.

HON. JAMES WILSON,
Secretary of Agriculture.

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SCALE INSECTS AND MITES ON CITRUS TREES.[a]

INTRODUCTION.

The scale insects, or bark-lice, are the most important insect enemies of citrus, as they are also of most other subtropical plants. They are, as a rule, small and inconspicuous singly, but they multiply so rapidly that very soon an entire plant becomes infested—trunk, limbs, leaves, and fruit. The attacked tree is rarely killed outright, but its growth may be almost completely checked and its fruit rendered valueless.

Next in importance to the scale insects are the mite enemies of the orange and lemon, as represented by the mite which causes the rusting of the orange in Florida and the silvering of the lemon in California, and also the leaf mite, known from its coloring as the six-spotted mite of the orange. These mites occur with the scale insects, are subject to similar remedies, and may properly be considered in the same connection.

Of very great importance to the Florida grower of citrus fruits is the so-called white fly, the latter not being a scale insect in the ordinary acceptation, but in the essential features of life history and habits coming in the same category, and hence properly considered with the true scale insects.

There are many insect enemies of citrus plants other than the scale insects and mites, but, for this country, at least, these others, in the main, have no great economic importance, or are only very occasionally abundant enough to be especially destructive.

Occurring about the orange and other citrus trees will also be seen many other insects which play a beneficial rôle, preying upon or parasitizing the scale insects living on these trees. It is very important to make the acquaintance of these beneficial species, more particularly to avoid, whenever possible, killing them in the warfare waged against the injurious ones.

[a] No one can discuss the insect enemies of citrus plants without acknowledging indebtedness to the very comprehensive and valuable work, now long out of print, prepared by the late H. G. Hubbard and published by this Department in 1885, under the title "Insects affecting the orange." The practical side of Mr. Hubbard's work is especially to be remembered, and particularly that he devised kerosene-soap emulsion, which, with allied washes, has for many years been the leading means of controlling scale insects.

INFLUENCE OF CULTIVATION, PRUNING, AND CLIMATE.

With the orange and lemon as with other plants, negligent cultivation and improper care, or any unfavorable conditions of climate which weaken the vitality and vigor of the tree, encourage the presence and multiplication of the insect enemies. On the other hand, vigor of growth is repellent to insect attack; and it will be almost invariably found that the unhealthy tree is the one first severely infested with scale insects or mites. This does not mean that vigorous healthy trees will not be attacked, but such trees are less apt to be completely invaded. As a means of protection against scale insects, a proper system of cultivation and pruning is therefore highly important.

The value of pruning as a means of preventing scale-insect injury can not be too strongly urged. Scale insects thrive best where they are protected from direct sunlight and free movement of the air, hence trees of dense growth, unpruned, are almost certain to have their centers, at least, scaly. A well-pruned tree, in which free access is given to light and air, is much less apt to be badly attacked than a thick-headed tree, the interior of which is entirely shaded, thus furnishing the conditions most favorable for the well-being of scale insects.

The abundance or scarcity of scale-insect pests is very much influenced by climatic conditions. A moderate amount of moisture and warmth are the favoring conditions. On the other hand, a very dry climate accompanied during the summer season by excessive heat, will frequently destroy most scale pests, as will also a high degree of humidity with high temperature such as characterizes many areas within the Tropics, the latter condition developing fungous diseases which often keep most scale species well nigh exterminated. The favoring intermediate climate is illustrated by the citrus districts of Florida, Jamaica, and the West Indies, where scale enemies are more troublesome than they are in the drier climate of California. On the Pacific coast, also, the moister ocean districts are worse infested than the drier regions farther inland with greater elevation. Under the latter conditions the black scale, for example, has been almost entirely exterminated by a temperature holding for several days above a hundred degrees, and similar results have been noted with other species.

PERIODICITY IN SCALE INSECTS.

With most insects injurious to cultivated plants a periodicity is noted in their occurrence in injurious numbers. In the case of subtropical species, like the scale insects affecting citrus plants, this periodicity is not so marked as it is with insects in temperate latitudes. That there may be more or less well-defined periods of destructive abundance separated by periods of comparative scarcity is illustrated

by the noted epidemic of scale infection referred to by Hubbard as prevailing throughout the entire orange, lemon, and olive districts along the shores of the Mediterranean from Italy to Spain during the first decade of the present century, which later subsided very largely of itself, efficient remedies at that date being practically unknown.

In this country, scale infestation varies considerably from year to year. The fluted scale, in California, increased enormously during the first ten or fifteen years and threatened the very existence of the citrus orchards. Thanks, however, to the Australian ladybird, and, doubtless also to many native predaceous and parasitic insects, it is no longer feared in California. The long scale in Florida, also, was much more injurious in the first years of its activity than it has been since. In 1896 the black scale was very abundant and destructive in the orange districts about Riverside, Cal. Partly owing to adverse climatic conditions and partly to natural enemies, this insect has almost disappeared from this district, which is now one of the least affected by scale insects.

These facts are cited to give the citrus grower whatever encouragement they may offer, but not with the idea of belittling the need of remedial operations.

NATURE OF THE INJURY OCCASIONED BY SCALE INSECTS.

The damage occasioned by scale insects is of several kinds. The first and principal injury is the extraction of the juices of the plant, the scale insect in its relation to its food plant being a mere pumping machine, which is continually absorbing the sap from its host. While the amount extracted by a single insect is very small, when multiplied by millions it greatly weakens the plant. With some species the excess is thrown off in the form of so-called "honeydew," which accumulates in drops and spreads out over the bark or leaf as a sticky liquid. This liquid attracts ants, which very often gives rise to the erroneous belief that the ants are depredating on the plant.

Another form of injury results from the honeydew excretion, which not only prevents normal respiration, but develops a black fungus covering the leaves, twigs, and fruit, and still further stifling the plant and reducing the marketable value of its products.

Associated with the damage due to the absorption of the juices of the plant by the scale insect is a diseased condition, particularly to be noted in the limbs, caused by the irritation excited by the beaks or by the injection of some poisonous liquid.

The extreme injury by scale insects arises from the further fact that they are active the year round in climates where citrus trees can be grown. Their most rapid breeding period is from May to August, but continues through October and November. In the winter or rainy season they are more dormant and breeding is at a much lessened rate.

THE NATURAL ENEMIES OF THE CITRUS SCALE INSECTS.

The natural predaceous enemies of scale insects of greatest importance are various species of ladybirds, as illustrated by the Australian ladybirds (figs. 21 and 29) imported to control the fluted and black scales, and a great many native species, which are very effective agents in the control of these and other scale pests. The work of ladybirds is especially important against the young of the armored scale and against the softer and freely moving scale insects which secrete no protective covering. Whenever, therefore, ladybirds of any species are found to be abundant on scale-covered trees, they may be safely recognized as friends and working in the interest of the grower. If they are very abundant, it may even be unwise to fumigate or spray. The black scale has been completely controlled on certain ranches in California by its imported ladybird enemy, and this control has been brought about by the entire cessation of all insecticide operations. Most of our ladybirds, however, will probably stand a spraying without being killed, and, as a rule, it is hardly worth while to take the risk of loss while waiting for them to do their work. The experience, however, on the Cooper ranch and in other localities in California has certainly demonstrated the advantage of giving natural enemies a fair chance.

The other important class of enemies of scale insects are the hymenopterous parasites. The recognition of these is not so easy, but if scales are found pierced with minute round holes, it is a safe indication that they have been parasitized, and that the parasites have escaped and are multiplying in the younger scale insects on the trees, and here again if the parasitism is found to be general, it may be inadvisable to spray or fumigate.

The other natural enemies of scale insects are not so important as those mentioned; still they are of service, and should be recognized. These include the larvæ of the lace-winged flies (*Chrysopa* spp.), which feed on the young of both the armored and the unarmored scales. There are also a few dipterous, or fly, parasites of scale insects, and the larvæ of several species of Lepidoptera are carnivorous and feed on the larger species of scale insects, such as the Lecaniums and wax scales.

A most desirable outcome would be to secure a complete and practical control of scale insects by their natural enemies; but, so far, this has been fully accomplished in the case of the fluted scale only. Very encouraging results have been secured, however, with other parasites, and the introduction of these is being actively prosecuted. Nevertheless, spraying and fumigation must be relied upon for some time to come, or at least until the natural enemies have been more fully studied and better means of successfully colonizing them devised. Climatic conditions also affect the activity of these enemies to such an extent that the same results may not be counted on in different localities.

In considering the agency of control afforded by the natural enemies the fact must not be lost sight of that these are dependent on the scale insects for their existence, and that, therefore, a fairly complete extermination of the host insects means a like extermination of its enemies. There is, therefore, a natural alternation or periodicity in the abundance of the scale insect and its parasites. A more even balance may be maintained to a certain extent by artificial introduction of the parasitic insect the moment the scale has begun to be abundant, in this manner assisting the early multiplication of the natural enemy. This is now the practice with the fluted scale in California, South Africa, and Portugal. To succeed in such efforts, it is necessary to have an efficient parasite or predaceous insect, and also regular breeding places where these may be secured when wanted. These conditions may be naturally supplied when a whole district, such as California, is under constant observation and the localities where the parasite and scale are occurring together are known, so that from such points the ladybirds or other enemies may be collected and shipped to the districts needing them.

THE DIRECT MEANS OF CONTROLLING CITRUS SCALE INSECTS.

Scale insect enemies of citrus trees are directly controlled in two ways: (1) By spraying the infested plants with some liquid insecticide, (2) by subjecting them to the fumes of hydrocyanic-acid gas, commonly designated as "gassing." Each of these methods of control has its place.

THE GAS TREATMENT.

