TECHNICAL BULLETIN.

HATCH EXPERIMENT STATION

—OF THE—

MASSACHUSETTS

AGRICULTURAL COLLEGE.

NO. 1.

THE GREENHOUSE ALEYRODES (A. vaporariorum Westw.)

AND THE

STRAWBERRY ALEYRODES (A. packardi Morrill):

A STUDY OF THE INSECTS AND OF THEIR TREATMENT.

By AUSTIN W. MORRILL, Ph. D.

AUGUST, 1903.

The regular Bulletins of this Station will be sent free to all newspapers in the State and to such individuals interested in farming as may request the same. Technical Bulletins are sent only to those persons interested in the subject treated of in each case.

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HATCH EXPERIMENT STATION

OF THE

Massachusetts Agricultural College,

AMHERST, MASS.

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Hatch Experiment Station, Amherst, Mass.

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ADDENDA AND CORRIGENDA.

Unfortunately it was impossible for me to correct the proof of this bulletin, but I take this opportunity to call attention to the errors I find in its completed form.

A. W. MORRILL.

Victoria, Texas, Aug. 15, 1903.

Page 8, line 1 from top, for *Therefore the Homoptera* read *The Homoptera.*

Page 11, line 2 from top, for *by* read *after.*

Page 14, line 13 from bottom, for *which appears to extend* read *which appears to be part of a spiny surface that extends.*

Page 16, line 16 from top, for *on a line about* read *on a line with the bases of the legs of its respective side of the body about.*

Page 20, line 14 from top, for *letter C* read *letter J.*

Page 24, line 14 from top, for *dark white* read *black.*

Page 26, line 11 from lop, for *common* read *small.*

Page 28, line 18 from top, for *LLL* read $L^{I}\ L^{II}\ L^{III}$.

Page 29, line 10 from top, for *from plant to* read *from one plant to.*

Page 30, line 10 from top, for *the sense the* read *the sense of the.*

Page 33, line 7 from bottom, for *series* read *species.*

Page 35, line 11 from top, for *generous* read *general.*

Page 42, line 5 from bottom, for *Buck's* read *Bush's.*

Page 46, line 9 from bottom, add *Plants : Tomatoes, badly infested.*

Page 47, line 1 from top, for *cheek* read *check.*

Page 47, line 11 from bottom for *these latter* read *Insecticides of this class.*

Page 49, line 4 from top, for *inexpensive* read *rather expensive.*

Page 50, line 20 from top, for $1.50 read $1.00.

Page 53, line 10 from top, read *on strawberries in Ohio, etc.*

Page 60, experiments Nos. 1-11 for *gms. per cu. ft.* read *lbs. per* 1000 *cu. ft.*

Between experiments 11 and 12 read EXPERIMENTS WITH POTASSIUM CYANIDE.

Page 63, line 6 from bottom, for .1 *gram* read .01 *gram.*

INTRODUCTION.

The following paper is the result of studies begun more than two years ago at the Entomological Laboratory of the Massachusetts Agricultural College, as a consequence of complaints made to the Hatch Experiment Station of serious injury caused by the Greenhouse Aleyrodes (*Aleyrodes vaporariorum*), and the need of more satisfactory methods of controlling the pest than those previously known. Mr. J. B. Knight, who was at that time pursuing the graduate course for the degree of Doctor of Philosophy at the college, began a study of the different stages of the insect, but having given up the work to accept a position in India, the study of this insect was taken up by the present writer. Mr. Knight's description was briefer than the one here given, and has been used only for comparison, none of his work having been incorporated in this paper.

Having discovered in the course of my studies that the Strawberry and Greenhouse Aleyrodes were distinct species, rather than the same, as was generally supposed, I have extended the scope of the work as previously outlined, to include a discussion of both. At present, there are about sixty-five American species of the genus *Aleyrodes* known.* Of these, the two species which form the subject of this paper, *A. vaporariorum* Westw., and *A. packardi* Morrill, with the Orange Aleyrodes, *A. citri* Riley and Howard, are the only ones which have thus far proved to be of much economic importance in the United States. *A. citri*, which was first described from Florida, has been recorded in greenhouses as far north as Michigan,† and Quaintance ‡ states that it occurs generally in greenhouses; its attacks, however, are almost wholly confined to orange and lemon trees. This species has never been recorded from Massachusetts.

I have followed the original spelling of Latreille in the use of

* Including twenty Californian species, the descriptions of which are unpublished at the time of this writing (Psyche, vol. ix, p. 328.)

† Davis, Miscellaneous Bull. (Special Bull. No. 2) Mich. Expr. Station, p. 24, (1896.)