The gassing method (figs. 1–6) is undoubtedly the most effective means known of destroying scale insects. It has been in general use

FIG. 1.—Method of hoisting tent over orange tree.

in California for fifteen years, and to a less extent elsewhere on citrus trees, and the methods are now thoroughly perfected and highly satis-

factory. Gassing should undoubtedly be employed wherever the expense of the treatment, which is the one objection to it, is not an object as measured by the value of the crop protected. For most

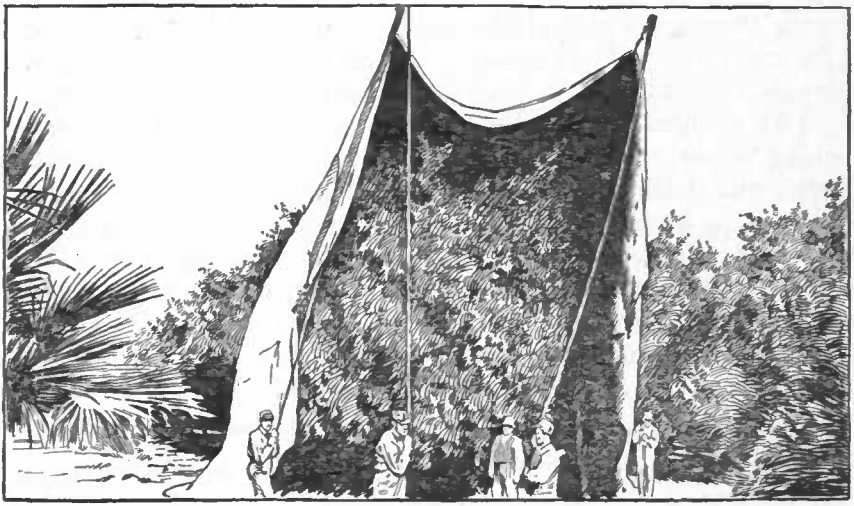

FIG. 2.—Tent carried over tree by the falling of pulleys.

species of scale insects, one good gassing is worth as much as two or three sprayings, and, when done at the right season and properly, it very frequently will almost, if not quite, exterminate the scale insects from the treated trees, giving them comparative immunity

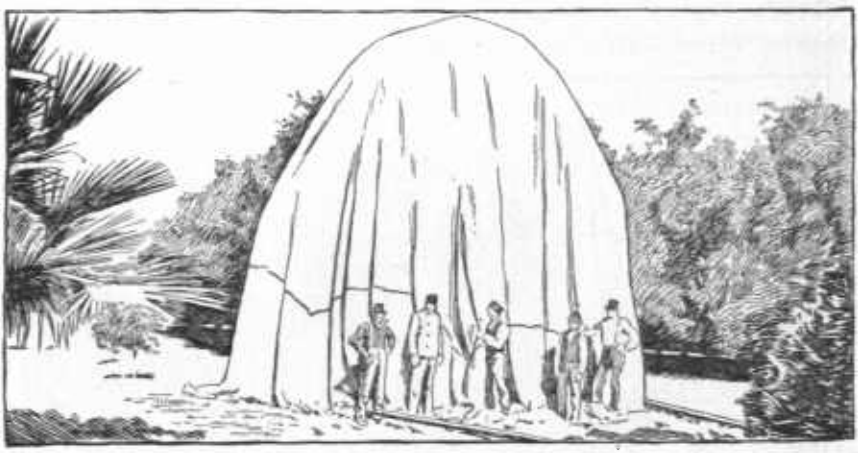

FIG. 3.—Tent in position for fumigation.

often for two or more years. The use of hydrocyanic-acid gas is, therefore, strongly urged wherever the conditions warrant it. Gassing is especially desirable for trees that have a dense habit of growth, such as the orange, which develops a large, thick head, the spraying

of which thoroughly and completely is almost impossible, especially after the trees have attained any size. Furthermore, with gas there is no danger of spotting the fruit as may happen with improper spraying.

FIG. 4.—Removing tent by horse power.

The more straggling growth of the lemon makes gassing less necessary, notably where the open system of pruning is adopted.

Successful as gassing is, it is not effective in the same degree against all the scale insect enemies of citrus plants. It is especially valuable

FIG. 5.—Series of tents for continuous operations.

against the black scale and the red scale of California, but with such of the armored scales as are oviparous, or deposit beneath the old scales eggs which undergo a certain amount of incubation before hatching, gassing is not always effective. Under such circumstances the

eggs may not be killed, rendering it necessary to make an additional treatment after a sufficient period has elapsed to allow all the eggs to hatch and the young to escape.

The black scale is especially adapted to control by gassing on account of its being, in the main, single-brooded. Applied late in October or early in November after all the young scales have hatched, badly infested orchards have been completely cleaned by a single treatment. Gassing in midsummer for this insect will be ineffective, because a large percentage of the old females at this period cover and protect unhatched eggs.

Gassing consists in inclosing a tree at night with a tent and filling the latter with the poisonous fumes generated by treating refined potassium cyanide (98 per cent strength) with commercial sulphuric

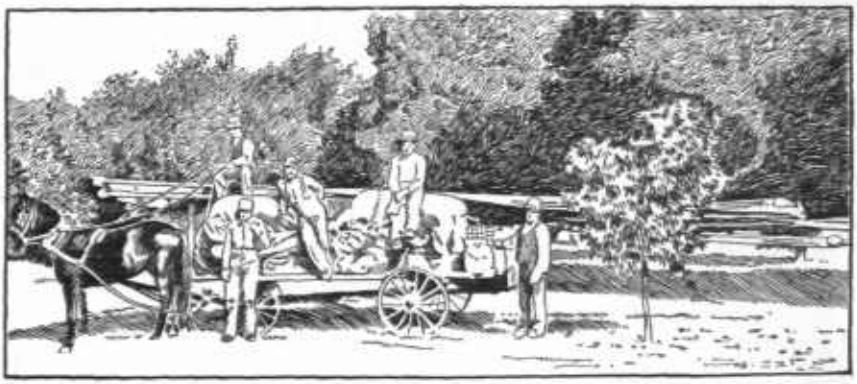

FIG. 6.—Tents, tackle, and chemicals loaded for transportation.

acid (66 per cent) and water. The treatment should continue from thirty to forty minutes, the longer time being preferable. The work is done at night to avoid the scalding which follows day applications, at least in bright sunlight.

The proportions of the chemicals as now employed in California are considerably in excess of the amounts recommended a few years since. The gas treatment was first chiefly used against the black scale, and at a season of the year when these scales were all in a young stage and easily killed. The effort is now made not only to kill the black scale, but also the red scale, and to do more effective work with both than formerly. The proportion of chemicals commonly employed in Los Angeles, Orange, and some other counties in southern California are indicated in the following table, published by the horticultural commissioners of Riverside County, Cal.:

Amounts of chemicals ordinarily used in gassing.

Height of tree.	Diameter through foliage.	Water.	Cyanide C. P. (98 per cent).	Sulphuric acid (66 per cent).
Feet.	*Feet.*	*Ounces.*	*Ounces.*	*Ounces.*
6	4	2	1	1
8	6	3	1½	1½
10	8	5	2½	2½
12	14	11	5	5½
16	16	17	8	9
20	16–20	22	10	12
20–24	18–22	30	14	16
24–30	20–28	34	16	18
30–36	25–30	52	24	28

The amounts here recommended are thoroughly effective for the black scale at the proper season, and generally effective also for the California red scale and other armored scales. Where the treatment is designed to be absolutely one of extermination, and the expense is not considered, from one-third to one-half more of cyanide and acid is employed, as indicated in the table following, furnished by Mr. Felix G. Havens, of Riverside, Cal.

The greater expense entailed by this larger quantity of chemicals is offset by the more effective results and the longer intervals between treatments:

Excessive amounts used for extermination.[a]

Height of tree.	Diameter through foliage.	Water.	Sulphuric acid (66 per cent.)	Cyanide C. P. (98 per cent).	Time to leave tent on tree.
Feet.	*Feet.*	*Ounces.*	*Ounces.*	*Ounces.*	*Minutes.*
6	3 to 4	3	1½	¾ to 1	20
8	5 to 6	6	2½	2	30
10	7 to 10	15	5 to 6	4 to 5	35
12	9 to 12	20 to 30	7 to 9	5½ to 7½	40
14	12 to 14	30 to 35	9 to 12	8 to 10	40
16	12 to 15	35 to 40	12 to 14	10 to 12	40
18	14 to 16	45 to 55	15 to 18	12 to 15	40 to 50
20	16 to 18	60 to 70	20 to 22	16 to 20	45 to 50
22	16 to 18	70 to 75	22 to 25	20	50
24	18 to 20	75 to 80	25 to 30	22 to 26	50
27	20 to 24	85 to 100	30 to 36	28 to 32	60
30	20 to 28	100 to 110	36 to 44	32 to 38	60

[a] A fumigation of the orangery of the Department of Agriculture demonstrated that half an ounce of cyanide to the hundred cubic feet kills the eggs, even of the black, purple, and other scales. The results are scarcely comparable to the proportions recommended in the tables on this page, for the reason that in these tables the amount of cyanide is greatly lessened with larger trees, and furthermore, that the orangery probably retained the gas more effectually than would be the case with cloth tents. Nevertheless, it is interesting to know that a comparatively inconsiderable strength of cyanide, when applied under the best conditions, will prove thoroughly effective against the eggs as well as the insects.

For small trees ordinary earthenware vessels may be used to generate the gas. For large trees requiring heavy doses tall wooden pails have proved more practicable, two generators being employed for the very largest trees. It is important that the water be put in the vessel first, and then the acid, and lastly the cyanide. If the water and cyanide are put in the vessel first and the acid poured in afterwards there is danger of an explosion, which will scatter the acid and burn the tents and the operator. In the spring, when the trees are tender with new growth, and in early fall, when the oranges are nearly grown and the skins are liable to be easily marred, and also with young trees, it is advisable to add one-third more water than ordinarily used, or use the cyanide in larger lumps. This causes the gas to generate more slowly and with less heat, and if the tents are left over the trees a third longer the effectiveness of the treatment will not be lessened.

The extremely dangerous nature of the gas must be constantly borne in mind and the greatest caution should be taken to avoid inhaling it. The person handling the chemicals should always have an attendant with a lantern, to hold up the tent and enable the cyanide to be quickly dropped into the generator and to facilitate the prompt exit of the operator.

As with spraying, the gassing is often done (and this is very desirable also) by individuals or companies who make a regular business of it, charging a fixed rate per tree, depending on size—from 10 cents to a dollar or more. Much of this work is also done under the direct supervision of the county horticultural commissioners, which gives a greater assurance of efficiency.

Practically, the only tent now used is the so-called "sheet tent," which is drawn up over the tree by means of pulleys (figs. 1–3). For very large trees, averaging 30 feet in height, it is sometimes necessary to employ two sheets to effect a complete covering.

Some of the tents employed are of great size, the one illustrated in the figures, from photographs secured by Mr. Havens, having a diameter of 76 feet. As described by Mr. Havens, it is constructed of a central piece 50 feet square, of 10-ounce army duck. Four triangular sidepieces, or flaps, of 8-ounce duck, 10 feet wide in the middle, are strongly sewed to each side of the central sheet, forming an octagonal sheet 70 feet in diameter. About the whole sheet is then sewed a strip of 6-ounce duck, 1 yard wide. The tent is handled by means of ropes and pulleys. A 1½-inch manila rope is sewed about near the edge of the central piece in an octagonal pattern. Rings are attached to this rope at each of the eight corners thus formed, and also on opposite sides of the outer edge. To these rings the pulley ropes are fastened and the tent is elevated over the tree and handled as indicated in the plates.

The treatment is made altogether at night, although it would be

possible to treat trees also on a very dark or cloudy day. In California, however, at the time the gas treatment is made, such days are infrequent. About 50 trees of the largest size, 30 feet high or thereabouts, can be treated in a night with an equipment of twelve or fifteen tents (fig. 5). By the time the last tent is in place, the fumigation in the first is completed, and it can be taken down and moved forward, and so on with the others; thus the men at work handling the tents are kept continuously employed. Working in the same way with smaller trees, the number which can be treated in a single night is very considerable, it being possible to gas from 300 to 500 trees, averaging 10 feet in height, in eleven or twelve hours, employing 35 to 40 ring tents.

SPRAYS FOR CITRUS TREES.

It may often happen that gassing is impracticable or that the expense of the treatment is not warranted. This last may be the case where the rancher has not sufficient capital to keep up the heavy

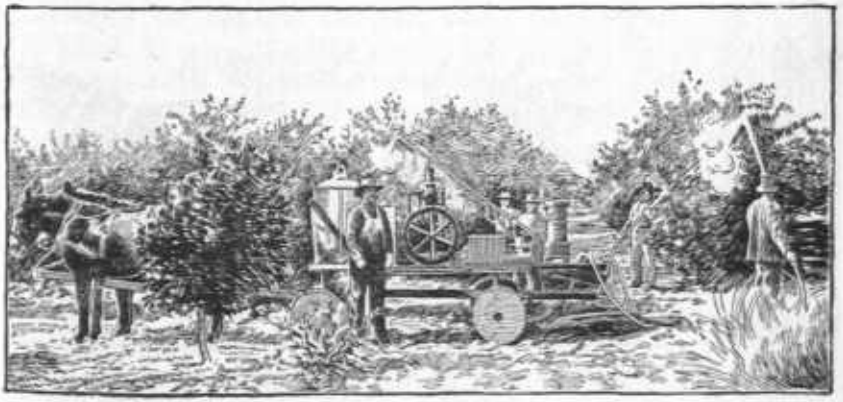

FIG. 7.—Gasoline-power spraying outfit with four lines of hose in operation.

outlay necessitated by the treatment of young stock which yields no revenue. Gassing is also difficult and less desirable where, as for the lemon in southern California, the low, open-center pruning is adopted, the trees under this system of pruning often having an expanse of 20 feet, with a height of scarcely more than 6 feet. This open system of pruning and more straggling form of growth, on the other hand, makes the lemon easier to treat with liquid sprays, and under such conditions spraying will probably prove more practicable and profitable than gassing. Nevertheless, where lemon trees are of a form and size to admit of it, and the crop warrants the expense, gassing is always to be recommended.

The expense of spraying is not heavy, compared with that of gassing. In most of the citrus districts of California where spraying is practiced to any extent there are individuals who make a business of treating orchards at a charge of a cent a gallon for the liquid applied, or about

double that price when they furnish as well as apply the insecticide. This work is now commonly done with a power apparatus (fig. 7),[a] and usually in a fairly satisfactory manner. The difficulty in depending on the public sprayer is that it is very often not available when much needed. For a large ranch the possession of a power spraying outfit will probably prove economical in the long run, and anyone contemplating securing one is referred to the general article on such machines, by Dr. L. O. Howard, in the Yearbook of this Department for 1896.

For the small rancher, having from 10 to 30 acres of orchard, it is not necessary to go to the expense of a steam or a gasoline spraying apparatus. There are a great many excellent force pumps on the market which may be easily equipped with suitable hose and nozzles, and which will do the work of spraying very satisfactorily. A hand force pump with suitable connections, which may be equipped for

FIG. 8.—Hand-power spraying outfit with two lines of hose in operation.

work at a cost of from $25 to $30, will meet all requirements. The pump for such an outfit should be capable of easily producing a pressure of 100 pounds, which will supply four cyclone nozzles attached to two lines of hose. With such an apparatus (fig. 8), the writer was able to spray easily 50 gallons an hour, or 500 gallons a day, working with three men, and this covers also the time lost in mixing the insecticide and refilling. The cost of applying the same amount of liquid by a contract sprayer would probably be a little less, but under personal supervision, the work will undoubtedly be better done and with less waste of material, and, of more importance still, at the time when most needed and when the greatest advantage will result.

Trees under seven years old will probably require from half a gallon to a gallon of spray per tree. For an orchard of 10 acres, or about 860 trees, the cost of spraying would be about $8 for the spray and

[a] From photograph furnished by F. Kahles.

as much more for the labor. In other words, spraying with the insecticides commonly employed, such as "distillate," kerosene emulsion, and resin wash, may be safely estimated to cost about 2 cents a gallon for the amount of liquid used, or not exceeding 2 cents per individual tree under seven years of age. On the other hand, gassing trees seven years old will cost from 12 to 15 cents per tree, or the equivalent of from five to seven sprayings. The advantage, therefore, of spraying, for the small owner, and for trees especially suited by form of growth or pruning to such treatment, is evident.

The oily washes are by far the best for use on citrus trees against scale insects. The attempt has been made in various places to substitute lye washes for the old standard kerosene washes, but the effect has, as a rule, been disastrous. Lye strong enough to kill scale insects applied to a tree, as demonstrated by Hubbard fifteen years ago, is very destructive to the tender growth of the tree, and the damage from the wash is often greater than that occasioned by the insects themselves. In California, the kerosene and resin washes formerly used have now given place, to a considerable extent, to a modification of kerosene emulsion known as "distillate." As now employed, the washes in the order of their popularity are: (1) Distillate; (2) resin wash; (3) kerosene emulsion. The probability is that distillate will ultimately supplant the other two on account of its equal, if not greater, efficiency and smaller cost.

Distillate.—This wash was originated by Mr. F. Kahles, and has found very general use in the Santa Barbara region, and also in the lemon districts adjacent to San Diego, as well as in other citrus districts in California. It is substantially an emulsion of crude kerosene, made in the same way as kerosene emulsion, except that a greater amount of soap and only half as much oil are used. Its cheapness results from the latter fact. In spite of this lessening of oil it seems to be, if anything, stronger than kerosene emulsion.

It is termed distillate spray, because the oil used is a crude distillate of the heavy California petroleum, or the crude oil minus the lighter oils.

The emulsion or "cream," as it is generally known, is prepared as follows: Five gallons, "28° gravity," untreated distillate; 5 gallons water, boiling; 1½ pounds whale-oil soap. The soap is dissolved in the hot water, the distillate added, and the whole thoroughly emulsified by means of a power pump until a rather heavy, yellowish, creamy emulsion is produced. For use on lemon trees it is diluted with 12 parts of water, and with 15 parts of water for the orange. The "distillate cream" is prepared and sold by oil companies and private individuals at from 10 to 12 cents a gallon, making the dilute mixture, as applied to the trees, cost in the neighborhood of a cent a gallon.

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Kerosene emulsion, made by the same companies, costs from 12 to 15 cents a gallon. In using these oil emulsions it is advisable to first break the water by the addition of a little lye, one-fourth pound being ample for 50 gallons of water.

Kerosene emulsion.—This wash, made according to the old formula (kerosene, 2 gallons; whale-oil soap, one-half pound; water, 1 gallon), is prepared in the same way as the distillate and used at the same strength. It does no harm to use double the quantity of soap indicated, securing in this manner a rather more stable emulsion. This emulsion, while perhaps somewhat less efficient than the distillate emulsion, is always available where the latter may not be in reach. It may be prepared on a small scale with an ordinary hand pump, but is best prepared in large quantities with a gasoline or steam-power pump to mix and emulsify it after the soap has been dissolved in the water by boiling.

The resin wash.—This wash is especially valuable against the California red scale. It may also be used against any other scale insect, including the black scale and the various armored scales affecting citrus trees. The wash is made as follows: Resin, 20 pounds; caustic soda (78 per cent), 5 pounds; fish oil, 2½ pints; water to make 100 gallons. Ordinary commercial resin is used and the caustic soda is that put up for soap establishments in 200-pound drums. Smaller quantities may be obtained at soap factories, or the granulated caustic soda may be used, 3½ pounds of the latter being the equivalent of 5 pounds of the former. Place these substances with the oil in a kettle with water to cover them to a depth of 3 or 4 inches. Boil about two hours, making occasional additions of water, or until the compound resembles very strong black coffee. Dilute to three times the final bulk with hot water, or with cold water added slowly over the fire, making a stock mixture to be diluted to the full extent as used. When sprayed the mixture should be perfectly fluid, and should any sediment appear the stock mixture should be reheated; in fact, the wash is preferably applied hot. This wash is more difficult to prepare than the emulsions referred to above, and is therefore much less employed.

CITRUS SCALE INSECTS: CLASSIFICATION AND CHARACTERISTICS.

For the purpose of this paper a very simple classification of citrus scale insects may be adopted, namely: (1) The armored scales, or those forming a protective covering scale and losing their limbs and the power of changing their situation as soon as they settle down to feed as newly hatched larvæ; (2) those species which secrete no covering shell or scale and retain their limbs and the power of moving about during most of their lives.

The species belonging to both groups are commonly called scale insects, although the term might seem properly to apply only to the

first group; nevertheless, the old insects in the second group, when they become hardened, and, in fact, the younger stages also, greatly resemble scales; hence, the name may properly apply to them as well.

These insects all belong to the family Coccidæ of the order Hemiptera, or true bugs, being allied to plant-lice and other suctorial insects of this order. In the larval stage the scale insects, except in point of size, closely resemble the larvæ of the higher forms of Hemiptera, and are active and can run about on plants or may be carried from one plant to another by the wind, or by birds or other insects to which they may attach themselves.

In the case of the armored scales, as soon as the young have undergone their first molt they appear as mere sacks provided with long sucking beaks, but without legs or eyes, and are very much degraded structurally from the larval condition. The unarmored scales, while retaining their limbs throughout life, are not apt to move very much after they have once settled and begun to feed, except in the case of one or two species. The power of locomotion, however, is retained, and in the case of the fluted scale and mealy bug is often actively brought into play; the Lecaniums and wax scales are apt to migrate late in their lives from the leaves to the twigs. The female insects of both groups remain on the plants and never advance to a winged stage. The males of both groups, however, while paralleling the development of the females in the early stages, in the later stages transform to pupæ, and eventually emerge as minute, two-winged gnats. The life of the winged male is very short, and its sole function is to fertilize the eggs of the female. It is a very delicate creature, having no mouth parts, but in place of them a second pair of prominent eyes.

GROUP 1.—THE ARMORED SCALES.

The majority of the important scale-insect enemies of the orange belong to the group known as armored scales because the insects begin to excrete as soon as they thrust their beaks into the tissues of the plant a waxy covering which protects the growing insect and forms a definite scale-like shield entirely independent of the insect itself. This group includes the long scale, purple scale, the red scale of California and the red scale of Florida (an entirely distinct insect), the oleander scale, the chaff scale, and other less important species.

In general habits these armored scales are very similar. The eggs, which are developed in enormous numbers, may be extruded under the covering scale of the mother insect and undergo a longer or shorter period of incubation before hatching, or the young may be partly or fully developed within the body of the mother and emerge as active insects, or more properly shake off the egg envelope at the moment of birth, so that certain species appear to yield living young. The young

of these different species of armored-scale insects very closely resemble each other, and can not be distinguished without careful microscopical study. While very minute, the young are yet visible to the naked eye, and during the breeding season may be seen, by sharp inspection, running about on the leaves, twigs, and fruit. In color they are usually light lemon-yellow. They have six well-developed legs, also antennæ and eyes, and are highly organized in comparison with the degraded condition soon to be assumed. After finding a suitable situation, often within a few minutes from the time of their emergence, though sometimes not for an hour or two, they settle down, thrust their long slender hair-like beaks into the plant, and immediately begin growth, the first evidence of which is the secretion of waxy filaments from the upper surface of the body, which mat down and form the beginning of the scale covering (fig. 12). This waxy secretion continues during the life of the insect, the covering scale being enlarged as the insect increases in size. The females undergo two molts, and the skins thrown off in these molts form a definite part of the scale, being cemented to it closely with the wax. The female insect, after the second molt, soon reaches full size, and when fertilized by the male begins to develop her numerous progeny.