‡ Quaintance, U. S. Dept. Agric., Div. ent., Tech. ser. Bull. No. 8, p. 22, (1900.)

the generic name of these insects, no typographical error being evident. Four common names for the members of this group are known to the writer, viz.: Aleyrodes, white fly, mealy wing and snowy fly, the latter name apparently being in use only in England. The common name, Aleyrodes, derived directly from the name of the genus, will be used hereafter in this paper in preference to the others.

The bibliography of each species is numbered, and whenever I have had occasion to mention any of those writings I have referred to them by their number only. Other references are found in the foot notes.

This paper represents a little more than half of a thesis presented to the faculty of the Massachusetts Agricultural College in June, 1903, for the degree of Doctor of Philosophy. I wish to acknowledge here my obligations to Professors C. H. and H. T. Fernald, under whose able supervision and direction I have pursued my graduate studies in the Entomological Laboratory of the college during the past three years.

Systematic Position of Aleyrodes.

The two genera, *Aleyrodes* Latreille and *Aleurodicus* Douglas, constitute the family of Homoptera* called Aleyrodidæ. The latter genus is distinguished from the former by the presence of a distal and a basal branch to the median vein in both pairs of wings. The insects of this family were for a long time classed with the Coccidæ, or scale insects, on account of the resemblances between the immature stages. The differences between the two groups of insects in their metamorphosis and the form of the adults have been used as the chief characters to distinguish the family Aleyrodidæ from the Coccidæ, and the former is now given a systematic position between the latter family and the Aphidæ, or plant lice. The larval and pupal stages of the Aleyrodidæ are distinguished from those of the Coccidæ by an opening on the dorsum of the last abdominal segment known as the "vasiform orifice." The insects undergo a complete metamorphosis, thus differing in a marked degree from all other Homopterous insects, except the Coccidæ, where the male alone undergoes a complete metamorphosis. In both these families the metamorphosis, though complete, is of a peculiar nature, and differs in some respects from that of the true Metabola, or such insects with complete metamorphosis as Lepidoptera (butterflies and moths), Diptera (flies), and Coleoptera (beetles). Both males and females of the Aleyrodidæ have in the adult condition two pairs of well-developed wings, while in the adult male Coccidæ the hinder pair of wings is represented by minute appendages called halteres. There is much evidence to show that incomplete metamorphosis is the ancestral condition of insects, and therefore in general, insects with complete metamorphosis represent a higher degree of specialization and are younger than those which have retained the former condi-

* For the benefit of those who are not familiar with the classification of insects, it is here explained that the Homoptera and Heteroptera are two sub-orders of the Hemiptera. The former is distinguished from the latter by the form of the wings, which are of the same thickness throughout and usually sloping at the sides of the body, and by the position of the origin of the beak, which is at the hinder part of the lower side of the head. The Homoptera include such insects as plant lice, scale insects, cicadas and leaf hoppers. To the Heteroptera belong the true bugs, such as the squash bug and chinch bug.

tion. Therefore, the Homoptera are generally believed to be more primitive than the Heteroptera. The Aleyrodidæ and Coccidæ represent the highest degree of specialization among the Homoptera* and even surpass the Heteroptera in that both have attained a complete metamorphosis. At first glance it appears that the former family, having a complete metamorphosis in both sexes, is a more specialized form than the latter family, but this is more apparent than real. It is in accordance with our belief in regard to the origin of complete metamorphosis that the ancesters of the Coccidæ in the adult condition were winged in both sexes, and that the adult form was the result of gradual changes in the immature insects. The Coccid branch, therefore, was derived from the primitive Homoptera with incomplete metamorphosis. In the course of time the younger stages, through the action of natural selection, departed from the original type in which they resembled the adults, as do the other Hemimetabola (insects with incomplete metamorphosis) to-day, so that they approached and finally attained a complete metamorphosis in both sexes. It is not impossible that the degeneration of the female began during the latter part of this process. If this view be correct, the female Coccids have now attained a secondary incomplete metamorphosis. The male Coccids were evidently prevented from losing their wings by natural selection in order that they might continue to be active in fertilizing the females. Even the adult males are, however, degenerated, having lost their mouth organs, and are so delicately constituted as to live but a few days at the most. The Aleyrodidæ have gone through a series of changes similar to those of the Coccidæ up to the point where complete metamorphosis was attained, and it is at that point that we find them to-day, although the different species are specialized in various other directions. In tracing the two lines of development backward, beginning with our present forms, do they unite before they reach the primitive Homopterous branch, or is it simply a case of development along parallel lines owing to the two forms living under similar conditions? The general resemblance of the two families seems to point to a union of the two lines, although, as a rule, the immature stages of insects are of uncertain value in the study of phylogeny.

† The Cicadidæ attain a high degree of metamorphosis, but it can hardly be considered complete.