The preliminary stages of the male scale insect exactly correspond with those of the female. After the first molt, however, the male assumes a slightly different appearance, being more elongate than the female at this stage. With the second molt the male diverges entirely from the female; the old skin is thrust out from beneath the covering scale, and does not become a part of it, as with the female, so that in the case of the male insect the first-shed skin only is associated with the scale, which never becomes more than one-half the size of that of the female. With this second molt the male insect transforms to a preliminary pupal stage, in which the antennæ, legs, and wings are partially developed. A third molt occurs with the male insect, resulting in the final pupal stage, which exhibits more fully formed legs and wings than the preceding stage and also the so-called terminal style. A fourth and last molt of the male produces the perfect insect, which escapes from beneath the covering scale and can fly about (fig. 11, *e*).

The periods between the moltings vary with different species and with weather conditions. Most of the species, however, reach full growth in from four to six weeks in summer; development is slower in winter.

The female insect, having once thrust her beak into the tissues of the plant as a larva and begun the secretion of a covering scale, never moves from her position; and, in fact, if she be removed by force is never again able to penetrate the bark with her sucking beak, and soon perishes. The opportunity for the local spread of these insects is, therefore, limited absolutely to the larval stage, as in this respect they

differ from the Lecaniums and mealy bugs, which have the power to move about until nearly the end of their growing period.

The number of eggs from a single female varies somewhat with the species, but may be from 100 to 500, the number being less in unfavorable seasons. The progeny from a single female in a year, if they should all survive, would represent almost inconceivable numbers, running into the billions. It is not to be wondered at, therefore, that plants become thoroughly infested with these insects in a very short time, especially in climates where the breeding is but little checked by the winter season.

The waxy covering makes it necessary to use rather strong washes to penetrate the scale. The difficulty increases when the old scale protects a mass of eggs, as is usually the case with the species of Mytilaspis, represented by the long and purple scales; and it is not always possible with the best washes to kill all the eggs of these species, hence the necessity of spraying repeatedly to destroy the young as they emerge. Remedial operations should be instituted as far as possible when the greatest percentage of the scales are in a young or partly mature condition.

FIG. 9.—Long scale (*Mytilaspis gloveri*): Group figure, showing cluster of male and female scales on fruit of orange—enlarged 7 diameters (original).

The Long Scale.

The long scale (*Mytilaspis gloveri* Packard—fig. 9) is supposed to have originated in China, but in common with most of the other species discussed has now a world-wide distribution, being represented in practically every important citrus region. It made its appearance in Florida about 1838, and soon became a very serious pest in that State and elsewhere in the Gulf region. At its first appearance it was vastly more destructive than later on, parasitic and natural enemies having in later years kept it decidedly in check. At present it is everywhere distributed throughout Florida and Louisiana in the orange and lemon groves, and also on wild orange. Strangely enough, it was a long while getting into California. About 1889 or 1890, however, in company with the purple scale and rust mite, it was carried into California on a lot of stock from Florida, but it has not developed as a very serious pest in the Pacific coast region.

This insect is characterized by its very elongate form; in other respects it closely resembles *Mytilaspis citricola*, and also the common oyster-shell scale of the apple and other deciduous fruits. In color it

is a rather rich reddish, often obscured by extraneous matter taken from the surface of the leaves or bark. It apparently requires a great deal of moisture to thrive well, and hence is apt to be abundant on oranges or other plants grown in conservatories, and this also accounts, doubtless, for its greater multiplication and injury in Florida than on the Pacific coast.

Breeding continues practically throughout the year. According to Hubbard, there are three periods in Florida when the young are especially abundant, marking in a rough way the appearance of the main broods, namely, in March and April, in June and July, and in September and October; the fourth, irregular brood, occurring in January or February.

The treatment for this scale is the use of the oily washes and fumigating with hydrocyanic-acid gas. It is much more easily controlled than the purple scale.

The Purple Scale.

The original home of the purple scale (*Mytilaspis citricola* Packard) (figs. 10 to 12) is unknown, but it now occurs practically wherever

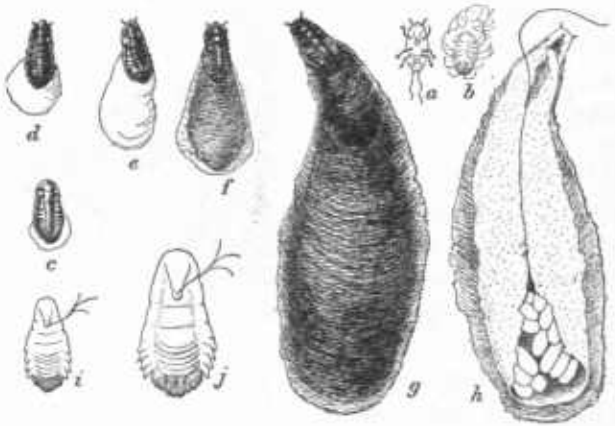

FIG. 10.—Purple scale (*Mytilaspis citricola*), showing different stages of female: *a*, newly hatched larva; *b*, same with first waxy secretion; *c* to *f*, different stages of growth; *g*, mature scale; *h*, same inverted, showing eggs; *i* and *j*, half-grown and full-grown female insects removed from scale—all much enlarged (original).

the orange or lemon is grown. It was probably introduced into this country at an early date. It is frequently associated with the long scale, and is one of the most troublesome scale insects affecting the orange and lemon, because it is very difficult to get an application on the trees strong enough to kill all of its eggs with one treatment. For many years the purple scale was limited in this country to Florida and the Gulf region, but some years since it was carried on Florida stock into southern California, where, fortunately, it has not yet become widely distributed. In general color it is a brownish purple, and in shape duplicates the oyster-shell scale of the apple. The life

history and habits are the same as those of the long scale. The purple scale is not limited to citrus fruits, but occurs also on many other plants.

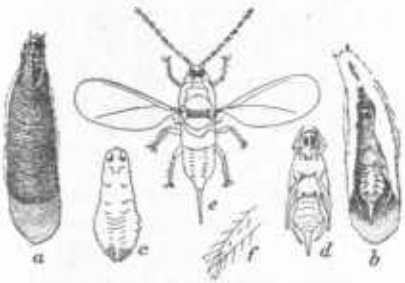

FIG. 11.—Purple scale (*Mytilaspis citricola*), showing different stages of male: *a*, fully developed male scale; *b*, same inverted, showing male pupa within; *c*, propupa; *d*, final pupal stage; *e*, mature winged insect; *f*, foot of same much enlarged—all greatly enlarged (original).

FIG. 12.—Purple scale (*Mytilaspis citricola*), illustrating the formation of the scale covering: *a*, newly hatched young, with enlarged antennæ at left and leg at right; *b*, side view of forming scale; *c*, same from above—all greatly enlarged (original).

Neither the gas treatment nor any of the washes is a certain remedy for this scale, except in the immature stages. Occasionally a very strong treatment will kill the eggs, but it is usually necessary to repeat the application once or twice at intervals of two or three weeks to effect anything like extermination.

The Red Scale of Florida.

This is another scale insect (*Aspidiotus ficus* Ashmead) of world-wide distribution. As an orange scale it is not a very serious pest on trees grown out of doors, but on trees grown in conservatories or under glass it is very apt to thickly infest the leaves and fruit. It has a very wide range of food plants and is one of the commonest of scale insects. This and the following species differ from the Mytilaspis scales in being nearly circular in general outline, with the molted skins in the center of the scale instead of at the small end (fig. 13). The color of this scale is a rich reddish

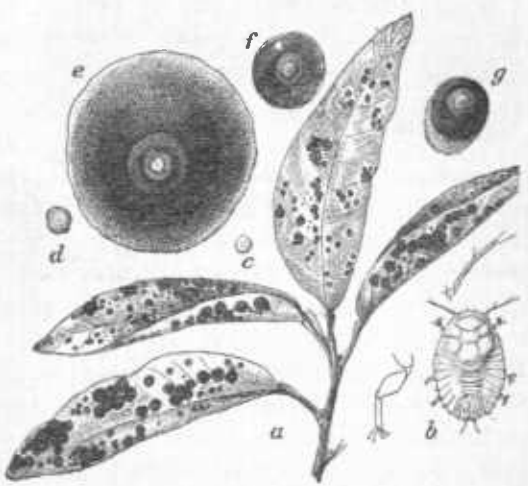

FIG. 13.—Florida red scale (*Aspidiotus ficus*): *a*, leaves covered with the male and female scales—natural size; *b*, newly hatched insect with enlargements of antennæ and leg; *c*, *d*, *e*, *f*, different stages in the development of the female insect, drawn to the same scale; *g*, adult male scale—similarly enlarged (original).

brown, almost black. The central portion, however, is much lighter, giving the appearance of a dark ring with a light center. The number of generations can not be accurately given, breeding going on throughout the year, but undoubtedly in greenhouses and tropical regions six or seven generations are not unusual, and in subtropical regions five generations may be safely counted. It seems never to have attracted any attention as an enemy in the orange and lemon groves of California, the dry climate evidently not suiting it. The moist climate of Florida and the Gulf region seems more favorable to it.

The Red Scale of California.

This species (*Aspidiotus aurantii* Maskell) (fig. 14) is entirely distinct from the red scale of Florida. Its name comes not from the covering scale, as with the Florida species, but from the fact that the body of the mature female turns a reddish brown and shows through the thin transparent waxy scale. This insect, although for years very common and destructive in the groves of southern California, and enjoying also a cosmopolitan distribution, has, curiously enough, never appeared in a destructive way elsewhere in this country. Its origin is a matter of some uncertainty. It is now widely distributed, and has undoubtedly been a scale pest in oriental countries for centuries. It is not limited to citrus plants, but may occur on almost any plant growing in tropical or subtropical regions. It is the most destructive and injurious of all the scale insects affecting the orange in California, being especially troublesome in the districts about Los Angeles. So far no effective parasites or predaceous insects have been found to combat it. It is controlled by the oily washes, and also by the gas treatment. The young are born free, or, in other words, the insect is semi-oviparous, and therefore any wash which will kill the old scale will destroy the young also.

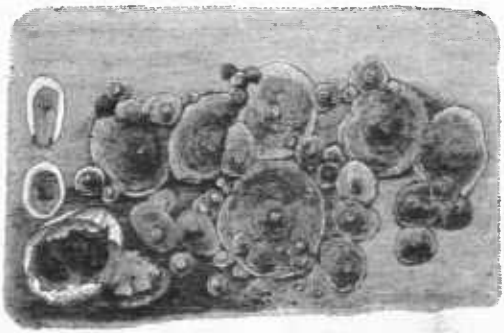

FIG. 14.—California red scale (*Aspidiotus aurantii*), illustrating a group of the female and male scales as they occur on an orange leaf—enlarged about 7 diameters (original).

This insect has, in California, a rather well-marked variety, known as the yellow scale (*Aspidiotus citrinus* Coq.). This variety does not differ in any structural feature from the red scale, but the mature insect remains yellowish in color. This variety is attacked by quite a number of parasitic flies, which keep it more or less in check, so that it is not, as a rule, so abundant as the red variety.

The Oleander Scale.