The resemblance of some of the members of the Homopterous families Psyllidæ and Aphidæ to Aleyrodes is worthy of mention. Many years ago, Signoret, who was a prominent French entomologist and an authority on the Coccidæ and Aleyrodidæ, classed with the latter family the genus *Spondyliaspis*, which Maskell* states belongs without doubt to the family Psyllidæ. Among the Aphidæ, some of the Pemphiginæ bear a striking resemblance to the larvæ and pupæ of Aleyrodes. These cases at least illustrate how insects like the Aleyrodidæ and Coccidæ could have arisen from primitive Homopterous forms which had well developed legs in all larval stages, and well developed legs and two pairs of wings in both sexes of the adult.

From our present knowledge it seems probable that the Aleyrodidæ and Coccidæ are more closely related to one another than either is to any other group, but further study of the least specialized members of each family is necessary before any definite conclusions can be drawn.

Methods of Study.

Aleyrodes, on account of their delicacy and small size, offer some difficulties to a beginner. The immature stages are best handled with a needle, aided by a good hand lens. The needle should be inserted between the body of the insect and the leaf, preferably from the side. The insects can then be lifted and deposited on a slide by rolling the needle, or if the larva is in the first instar and crawling, it may be allowed to crawl off the needle point. In the latter case the slide should then be placed in a strong cyanide bottle for about five minutes. No cover glass need be used for ordinary study with a one-fifth or even Zeiss F objective. To use an oil immersion lens a thin cover glass should be placed over the insect, resting on three or four dots of thick balsam. In this paper the descriptions and drawings of the immature stages are based principally on fresh specimens mounted as above.

* Transactions New Zealand Institute, vol. xxviii, p. 415.

For permanent mounts two methods may be used with success. The first is especially desirable for pupæ and pupa cases, particularly when these are provided with long dorsal wax rods, as in the two species treated in this paper. A small dot of balsam is placed in the center of a ring of very thick balsam, which should be three-quarters of an inch in diameter and varying in height according to the height of the specimen and the length of the dorsal wax rods. A pupa or pupa case is then placed on the dot of balsam in the center of the ring. Some annoyance may be saved by examining the specimen at this time to make sure that it is uninjured. If a living pupa is used, the slide should now be placed in a strong cyanide bottle for at least fifteen minutes to insure against the mount being spoiled by the emergence of the adult. A circular three-quarters inch cover glass should be placed on the ring of balsam and sealed, so as to make the chamber air tight. I have found chloroform balsam more satisfactory than xylol balsam for the ring, as the former hardens much more quickly. If the balsam is not thick enough to prevent the cover glass from settling, three cubical blocks of wood of suitable size may be imbedded in it. If preferred, zinc cement may be used in the place of the thick balsam. Specimens of the younger stages may be mounted in a similar manner, except that they should not be fastened to the slide, and before sealing the cover glass they should be gently heated over a flame, until all the moisture is driven off and nothing remains but the dried bodies. The results are very uncertain, however, for if the heat is applied too rapidly the bodies will shrivel.

The writer has found the following simple method the best for preparing permanent mounts of the first, second and third instars. Put a drop of xylol on the middle of a clean slide, remove several living specimens—of all three larval instars if desired—directly from a leaf and place them in the xylol. From time to time for from five to ten minutes, xylol should be added to make up for the loss by evaporation, and when the insects are apparently well cleared the xylol can be drawn off from one side by a piece of filter paper, leaving the specimens in the middle of the slide. A drop of thin xylol balsam should now be placed immediately on the specimens, and a cover glass added. If by examination with a compound microscope the sides of the larvæ are found to be curled inwardly, a slight pressure on the cover glass will flatten them out to their natural form.

Pupæ may be mounted in xylol balsam by dehydrating them in xylol for a few hours or a day.

With adults the best results are obtained by a somewhat longer process of dehydration. They may be killed in hot water or in a cyanide bottle. They are then placed in thirty-five per cent alcohol, a few drops of ether on the surface of which will dissolve the wax from the wings and bodies of the insects and allow them to sink. After an hour the specimens are run successively through the following: Fifty, seventy, eighty, ninety, ninety-five and absolute alcohol; then an equal mixture of absolute alcohol and xylol; and finally, pure xylol, leaving them at least an hour in each.

The alcohol and xylol should be kept in small vials, tightly stoppered and correctly labelled. The specimens may be removed from one vial to another by means of a pipette or dropper and a toothpick, the latter acting as intermediary; the specimens being deposited on the end of the toothpick and then placed in the next vial in the series. This allows the transference of the specimens with a minimum amount of the lower percentage alcohol being transferred at the same time to the higher. An equally satisfactory, and perhaps less troublesome, method is to keep the specimens in the same vial and to replace the dehydrating media, successively returning each in due time to its stock vial.

For the study of the tracheal system, specimens of the immature stages may be mounted in xylol by the ordinary method, except that they should not be left more than five minutes dehydrating in xylol. If a large number of specimens are mounted, some of them will almost invariably show the main branches of the tracheal system as conspicuous dark lines, owing to the presence of air in them.

For the study of the life history, leaves of plants with eggs or young attached, may be kept for two or three weeks in tightly stoppered bottles containing a little wet cotton. If moisture collects on the sides of the bottle, the cork should be removed for a short time each day, otherwise the leaves will soon turn dark and decay.

In determining the results of treatment with insecticides, positive conclusions within a few days after the treatment is applied, as to whether or not the young insects are alive, are difficult to obtain. When placed upon their backs, the live larvæ and pupæ usually show some movement of the mouth setæ. When examined from the dorsal side with transmitted light, living specimens usually show more or less movement of their internal organs. More satisfactory examination can be made with a hand lens several days after the treatment, when the dead insects are brownish in color.

The Greenhouse Aleyrodes, Aleyrodes vaporariorum Westw.

DESCRIPTION.

Egg. (Plate II, Figs. 1 and 2.)

The egg is irregularly ovoid, the apical end being the more pointed, and one side more or less flattened. On the basal end, usually a little to one side of the center, toward the more rounded side, is a short, slender stalk, which is inserted in the leaf. The length of the stalk varies from one-fourth to one-eighth the length of the egg, its diameter being about .01 mm. Its form varies, being seemingly determined by the epidermal cells of the leaf between which it is inserted, and it is frequently encircled near its base by a transverse ridge. Color of egg when first laid, light yellowish green, glistening; chorion very soft and delicate, somewhat viscid. The eggs are translucent at first, but gradually become darker, until finally, after two or three days, they are opaque. At this time the chorion has become quite hard, and it is difficult to detach an egg from the leaf without injuring it. In the course of a few days the egg, by contact with the adults, usually becomes more or less covered with a flour-like substance. Parts of the egg not so covered appear of a metallic bronze color. The surface of the egg is unmarked, but within and usually about in the center, may be seen a rounded, orange colored body, surrounded by colorless yolk globules. The developing embryo can be plainly seen.

The length of the eggs, exclusive of the stalk, varies from .187 to .236 mm.; the greatest transverse diameter varies from .077 to

.11 mm. Average measurements of twenty eggs from several different females gave: Length, .209 mm.; greatest transverse diameter, .0901 mm.

First Instar. (Plate II, Figs. 3, 4 and 5. Plate III, Fig. 9.)

In the first instar, the insect is oval in general form, the anterior end being the more broadly rounded, the sides of the thoracic region being approximately parallel and the abdomen narrowing posteriorly. A longitudinal rounded dorsal ridge about one-third as wide as the body, runs nearly the entire length. On each side of this ridge is a flattened area considerably thicker than the narrow, thin rim which surrounds the whole. The change in thickness of the body at the inner edge of the thin marginal rim is quite abrupt. The dorsal surface of the body also shows irregular elevations, depressions and sutures, the latter more or less distinct, marking the thoracic and abdominal divisions. Except in specimens mounted in balsam, these divisions do not appear to cross the thin marginal rim. The body as a whole is quite thin at first, but before the first moult takes place it becomes well rounded above, the dorsal ridge disappearing at the same time. From the under side of the thin marginal rim many minute glistening granules may be seen, which appear to be arranged in rows. The margin of the body is entire, except for the attachment of the spines. Eighteen spines arise on or near the margin of the body on each side, and all except numbers two and sixteen, counting from the anterior end, arise from the extreme margin. Number two arises on the under side of the thin marginal rim a little behind number one. Number sixteen arises just inside the margin on the ventral side, a little nearer number seventeen than fifteen. The distances between the base of numbers three and four and four and five are about equal, and greater than between any other adjacent spines. Except numbers two, four and sixteen, the spines are situated at nearly regular intervals. Numbers one, three and four are horizontal and curved anteriorly; number two is directed downward and curves inwardly. The remaining spines are horizontal, and excepting numbers sixteen and eighteen curve posteriorly. Number sixteen curves outward and downward, and number eighteen, in respect to its mate, diverges at the base and converges outwardly, the extreme tip being extremely slender and inconstant in position.

Corresponding spines in different individuals vary slightly in length, but the following figures indicate about the average proportionate lengths. To obtain true lengths in millimeters multiply the figures given by .0035.

$\frac{1}{7}, \frac{2}{8}, \frac{3}{8}, \frac{4}{6}, \frac{5}{6\frac{1}{2}}, \frac{6}{5}, \frac{7}{4}, \frac{8}{3}, \frac{9}{6}, \frac{10}{2\frac{1}{2}}, \frac{11}{2\frac{1}{2}}, \frac{12}{3}, \frac{13}{4}, \frac{14}{4\frac{1}{2}},$
$\frac{15}{5}, \frac{16}{14}, \frac{17}{7}, \frac{18}{44}.$

A marginal wax secretion appears soon after the young larva settles down. This arises from minute marginal pores, in the form of narrow ribbons, which unite laterally and form a continuous fringe, the outer edge of which is ragged. This wax is dull, translucent, and contains many opaque brownish granules. The width of the fringe is never more than one-fourth the width of the body.