This species (*Aspidiotus hederæ* Val.) is not distinctively an orange pest. It occurs on a great variety of plants and has a world-wide distribution. It occasionally occurs on the lemon and orange, especially in California, not apparently being so likely to attack this plant in Florida. It is a very delicate scale, with a very thin waxy covering, and yields readily to treatment. It frequently occurs on the oleander, and is commonly known as the oleander scale (fig. 15). The male scales are white and very greatly exceed the females in abundance (much more so than indicated in the accompanying illustration). The female scales are light buff in color with a faint purple tinge, rather than white, are two or three times the size of the male scales, and rather larger also than the scales of the species already described. The fruit of the lemon and orange is often invaded by the females of this species.

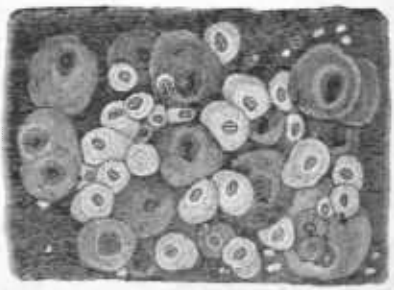

FIG. 15.—Oleander scale (*Aspidiotus hederæ*), illustrating a group of the female and male scales as they occur on a leaf—enlarged about 7 diameters (original).

The Chaff Scale.

With this scale insect (*Parlatoria pergandei* Comstock) the molted skins are at one end of the scale, as in the case of Mytilaspis, and the scale is oval or nearly circular, as in the case of Aspidiotus. It is very apt to be clustered thickly, often overlapping on leaves or twigs and fruit, giving the surface a rough appearance, as though covered with loose chaff (fig. 16). In color the female scale is light straw-yellow, the female insect showing through, usually with a greenish tinge. The number of generations and life history correspond very closely with the species already described. As a rule, the chaff scale by preference remains on the trunk and branches, covering these portions of the plant densely before going on the leaves and fruit. This fact renders it somewhat less noticeable than the other species, and its presence may, for a time, be overlooked.

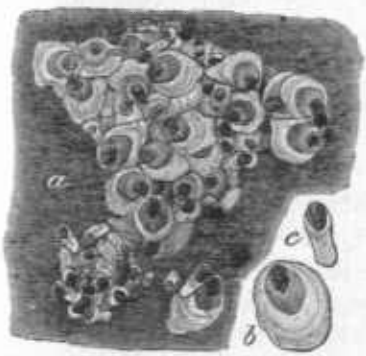

FIG. 16.—Chaff scale (*Parlatoria pergandei*), illustrating a group of the female and male scales as they occur on a leaf—enlarged about 7 diameters (original).

The chaff scale has been destructive, so far, only in Florida and the Gulf region, having apparently been introduced from the Bermuda

Islands or some of the West Indies. It is closely allied to certain scale insects occurring in the Old World, and probably came to this country from Europe or Asia. It yields to the same treatments which are advised for the other armored scales.

The Orange Chionaspis.

This species (*Chionaspis citri* Comstock) occurs in the orange groves of the Eastern United States, and is also especially troublesome in Louisiana. Professor Morgan reports that its presence on the trees causes a bursting of the bark and very ugly wounds, followed in very many cases by the rotting of the trunks of the older trees. The orange Chionaspis (fig. 17) is found also in several of the West Indian islands, Mexico, and in most foreign countries where citrus fruits are grown. The male scales are striking objects on account of their white color, and the females are readily distinguished from the other armored scales of similar general shape by the distinctly ridged appearance of the waxy portion. The orange Chionaspis is readily controlled by the same treatments advised for the other armored scales.

FIG. 17.—Orange Chionaspis (*Chionaspis citri*), illustrating a group of the female and male scales as they occur on a leaf—enlarged about 7 diameters (original).

GROUP 2.—THE UNARMORED SCALES.

The species to be considered in this group include three Lecaniums, the mealy bug, two wax scales, and the fluted scale. Strictly speaking, the Lecaniums are the only ones which secrete no covering. The mealy bug secretes a waxy or mealy powder, which covers its body, and a similar secretion in less amount is made by the fluted scale. Both of the latter species secrete very abundant quantities of wax for the protection of their eggs. The wax scales cover themselves with copious waxy secretion, which, however, attaches firmly to the body, and can not be considered as a separate covering in the sense of the scale of the armored species. The development of the different species in this group is very similar, in that they all retain the power of locomotion until nearly the end of their lives, and do not suffer the loss of limbs and the marked retrograde development already described in the case of the armored scales. They excrete liberally the honeydew, which is followed by the smut fungus. In this group are included some of the worst scale pests of the orange and lemon, notably the black scale, the fluted scale, and the mealy bug. Not being so firmly attached nor

so protected by a covering shell or scale, they are as a rule more easily destroyed by fumigation or sprays, and they fall a more ready prey to attacks of predaceous and parasitic insects. All of the species are egg-laying. The Lecaniums and wax scales deposit their eggs in cavities under their bodies, formed by the contraction of the female insects, so that ultimately the mothers become mere shells over vast numbers of eggs and hatching young. The mealy bugs and fluted scale excrete a quantity of cottony fibers, which are stocked with eggs. After a certain amount of incubation, the young hatch and escape from beneath the old parent scales or burrow out of their cottony nests. In transformations and general life history, except in the points noted, these scale insects closely duplicate the habits of the armored scales.

The Black Scale.

This scale insect (*Lecanium oleæ* Bernard—figs. 18, 19, and 20) is notably an olive pest, but it also attacks citrus fruits, and is quite as destructive to the latter as to the olive. It is an insect of world-wide distribution, having been an important enemy of the olive and citrus fruits in the Old World as far back as we have any records. It also affects a great variety of other fruits and plants. It occurs more or less in greenhouses, and has undoubtedly been transported to various parts of the world upon greenhouse plants as well as upon the various subtropical fruits. In the United States it is especially destructive only on the Pacific coast, and while it occurs generally in Florida it has never there assumed any great importance as an enemy of the orange or lemon. It not only saps the vitality of the plants by the extraction of their juices, but also abundantly secretes honeydew, which results in a badly attacked plant becoming thoroughly coated and blackened with the sooty fungus.

FIG. 18.—Black scale (*Lecanium oleæ*): Group of scales, showing natural position and appearance—enlarged 4 diameters (original).

The adult insect is dark brown, nearly black, in color. Its characteristic features are the one longitudinal and the two transverse ridges. Very often the portion of the longitudinal ridge between the two transverse ridges is more prominent than elsewhere, giving a resemblance in these ridges to a capital letter H. The general surface of the body of this scale insect is shagreened or roughened, which will distinguish it readily, under a hand lens, from the allied species, even before the ridges have become prominent. Very fortunately for the citrus grower, the development of this insect is slow, and it has but one brood annually. The young, however, appear over a very wide interval of time, and this gives the appearance of more than one brood.

On reaching full growth, early in the summer, the female insect deposits her eggs beneath her already much-hardened parchment-like skin, the lower surface of the body gradually contracting until there is nothing left but the shell, covering a mass of hundreds of eggs. The eggs will hatch in a comparatively short time, but, as the females come to maturity at different dates, the young from this species are constantly appearing and spreading over the infested plants between June and the end of October. The growth, however, is very slow, and even those earliest hatched do not reach maturity until late in autumn, the latest maturing in June and July of the following year.

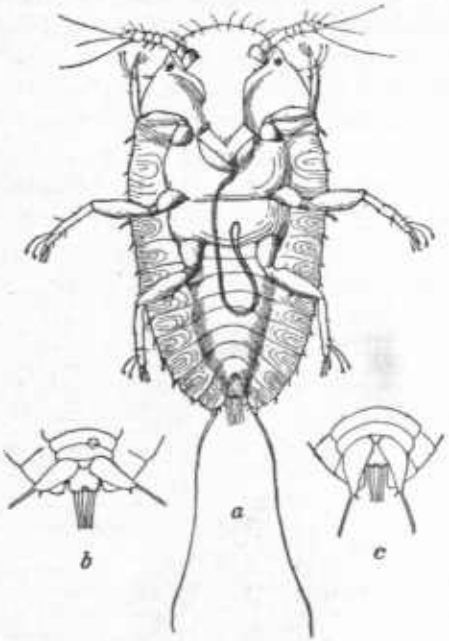

FIG. 19.—Black scale (*Lecanium olex*): *a*, greatly enlarged drawing of newly hatched larva, viewed from beneath, with enlargements of anal extremity viewed from above—*b*, showing anal segment extruded, and *c*, same retracted (original).

While retaining the power of movement practically throughout its development, this scale insect is very little apt to change its position after it is once settled, or, at least, after it is half grown. There is a general migration from leaf to twig, but the scale often develops

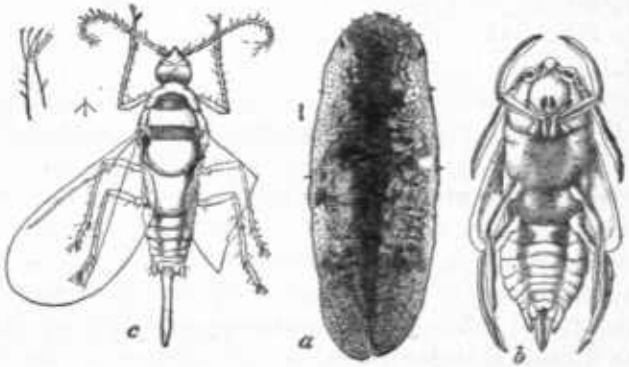

FIG. 20.—Black scale (*Lecanium olex*), male series: *a*, fully developed male scale; *b*, pupa; *c*, winged adult—natural size indicated by hair lines (original).

on the leaf if the latter remains vigorous and supplies it sufficient nourishment.

In view of the extraordinary abundance of the black scale it is surprising that until very recently the male insect had not been discovered, in spite of the most careful search for it. What we know of this stage is due to Dr. B. W. Griffith, of Los Angeles, Cal., who has found the male scales on oleander, orange, lemon, pepper, and ivy leaves between the months of November and April, in Los Angeles County. The accompanying illustrations of this sex (fig. 20) are based on material furnished by Dr. Griffith.

The natural enemies of the black scale promise to be very efficient in its general control and warrant special notice. They include both the parasitic flies and various species of ladybirds.

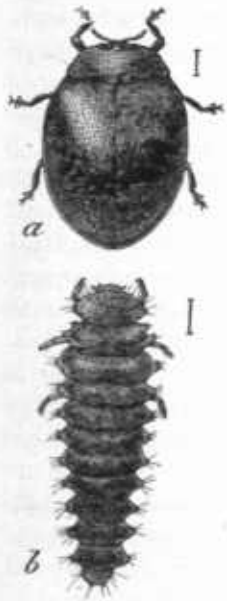

FIG. 21.—Imported ladybird enemy of black scale (*Rhizobius ventralis*): *a*, mature beetle; *b*, larva—both greatly enlarged (author's illustration).