The divisions of the thorax are not clearly marked, and it is a question where the head ends and the thorax begins. The abdomen shows eight and possibly nine segments, the last two or three being greatly modified on account of the vasiform orifice.

This (the vasiform orifice) is about as wide as long, its form being similar to an equilateral triangle with rounded corners (Plate II, Fig. 5.) The entire length from front to rear is about one-tenth the length of the body. The operculum is sub-elliptical in outline, flattened on the basal side. The posterior margin under high power objectives, shows two tooth-like projections—one on each side—between which minute spines can be seen, which appear to extend around on to the under surface of the operculum. The lingula (=lingua) is spatulate in outline, bearing eight longitudinal rows of minute setæ above, and two pairs of spines on the caudo-lateral margin, which curve upward and backward. The posterior ones are slightly longer than the others, and are about one-fifth as long as the orifice. The orifice is bounded laterally by chitinous thickenings which do not unite posteriorly. The posterior end of the orifice reaches in this instar nearly to the caudal margin of the body. Just inside the apex of the orifice is a glistening, crescent-shaped structure, whose convex side is directed posteriorly.

There are two pairs of simple, reddish-brown eyes—a dorsal and a ventral pair—situated nearly opposite each other just mesad to the thin marginal rim and about equidistant from the fourth and fifth spines on their respective sides of the body. These eyes are rounded and less than .01 mm. in diameter.

There are three pairs of dorsal spines. The first pair is situated on the cephalic region, one on each side, a short distance mesad from the eyes. The second pair is situated one on each side of the basal abdominal region, apparently on the third abdominal segment. These two pairs of spines are very minute, and require a high power objective for their detection. The third pair of dorsal spines is much larger, and situated one on each side of and a little anterior to the operculum of the vasiform orifice.

On the ventral side of the body (Plate II, Fig. 4) are the legs, antennae and mouth parts. The entire length of a leg (Plate III, Fig. 9) when straightened is about one-half the width of the body. The coxæ are short and stout, and near the base of each of the two posterior pairs on the inner side is a spine about as long as the diameter of the coxa. These spines are usually directed inward and backward. The trochanters are short; those of the anterior pair of legs are sub-cylindrical, about one-third as long as wide; those of the two posterior pairs of legs appear more or less hoof-shaped, and each of the six trochanters bears a short spine anteriorly. The femur is about twice as long as the coxa and trochanter together, sub-cylindrical in form, tapering toward its outer end. The tibia is a little longer than the femur and more slender, in each of the two posterior pairs of legs bearing on its outer side near its base a spine as long as the whole tibia itself. This extends obliquely outward, and is usually curved near its tip. In addition, all three pairs of tibiæ bear a number of minute spines. The tarsus, which consists of a single segment, is short, knobbed at the tip, with a stout curved spine about half as long as that borne on each of the two posterior tibiæ, arising on its outer side near its base.

Half way between the first and second pairs of legs in the middle line of the body is a conical fleshy papilla—the rostrum—from an opening in the apex of which, surrounded by four minute spines, the mouth setæ protrude. The length of the setæ varies, but when bent backward they usually extend to a point between the hind coxæ and the caudal margin of the body. In front of the rostrum is a prostomial plate or shield, subovate in form, the broader end being anterior. It is truncate where it touches the base of the mouth papillæ, slightly concave on the sides posteriorly, broadly rounded anteriorly with two movable papillæ on the anterior margin, each of which bears a long spine, about equal in length to those borne on the coxæ of the two posterior pairs of legs. A curving suture on each side of the anterior two-thirds of the plate divides it into three parts, a long central piece with two side pieces. On the ventral surface of the abdomen, underneath the operculum, is a pair of spines, one on each side, about equal in length to those which arise at the anterior end of the prostomial plate. These spines extend backward, usually reaching nearly to the caudal margin of the body. Anterior to and outside of the base of each of these spines there is a small pore, which probably represents the opening of some gland, as an amorphous, waxy (?) substance usually covers one or both openings after the larva is two or three days old.

Each antenna arises on a line about half way between the fore coxæ and the anterior margin of the body, and the length is between one-half and two-thirds the width of the body. Each consists of four segments, the basal one being short and stout; the second twice as long as the first, and more slender, reaching nearly to the margin of the body between the third and fourth spines of each side, (the antennæ usually being directed in that direction); the third segment very short, sub-globose, and bearing two or three short, stout spines; the fourth twice as long as the second, slender, its apical third bent anteriorly, minutely spined, and with a larger and more conspicuous spine arising at about two-thirds the distance toward the tip on the posterior side, and another still larger one at the tip. Each ventral eye is situated outside of and slightly behind the base of the antenna of its respective side of the body.

Segmentation from below is less distinct than from above. The color of the larva is pale green, semi-transparent, with two internal orange yellow bodies of irregular rounded form, situated one on each side in the basal abdominal region. These sometimes enclose a clear area. The tracheal openings are ventral and very difficult to distinguish in this instar, but their positions are marked by the granular appearance of the surrounding regions and by the abrupt terminations of the main branches of the tracheal system, which may be more or less plainly seen in the semi-transparent body of a newly hatched larva. Spiracle number one is located between and outside of the base of the second and third pairs of legs; number two between the base of the second and third pairs of legs; number three a little behind the base of the third pair of legs, and number four a little behind the ventral spines in the caudal region.

The length of the body in this instar varies from .26 to .30 mm.; average length about .28 mm.; the greatest width from .121 to .165 mm.; average greatest width about .16 mm.

Second Instar. (Plate II, Figs. 6, 7 and 8; Plate III, Fig. 10.)

In this stage the outline is more variable than in the first, varying from broadly oval to elliptical, usually with a slight inward curve on each side of the thoracic region. The margin is finely crenulate, but there is no well marked marginal rim as in the first instar. Immediately after moulting, the body is flat and thin, but before the next moult it becomes well rounded above. Three pairs of marginal spines are present. The first pair is on the cephalic margin, one on each side; the second pair on the caudo-lateral region, one on each side, and the third pair on the caudal margin. These probably represent spines numbers one, sixteen and eighteen respectively, of the first instar. The third pair is a little more than one-tenth the length of the body, the second pair is a little more than one-third the length of the third pair, and the first pair is very minute, sometimes apparently lacking. The first and second pairs usually become obscured soon after the ecdysis by the lateral wax fringe, which, however, never extends much beyond the basal half of the third pair. There are three pairs of dorsal spines; the first pair is on the cephalic region, as in the previous instar; the second pair is on the first abdominal segment, one on each side; and the third pair is near the vasiform orifice, one on each side, opposite the operculum. Of these spines, the second pair is invariably minute, as in the first instar, but the first and third pairs, while very variable in different individuals, are developed to a much greater degree than in the preceding instar, being sometimes as much as one-fourth longer than the spines on the caudal margin, or they may be but one-fourth as long as these spines. The variation in length of the two pairs of spines is apparently independent; in one specimen the first may be more or less longer than the third pair, while in another the third may be somewhat longer than the first pair, and, again, both pairs on the same individual may approach the maximum or the minimum in length. Toward the end of this stage, traces of the first and third pairs of dorsal spines of the third instar may be observed beneath the dorsal surface of the body. The first pair of spines arise directly beneath the bases of their ontogenetic predecessors, and are directed forward obliquely so that the two cross near their tips, in the middle line of the body. The developing third pair of spines are directed backward and outward, and like the first pair arise beneath the base of their predecessors. The segmentation of the abdomen is fairly distinct in the middle, while that of the thorax is more obscure.

The vasiform orifice (Plate III, Fig. 10) is relatively farther forward in this instar than in the preceding one, which is indicated by the comparatively greater distance from the apex of the orifice to the caudal margin of the body, and by the fact that the spines on the dorsum near the orifice now lie opposite the operculum, instead of anterior to it, as in the first instar. The vasiform orifice is of about the same general form as in the first instar. The operculum lacks the tooth-like process on each side of the caudal margin, and is proportionately longer than before, extending nearly one-half the distance toward the apex of the orifice. The lingula is spatulate, with two pairs of side lobes and one terminal lobe. When in its natural position its caudal end reaches to about three-fourths the distance from the anterior to the posterior end of the orifice. On each side of the terminal lobe arises a spine which extends backward to a little beyond the apex of the orifice. A smaller spine arises on each side between the two side lobes. The upper surface of the lingula bears about fourteen longitudinal rows of minute setæ. The apical half of the operculum and the lingula are more opaque than the other parts of the body. The chitinous ridges which bound the orifice laterally do not meet behind, although the intervening space between their ends is comparatively smaller than in the previous instar.

The eyes are proportionally smaller than before, and are situated internally instead of at the surface as in the first instar. The eyes on each side are about on a line with and outside of the two dorsal spines (first pair) on the cephalic region.