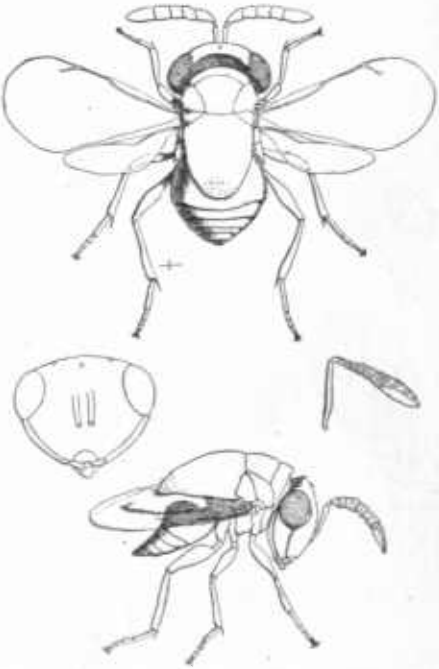

FIG. 22.—Imported chalcidid parasite of black scale (*Scutellista cyanea*), dorsal and lateral views—greatly enlarged (after Howard).

The ladybird enemy of special importance is the *Rhizobius ventralis*, imported by Mr. Koebele. This ladybird (fig. 21) has been colonized in various parts of California, and in districts where the climatic conditions proved favorable its work has been most satisfactory, notably on the ranch of Hon. Ellwood Cooper, at Santa Barbara. Hundreds of thousands of these beetles have been distributed in southern California and have accomplished in some localities a very great deal of good in keeping the black scale in check. Away from the moist coast regions, however, it is less effective, and experience has shown that this ladybird can not be completely relied upon to control the black scale.

A parasite which promises to be most effective in controlling the black scale is the very odd-shaped little chalcidid fly (fig. 22) known as *Scutellista cyanea* Motsch., first found attacking *Lecanium coffeæ* in Ceylon. It was later reported by Dr. Berlese as attacking a wax scale (*Ceroplastes rusci*) in Italy. Subsequent to its discovery in Italy, various efforts were made by Dr. Howard, with the assistance of Dr. Berlese, to introduce it into Florida and the Gulf districts, particularly as a means of controlling the wax scales. In the meanwhile it was found with the black scale in Cape Colony by Mr. Lounsbury, who, at Dr. Howard's suggestion and with his assistance and the cooperation of different persons in California, notably Mr. Craw and Mr. Ehrhorn, succeeded, in 1900, in getting the parasite into California, where it has been installed under conditions which promise a successful introduction of the species. During the last three years it has been constantly distributed in California and reports of its work are most favorable. In South Africa, as reported by Mr. Lounsbury, the black scale very rarely is abundant enough to be considered at all injurious, and this is apparently due to its parasitism by this little insect. If the latter can be induced to play the same rôle in California the saving will be second only to that accomplished by the Vedalia.

The remedial measures for the black scale are spraying with the oily emulsions and the gas treatment.

FIG. 23.—Soft scale (*Lecanium hesperidum*): Orange twig showing characteristic massing of the scales—natural size (after Comstock).

The Soft Scale.

This scale insect (*Lecanium hesperidum* L.—fig. 23), also known as the turtle-back scale or brown scale, is closely related to the black scale, but is a much softer and more delicate insect. It changes in color with age from a transparent yellow in the young to deepening shades of brown in the adult. The adult scale has a length of 3 or 4 millimeters, is turtle-shaped, and very much swollen, the body of the mother in the last stages becoming a mere cap filled with young. In the early stages the insect is thin and flat and semitransparent, so

that it is scarcely noticeable on the surface of the leaf or twig. It is very commonly found on various greenhouse plants, and has been carried to all parts of the world on such material. In climates suitable for the growth of the orange and lemon it occasionally gains a foothold on outdoor plants. It has a gregarious habit, and commonly lives in colonies, frequently covering the young limbs and the midribs of the leaves. These colonies are usually not of long duration, being soon attacked and exterminated by parasitic and predaceous enemies, the soft texture of the insect not furnishing much, if any, protection. The transformation and habits are very similar to those of the black scale. It, however, is much more rapid in growth, and, where the climate is favorable, goes through a continuous series of generations, or broods, throughout the season. It readily yields to oily washes or to the gas treatment.

The Hemispherical Scale.

This scale (*Lecanium hemisphæricum* Targ.—fig. 24) is also distinctively a greenhouse pest, and it can hardly be considered as especially injurious to citrus trees in orchards. It occurs all over the world, and occasionally will multiply to a slight extent on orchard trees. The individuals are about the same size as those of the last two species. In color it ranges from light brown in the young to dark brown, changing to reddish in the old scale. The adult scale is hemispherical in shape perfectly smooth and shiny, and this, with its color, readily distinguishes it from the other two species. The remedies are those used against the black scale.

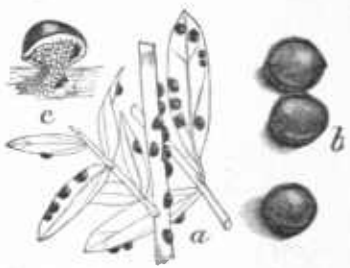

FIG. 24.—Hemispherical scale (*Lecanium hemisphæricum*): *a*, characteristic group of adult scales on olive—natural size; *b*, three female scales—considerably enlarged; *c*, scale lifted from leaf, showing mass of eggs (original).

The Florida Wax Scale.

This very curious and striking scale insect (*Ceroplastes floridensis* Comstock) secretes a white waxy covering, arranged in a very regular geometrical pattern (fig. 25). It was long known from Florida, where it is undoubtedly native, its principal food plant being the gall berry. It has now been carried, however, to other parts of the world, notably some of the adjacent West Indian islands, and also to the Old World. It was imported into California on stock from Florida in 1889, and possibly earlier, but has never gained any foothold on the Pacific coast. This insect often occurs on citrus plants, though rarely in sufficient numbers to be of very great importance. The white color and striking appearance of these scales cause them often to be noted,

and very natural fears of damage are excited, but as a rule the natural enemies and other causes result in very few of the young reaching the adult stage. This, as shown by Mr. Hubbard, not only follows the action of parasites, but also is due to the fact that the scale lice as they become old and gravid can not maintain their hold on the smooth surface of the lemon or orange leaf and fall to the ground and perish. The citrus plants, therefore, are not especially adapted to this insect and very rarely suffer long or seriously from it.

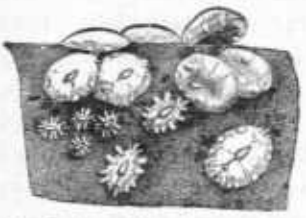

FIG. 25.—Florida wax scale (*Ceroplastes floridensis*): Group of scales, illustrating different stages of growth—enlarged about 4 diameters (original).

The Florida wax scale is three-brooded, development not being very rapid and extending over three or four months. The waxy secretions give an appearance to the young insect of an oval stellate object, the waxy prominences coalescing and disappearing with age.

The Barnacle Scale.

This insect (*Ceroplastes cirripediformis* Comstock—fig. 26), which is closely allied to the last, has been found in two or three localities in Florida, notably at Jacksonville and in Volusia County, on orange and quince, and also on a species of Eupatorium. It is frequently associated on citrus plants with the Florida wax scale. It has since been found on the same and other food plants on some of the West Indian islands and in Louisiana and California. The barnacle scale is much larger than the Florida wax scale, having an average length of 5 millimeters and a width of 4 millimeters. The waxy covering is a dirty white, mottled with several shades of grayish or light brown, and the division of the waxy excretion into plates is distinct, even to a late age. The development of the insect and secretion of the waxy scale covering is very similar to that of the last species described. The barnacle scale is of very little economic importance, and is mentioned merely because its presence might arouse suspicions of probable injury.

FIG. 26.—Barnacle scale (*Ceroplastes cirripediformis*): Group of scales on twig, illustrating different stages of growth—enlarged about 2 diameters (original).

The Fluted Scale.

Of all the scale insects attacking citrus plants, this species (*Icerya purchasi* Maskell—figs. 27 and 28) is perhaps the most notable, not so much from the damage now occasioned by it as from the problems of control which it has brought to the front and the international character of the work which it has occasioned.

The facts indicate that Australia is undoubtedly its original home, from whence it was introduced on Australian plants into New Zealand, Cape Town, South Africa, and California at about the same time. The evidence points to its introduction into California about the year 1868 on *Acacia latifolia*. It is a very hardy insect, will live for some time without food, and thrives on a great number of food plants. In California it spread rather rapidly, and by 1886 had become the most destructive of orange scale pests. The damage occasioned by it was of such a serious character as to threaten the entire citrus industry of the Pacific coast. The nature and habits of this insect made it almost impervious to any insecticide washes, and the orange growers of California were rapidly losing heart.

In 1889, however, through the agency of Mr. Albert Koebele, an assistant of this office, the natural ladybird enemy of the fluted scale was discovered in Australia and imported into California. This ladybird, *Novius* (*Vedalia*) *cardinalis* (fig. 29), multiplied prodigiously, and in a very short time practically exterminated the fluted scale, saved the State of California annual damage amounting to hundreds of thousands of dollars, and removed this scale insect from the roll of dreaded injurious species.

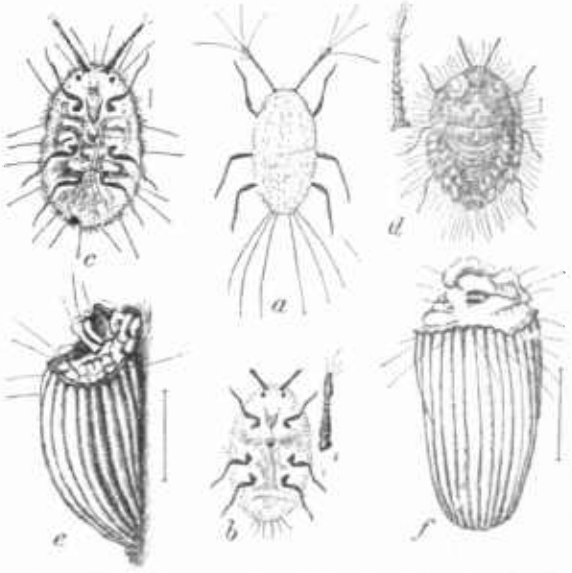

FIG. 27.—Fluted scale (*Icerya purchasi*), female series, illustrating the development of the female insect from young larva to adult gravid stage: *a*, newly hatched larva; *b*, second stage; *c*, third stage; *d*, full-grown female; *e* and *f*, same after secretion of egg sac—(original and after Riley).

The beneficial results derived from this ladybird have not been confined to California. Through the agency of this Department and in cooperation with the California State authorities, this ladybird has been sent to South Africa, Egypt, Portugal, and Italy, and in each of these countries its introduction has been followed by similar beneficial results in the control of the fluted scale.

While the fluted scale, at the time or soon after its injurious record in California, gained access to several foreign countries, very fortunately Florida and the Gulf districts remained long free from it.

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The first and presumably only introduction of this insect into Florida was an intentional one, though not malicious, and illustrates the risk run in importations of beneficial insects undertaken by persons unfamiliar with the subject. A nurseryman of Hillsboro County, Fla., hoping to duplicate against the common Florida scale insects the wonderful work of the imported Australian ladybird against the fluted scale in California and, ignorant of the fact that the ladybird in question did not feed on any of the armored scales which he especially wished to have controlled by it, got one of the county horticultural commissioners of California to ship him a lot of these ladybirds, together with some of the fluted scale as food. The whole lot was liberated on his premises and resulted, naturally enough, in stocking some of his trees very thoroughly with the fluted scale. The infestation coming to his attention, he sent, in June, 1894, specimens to the Division of Entomology and they were promptly determined as the dreaded California scale pest. Fortunately, the nurseryman in question realized the enormity of his offense and took, at Dr. Howard's earnest suggestion, immediate and active measures to exterminate the fluted scale on his premises, ultimately taking out and burning the trees.