On the ventral side of the body (Plate II, Fig. 7) the vestigial legs and antennæ can be plainly seen, their relative position being as before. The antennæ (Plate II, Fig. 8) are directed backward, and extend a little more than half way to the base of the fore legs. They are rather thick at the base, gradually tapering to the apex and bearing numerous blunt spines or papillæ. Of these, two near the base, one on each side, are especially prominent in most specimens. Two segments can usually be distinguished in the antennæ, the basal segment being about one-third as long as the apical one. Occasionally the basal third of the apical segment appears to be cut off as a third segment. The antennæ are immovable, or practically so, in this stage as well as the following immature stages. The legs are a little longer than the antennæ and of the form of a truncated cone, transversely wrinkled, with no distinct segments, and terminate in a rounded knob, which probably has an adhesive function. As a whole, the legs are suggestive of the prolegs of caterpillars. A transverse wrinkle which usually appears at about two-thirds the distance from the base to the tip, possibly indicates the line of division between two segments. A pair of minute spines is usually found on the basal parts of the second and third pairs of legs, one on the inner and one on the outer side. The external mouth organs appear as in the first instar. The anterior end of the prostomial plate is indistinct, and the pair of spines which occurs there in the first instar is now wanting. The pair of spines on the ventral surface below the operculum is present as before. Near these in some specimens the oval gland openings can be seen, their relative position being as before. Each spiracle, or tracheal opening, of the two anterior pairs appears to be double in this instar, consisting of a moderately large opening with a smaller one directly behind it.

The color of the body is the same as in the first instar; the length varies from .341 to .407 mm.; the width varies from .189 to .235 mm.

Third Instar. (Plate III, Figs. 11 and 12.)

In this instar the form, marginal and dorsal spines, marginal wax secretion, ventral spines and color of the body are as in the second instar. The legs are of about the same proportionate length, while the eyes are relatively smaller than before. The vasiform orifice is longer than wide, resembling a triangle with rounded corners in form, its apex distinctly indented. The lateral chitinous ridges do not unite posteriorly, but are connected by a median, crescent-shaped thickening. The operculum is nearly semi-circular, reaching to about one-half the distance from the base to the apex of the orifice, and the lingula has its side and terminal lobes more distinctly marked than before. The number of longitudinal rows of minute setæ on the upper surface of the lingula is now about eighteen. A shallow groove extends from the apex of the orifice to the caudal margin of the body. The antennæ arise nearer the base of the fore legs than in the previous instars, and may be partly concealed by them. They are indistinctly segmented, thick at the base, tapering toward the tip. The basal two-thirds of each is directed inward toward the antenna of the opposite side, while the apical third is bent backward toward the base, the whole forming a figure not unlike the letter C. The first two pairs of spiracles now appear as single slits, while the other two pairs are indistinct.

The length of the body in this instar varies from .493 to .583 mm., the width from .275 to .352 mm.

Pupa. (Plate III, Figs. 13 and 14; Plate IV, Figs. 15 and 16; Plate VI, Figs. 28–31.

The form of the pupa varies from irregularly oval to elliptical, the broadest part of the body being usually about two-thirds of the distance from the cephalic to the caudal margin. When freshly moulted the body is flat and thin, with no wax secretion, but as the insect grows it becomes raised from the surface of the leaf by a vertical wax fringe, the height of the body becoming about one-third of its width. The dorsum is rugose, less noticeably so along the middle; somewhat convex. There are three pairs of marginal spines as in the two preceding instars. The first pair on the cephalic margin are minute, as in the two previous instars, and frequently appear to be lacking; the caudal pair, arising a little inside the margin, are less than one-tenth the length of the body, and the spines on the caudo-lateral margin are less than one-half as long as the last mentioned. The caudal pair curve upward and backward, diverging at the base, usually converging posteriorly. There are three pairs of dorsal spines, as in previous instars. The first two pairs are minute —the first pair being somewhat longer than the second. The third pair is usually well developed, varying greatly in length in different individuals, though always longer than the other dorsal spines. In one specimen examined these were observed to be about one-third longer than the vasiform orifice, representing about the maximum length.

Eight abdominal segments are evident from above, except on the extreme sides ; that which appears to represent the ninth segment is much modified by the vasiform orifice being much narrowed posteriorly and somewhat flask-shaped in outline. This portion of the dorsum is much more clearly defined than in previous instars. The vasiform orifice (Plate III, Fig. 13) is similar in form to that of the previous instar. The chitinous ridges which bound it laterally appear to meet posteriorly, with a rounded chitinous thickening at the point of union. The operculum is nearly hemi-elliptical in outline (having the form of an ellipse cut through its shortest axis), reaching from the base of the orifice to a little over one-half of the distance toward the apex. The lingula has one large apical lobe and three pairs of smaller side lobes, and is densely covered with longitudinal rows (about twenty-five) of minute setæ. From each side of the apical lobe below arises a spine, which curves slightly upward and extends caudad beyond the apex of the orifice, its length being somewhat variable in different individuals, but never more than one-third the greatest width of the vasiform orifice. A second pair, less than one-fifth as long as these, arise, one on each side, between the first and second side lobes. In one instance a side view of a pupa case was obtained with the operculum and lingula extending almost perpendicularly to the dorsum of the case, and the ventral surface of the operculum and the ventral surface of the lingula showed minute setæ about the size of those present on the dorsal surface of the lingula. The anterior pair of side lobes of the lingula is frequently hidden by the operculum. A shallow but well marked furrow extends caudad from the apex of the orifice to the margin of the body, where a short cottony tuft of wax almost invariably occurs in full grown pupæ.