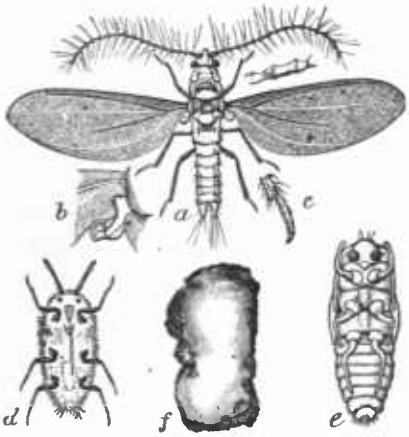

FIG. 28.—Fluted scale (*Icerya purchasi*), male series: *a*, male insect with greater enlargements of base of wing and foot at *b* and *c*; *d*, second stage of larva; *e*, pupa; *f*, cocoon—enlarged about 7 diameters (re-engraved from Riley).

It was hoped that extermination had been effected, but four years later (1898) the fluted scale was again received from the same district. In view of its quite general spread, as reported, in the immediate region, it seemed improbable that it could be easily exterminated, and the introduction of the Australian ladybird was urgently advised. During the spring and summer of 1899 the ladybird in question was successfully colonized in Florida by Mr. Gossard, with the assistance of Mr. Craw.

The fluted scale in Florida evidently does not multiply as rapidly as it does in California. Furthermore, as shown by Mr. Gossard, it is attacked by a fungous disease which appears suddenly in July and results in the death of from 25 to 70 per cent of the partly grown scales. We may hope that with the aid of this disease, and by means of the prompt introduction of its natural enemy, the fluted scale will never play the rôle in Florida which it originally did in California.

The habits and transformations of the fluted scale (figs. 27 and 28) closely parallel those of the species of Lecanium already described.

The general appearance of the insect, however, is strikingly dissimilar, owing to the waxy excretions from the ventral plate of the adult female insect. These are ribbed, or fluted, from whence the insect takes its name, and become the receptacle of a vast number of eggs, a single female being the possible parent of more than a thousand young. The waxy material constituting the egg sac issues from countless pores on the under side of the body, especially along the posterior and lateral edges. As this secretion accumulates the body is lifted, so that ultimately the insect appears to be standing almost on its head, or nearly at right angles to the bark. The eggs are laid in the waxy secretion as it is formed, the waxy fluted mass often becoming from two to two and one-half times as long as the insect itself. The young are of reddish color, very active, and spread by their own efforts and by the agency of the winds, birds, and other insects. The female insect is, for the most part, a reddish orange, more or less spotted with white or lemon.

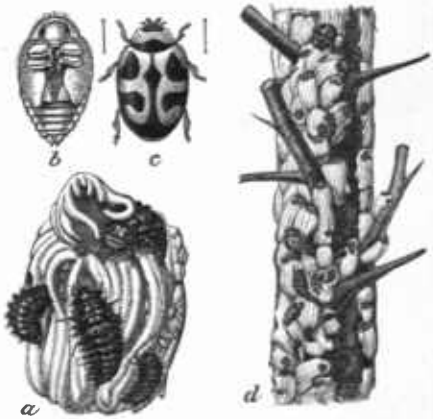

FIG. 29.—*Novius cardinalis*. Australian ladybird enemy of the fluted scale: *a*, ladybird larvæ feeding on adult female and egg sac; *b*, pupa; *c*, adult ladybird; *d*, orange twig, showing scale and ladybirds—natural size (author's illustration).

The early stages of the male are similar to the corresponding stages of the female. Before appearing as an adult, the male insect secretes itself in some crack in the bark, or in the ground, and exudes a waxy covering, which forms a sort of cocoon, in which the transformations are undergone, first into the pupa and then into the adult insect. The winged male (fig. 28) is rather large for a coccid, and has a reddish body with smoky wings.

The rate of growth of the fluted scale is comparatively slow, and it does not normally have more than three generations annually. This insect is quite active, the female traveling and moving about very freely nearly up to the time when she finally settles for egg-laying. The male is active up to the time when it settles down to make its cocoon.

The fluted scale exudes a great quantity of honeydew, and trees badly attacked by it are covered with the sooty fungus, characteristic of the black scale and the white fly.

The remedy for this scale insect is always and emphatically to secure at once its natural and efficient enemy, the *Novius cardinalis*. Where this insect can not readily be secured, the scale may be kept in check by

frequent sprayings with the kerosene or resin washes. Fumigation is comparatively ineffective against it, because the eggs are not destroyed by this treatment. Spraying is, for the same reason, effective only when it is repeated sufficiently often to destroy the young as they hatch.

The Mealy Bug.

The mealy bug (*Dactylopius citri* Risso) (fig. 30) of the orange and other citrus plants is especially destructive in Florida and the West Indies. It is not of much importance in California.

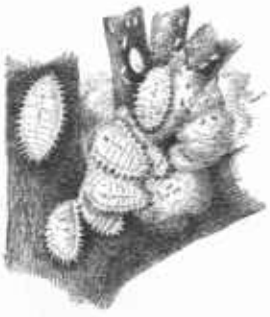

FIG. 30.—Mealy bug (*Dactylopius citri*): Mass of insects at fork of leaf, showing different stages and cottony excretion covering eggs—enlarged 4 diameters (original).

It occurs very commonly in greenhouses, and has been carried to every quarter of the globe. The insect is mealy white in color, the female attaining a length of nearly a quarter of an inch when fully adult. The edge of the body is surrounded by a large number of short waxy filaments. This insect is active in all stages and the eggs are laid in and protected by a cottony or waxy secretion, the female insect as this is developed being gradually forced from the bark, as in the case of the fluted scale. The adult winged male is light olive brown.

This species is somewhat gregarious and occurs in masses in the angles of the branches and leaf petioles and about the stem of the fruit. The remedies are the emulsions and oily washes, repeated as often as necessary to reach the young as they hatch.

IMPORTANT CITRUS PESTS OTHER THAN SCALE INSECTS.

THE WHITE FLY.

The white fly (*Aleyrodes citri* Riley and Howard) of Florida and the Gulf region (figs. 31 and 32) is not a scale insect, but belongs to a closely allied family. In general appearance and habits, however, at least in its economic features, it exactly duplicates the true scale insects. For many years this very interesting insect has been known to infest the orange trees of Florida and Louisiana and also to be a common pest on the orange in greenhouses. It has been found also on a number of plants other than orange, such as viburnum, cape jasmine, and the aquatic oak of the South. These other food plants are of significance only in indicating that it may be harbored in situations near orchards in which efforts have been made to exterminate it. The first careful description of this insect and general account of its habits was given by Riley and Howard in 1893, and from their article the data following are largely derived.

The white fly is limited, economically, to the citrus plantings of Florida and the Gulf region. It is widely distributed in greenhouses, as already noted, and has undoubtedly been carried to California on many occasions, but has never gained a foothold out-of-doors. The dry hot season of southern California probably accounts for this, and may prevent its ever becoming troublesome in that region. Its origin is unknown. It first came into prominence about 1885, but probably had been present in greater or less numbers for a much longer period, and perhaps is native to Florida.

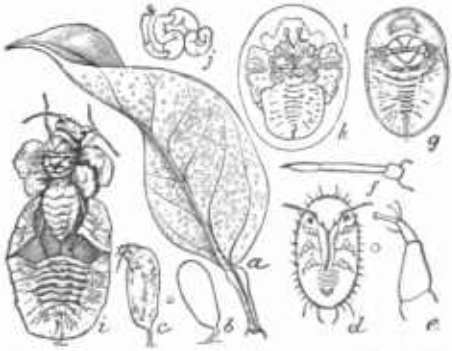

FIG. 31.—White fly (*Aleyrodes citri*): *a*, orange leaf, showing infestation on under surface—natural size; *b*, egg; *c*, same, with young insect emerging; *d*, larval insect; *e*, foot of same; *f*, larval antenna; *g*, scale-like pupa; *h*, pupa about to disclose adult insect; *i*, insect escaping from pupal shell; *j*, leg of newly emerged insect, not yet straightened and hardened—all figures except *a* greatly enlarged (reengraved from Riley and Howard).

While closely resembling a scale insect in its early stages, the white fly in the adult stage emerges, in both sexes, as a minute white gnat, having four chalky wings of a fine glandular texture, from which fact it is frequently called the "mealy wing." This active adult condition gives the white fly a distinct advantage over scale insects in means of spread.

The damage occasioned by it is greatly increased by the secretion, in the larval and pupal stages, of a honeydew similar to that secreted by the true scale insects. This is in enormous amount, and the sooty mold which develops in it frequently covers the entire upper surface of the leaves and produces very serious effects on the vitality of the plant; the fruit does not ripen properly, is deficient in quality and size, and keeps poorly, involving in addition the expense of washing before it can be marketed.

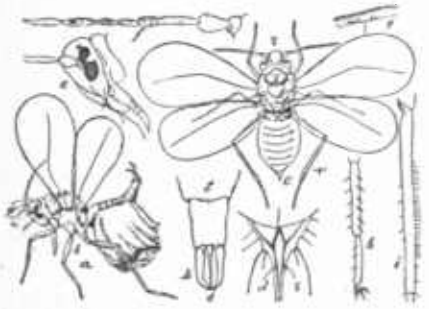

FIG. 32.—White fly (*Aleyrodes citri*): *a*, winged male insect, with enlarged view of terminal segments at *b*; *c*, dorsal view of winged female, with enlargements of ovipositor, head, antenna, wing margin, and leg at *d*, *e*, *f*, *g*, *h*, *i* (reduced from Riley and Howard).

The life round of the insect, briefly, is as follows: The winter is passed in the mature larval stage as a thin, elliptical, scale-like object on the under sides of the leaves. Early in the spring the transforma-

tion to the pupal stage occurs, this stage differing but slightly from the larval in appearance. The adults begin to appear by the middle of March and continue to emerge through April. The eggs deposited by this brood require about three weeks for development, hatching into larvæ from the middle of April to the 1st of May. The adults of the second brood begin to emerge by the middle of June and continue to appear until the middle of July. Between the middle of July and the middle of September a third brood is developed, the larvæ of which, hatching about the last of October, carry the insect through the winter. The number of eggs laid by a single female is in the neighborhood of twenty-five, and they are placed, by preference, upon new leaves, but all of the plant is taken when the multiplication of the insect makes it necessary. The young larva is active, resembling closely the larva of a true scale insect. The life of the adult ranges from ten to twenty days.

The most satisfactory remedies for this insect, as demonstrated by Messrs. Swingle and Webber, are the kerosene and resin washes. The treatments may best be made during the winter, between December and March, and again, if necessary, in May, and also in August or early in September. Two or three applications may be made in the winter. The application in August is made if the sooty mold is found to be spreading to the fruit. Since the insect lives on the under sides of the leaves almost exclusively, it is of prime importance that the under surface be thoroughly wetted with the spray, and it is necessary that the tree be opened up by pruning. Fumigation with hydrocyanic-acid gas is also a ready means of destroying this insect. It is undoubtedly kept more or less in check by parasitic and predaceous enemies, and is subject to attack by several fungous diseases, which may be of occasional value in preventing its undue multiplication.

THE RUST MITE OF THE ORANGE AND THE SILVER MITE OF THE LEMON.

This mite (*Phytoptus oleivorus* Ashmead—fig. 33) is an enemy of both the orange and lemon, affecting these fruits in a somewhat different way. For many years this mite was known only in Florida, and its injuries were notable only in the case of the orange. It is probably native to the Florida peninsula, possibly having originally some food plant other than the orange.

The lemon and orange groves of California were for a long time entirely free from the attacks of this mite, but about 1889 some carloads of citrus trees were taken into California from Florida and planted, without careful inspection, in the Rivera and San Diego Bay districts. This shipment of trees brought with it, unfortunately, two or three of the Florida scale insects, and also this rust mite, which has gained a foothold in the important lemon districts about San Diego,

and is now one of the worst pests the lemon grower has to deal with. For a number of years the effect of its attacks in California was ascribed to a fungous disease, and it was not until the writer visited the lemon districts about San Diego Bay in 1896, and identified the injury as due to the Florida rust mite, that its true nature was known. Our knowledge of its life history and habits and the remedies for it are chiefly due to the work of Mr. Hubbard in Florida.

This mite develops on both the leaves and fruit, although its presence on the former is often overlooked. On the foliage the presence of the mite causes the leaves to lose their gloss and become somewhat curled, as though by drought. The leaves are never killed, however, the attack resulting merely in the considerable checking of the vigor of the plant.

The presence of this mite affects the fruit of the lemon slightly differently from that of the orange. The ripening fruit of the orange, after having been attacked by the mite, becomes more or less rusted or brownish, and the rind is hardened and toughened. While the orange loses its brilliant fresh color and gloss, the toughening and hardening of the rind enables the fruit to stand long shipment, and protects it very materially from decay. The quality of the juice is rather improved by the mite than otherwise, the mite-attacked oranges being more juicy and sweeter flavored. As a result of this, a demand grew up in the Northern markets for the rusty fruit, and good prices were obtained for it.

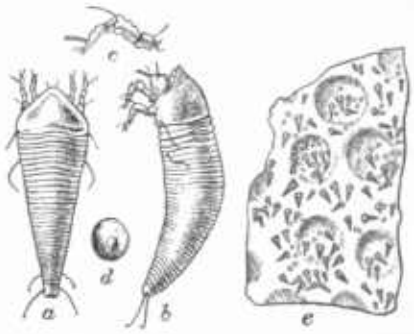

FIG. 33.—The rust or silver mite (*Phytoptus oleivorus* Ashmead). *a* and *b*, dorsal and lateral views of adult mite; *c*, leg of same; *d*, egg; *e*, lemon rind showing pits normal to surface and mites and eggs—all greatly enlarged. (*a* to *d* copied from Hubbard; *e*, original.)

In the case of the lemon, however, an injury to the rind is an important consideration, a perfect rind being a requisite of the fruit, on account of the numerous uses to which the rind is put and the valuable products obtained from it. The effect on the lemon is also somewhat different from that on the orange. The rind of both fruits, when attacked by this mite in the green stage, becomes somewhat pallid or "silvered," due to the extraction of the oils and the drying up and hardening of the outer layer of the skin. This whitening is much more marked with the lemon than with the orange, and, since the lemon is often picked while green, the subsequent rusting is not nearly so notable; hence, in California this mite is known chiefly as the silver mite. If the lemon is allowed to fully ripen on the tree, however, it also becomes bronzed or rusted, but rather lighter in shade than the orange.

As in the case of the orange, the rind of the lemon is hardened and toughened, but the juicy contents are not affected materially; furthermore, a silvered lemon will keep very much longer than a perfect lemon, and will bear long shipment without risk of much loss. Until very recently the rusted lemon in southern California found no market whatever, and was a total loss to the grower. The scantiness of the crop in 1900 resulted, however, in some shipments of rusty fruit being made under the name of "russet lemons," about half the normal price being obtained. Should the manufacture of citric acid assume very much importance in southern California, the mite-injured lemons could be used for this purpose. Nevertheless, considering the ease with which the mite may be controlled, there is no excuse for allowing it to maintain itself in injurious numbers in a lemon grove, since, irrespective of the appearance and value of the fruit, its work on the foliage materially lessens the healthfulness and vigor of the plant.

The rust mite avoids exposure to sunlight, and hence the lower half of the fruit is nearly always first invaded, and only gradually does the mite work its way around to the upper surface, very frequently a small portion exposed to the direct rays of the sun remaining unattacked. This gives the appearance, most prominently shown in the case of the orange, of a discolored band extending about the fruit. The multiplication of this mite goes on at all seasons of the year in the orange and lemon districts, being merely less prolific and active in winter than in summer. It has been supposed in Florida that dry weather is inimical to it, but the fact that it thrives in southern California would seem to throw doubt on this belief.

The rust mite itself is very minute (fig. 33), practically invisible to the naked eye. It is honey-yellow in color, and about three times as long as broad. It is provided with four minute legs at its head extremity, by means of which it drags its wormlike body slowly from one spot to another. The eggs are circular and are deposited singly or in little clusters on the surface of the leaf or fruit. They are about half the diameter of the mother and nearly transparent in color, having, however, a slight yellowish tinge. They hatch in four or five days in hot weather, but in cold weather the egg stage may last for one or two weeks. The newly hatched mite is very similar to the adult. About a week after hatching, it undergoes a transformation, or molt, requiring a period of about forty-eight hours, after which it escapes from the old skin, which remains adhering to the leaf or fruit for some little time. This moult brings the mite to its adult stage, in which it is somewhat darker in color than the young and opaque. No sexual differences have been discovered, and the number of eggs deposited by a single mite is not known. The entire development of the mite is short, probably not much exceeding, in warm weather, two weeks.

The food of the mite seems to be the essential oil which is abundant

in all the succulent parts of citrus plants, and which is obtained by the mites by piercing the oil cells with their beaks.

These mites, while excessively minute, are capable of very active locomotion, moving from one part of the leaf to another, as the conditions of light and food necessitate.

An estimate, made from actual count, indicates that the mites and eggs on a single leaf in midwinter may reach the enormous number of 75,000. This indicates for trees, in the active breeding season of summer, billions of mites. The mite is very readily distributed by means of insects and birds.

The rust mite is readily destroyed by various insecticides. The eggs, however, are much more difficult to kill, and practically no wash can be relied upon to reach and destroy all the eggs of this mite. Experience in California indicates that gassing is also ineffective against the eggs. The sovereign remedy for the rust mite is sulphur. It may be applied as a powder on trees, and, moistened by rain or dew, will adhere to the leaves for quite a long period, not being readily washed off even by a hard rain. When spraying is done for scale insects, the flowers of sulphur can be mixed and applied with the spray, accomplishing both purposes at once. A better method, perhaps, is to first dissolve the sulphur with lye, as follows:

Mix 20 pounds of flowers of sulphur into a paste with cold water, then add 10 pounds of pulverized caustic soda (98 per cent). The dissolving lye will boil and liquefy the sulphur. Water must be added from time to time to prevent burning, until a concentrated solution of 20 gallons is obtained. Two gallons of this is sufficient for 50 gallons of spray, giving a strength of 2 pounds of sulphur and 1 of lye to 50 gallons of water. An even stronger application can be made without danger to the foliage. This mixture can also be used in combination with other insecticides.

There are several species of mites which attack citrus plants, the most troublesome one of which, especially in Florida, is the one named above. Almost any insecticide will kill the adult mite, such as kerosene emulsion, resin wash, or even a simple soap wash, but unless the eggs are killed the trees will be reinvaded about as thickly as ever in the course of a week or ten days. The advantage of the sulphur treatment arises from the fact that the sulphur adheres to the leaves and the young mites are killed as soon as they come in contact with it.

THE SIX-SPOTTED MITE.

This leaf mite or spider (*Tetranychus sexmaculatus* Riley—fig. 34), is closely allied to the common red spider of greenhouses. It first made its appearance as an important orange pest in Florida in 1886. Following the severe freeze of the winter of 1885–86, the weakened trees

seemed to be especially favorable for the multiplication of this mite; it increased suddenly in enormous numbers during the dry weather of the early summer and was responsible for very considerable damage to the foliage of the orange.

The original food plant of this mite is unknown. It was first noted on wild orange, from which it spread to other citrus trees. It is probably a native of Florida.

Like its allies, this insect is greatly influenced by climatic conditions, and needs for its excessive multiplication dry hot weather. Therefore, in rainy seasons it is not especially troublesome, and it usually disappears as soon as rainy weather sets in. In Florida its period of greatest destructiveness falls between February and the middle of May. This mite was carried to California a decade or more ago with Florida stock, doubtless at the same time that several other Florida citrus insects were transported to the Pacific coast. In California, however, the principal mite injury seems to be due to an allied species, also brought from Florida, *T. mytilaspidis*.[a]

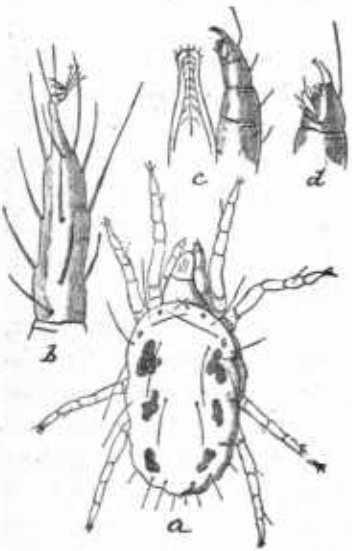

FIG. 34.—Six-spotted mite of the orange (*Tetranychus sexmaculatus*): *a*, dorsal view of adult mite—vastly enlarged; *b*, greater enlargement of foot; *c*, *d*, mouth parts (from "Insect Life").

The attacks of the six-spotted mite are confined largely to the under sides of the leaves, which are covered with a fine web, beneath which the mite feeds. The first indication of its presence is usually a yellowing in streaks and spots of the upper surface of the leaves. The under surface becomes soiled by the accumulated excrements in the form of minute black spots and by the web of the mite. On badly attacked trees the foliage curls and shrivels and the trees may lose half or more of their leaves, and similarly also a large percentage of the half-formed fruit. Being an accompaniment of drought in Florida, part of the damage may undoubtedly be ascribed to the effect of the dry weather.

The remedies are the same as for the rust of silver mite. The bisulphide of lime is also an effective wash. It can be made very cheaply by boiling together in a small quantity of water equal parts of lime and sulphur. Five pounds of lime and 5 pounds of sulphur, dissolved by boiling, should be diluted to make 100 gallons of spray. Gassing is ineffective.

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[a] See Bul. 145, Cal. Agr. Expt. Sta., for detailed account of this species.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent to any address on application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. The missing numbers have been discontinued, being superseded by later bulletins.

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