The vertical wax fringe is probably homologous to the lateral fringe of the previous instars, and consists of narrow ribbons of wax fused together laterally, which arise from the so-called marginal wax tubes. Above the points determined by C. W. Woodworth* as the

* Canadian Entomologist, vol. xxxiii, p. 173.

outer ends of the breathing folds in Aleyrodes citri (viz.. one on each side of the body opposite the first pair of spiracles and a single one at the anal end) the wax tubes are noticeably smaller than usual, and the ribbons secreted there are narrower than elsewhere. The dorsal wax secretion consists of a double submarginal series of glassy waxen rods and a more dorsal series of from five to eighteen (typically eight) rods. There seems to be no distinction between these rods except in size and position of origin. The outer series consists of from about fifty to seventy-five (fifty-seven to seventy-two being the limits actually observed) rods, fairly constant in size, in full grown pupæ being almost invariably less than one-fifth the width of the body in length. They are rather more blunt at the tips than the other rods, proportionally narrower, and usually curve downward over the margin. The series which I designate the inner submarginal series is distinguished from the outer series by the much larger size of the rods. There are typically ten or twelve (five or six pairs) in this series, but may be as few as five. They usually arise a little mesad to the rods of the outer series, and with the exception of the most anterior pair appear never to arise farther away from the outer series than the width of their bases. The anterior pair is almost invariably within twice the diameter of their base from the outer series. Typically, the inner series of rods consists of three on each side in front of the mesothorax; one on each side near the base of the abdomen; one on each side nearly opposite the vasiform orifice, and one on each side of the groove mentioned above which connects the apex of the vasiform orifice with the caudal margin of the body. In full grown pupæ the rods of the inner series are from five to ten times as long as those of the outer series. They are usually directed upward and curved inward over the dorsum. The rods of the dorsal series, typically eight in number, are of about the same size as those of the inner sub-marginal series, and arise as follows: The first pair on the cephalic region, one on each side about one-fourth the distance from the cephalic margin of the body to the base of the abdomen; the second pair, one on each side, about half way from the cephalic margin of the body to the base of the abdomen; the third and fourth pairs on the sides of the third and fourth abdominal segments respectively. The dorsal rods are subject to a great deal of variation (Plate VI, Figs. 28–30), the most frequent being the addition of rods on the fifth and sixth abdominal segments corresponding to those on the sides of the third and fourth. The most remarkable variation seen by the writer was a small rod produced on the middle line of the body just anterior to the vasiform orifice. All the wax rods arise from conical bases, and appear to be formed in sections, each section being sub-cylindrical, tapering gradually outward and ending in a cone, at the inner end of which is a conical cavity which fits over the outer end of the section directly behind it and nearer the surface of the body. Through the middle of each wax rod runs a narrow cavity. This structure is plainly seen, both directly under a microscope and by dropping a few of the wax rods into a drop of xylol on a glass slide and observing them as they dissolve.

A little outside of the outer submarginal series of rods, and alternating with them, is a row of minute pores, which vary in number, extending all around except at the caudal end. Sometimes one is absent and sometimes two occur where but one is normally present. Farther up on the dorsum there are about fifteen or sixteen pairs of similar pores. In general, it may be said that there is a double row of these on each side of the middle of the dorsum. None have been found by the writer on the second or the ninth abdominal segments. Other pores than those included in the above groups may sometimes be seen. Usually near each pore is a glistening point, which may be a minute seta, as it appears very much like the structures found in Aleyrodes fernaldi,* which are, however, many times larger.

On the venter (Plate III, Fig. 14) the legs, antennæ and mouth parts are distinguishable with some difficulty, except in specimens that have recently moulted. The legs and mouth parts are as in the previous instar. The antennæ now lie partly hidden in pockets situated, one on each side, just outside of the anterior pair of legs. They are directed backward and are straight, quite thick at the base, gradually tapering toward the tip, where they are abruptly narrowed and end in a short pointed process. Transverse wrinkles may be seen, but there is no distinct segmentation. A pair of spines occurs on the ventral surface, one on each side, below the operculum, as in previous instars. No eyes can be distinguished in freshly moulted

* Psyche, vol. x, p. 84.

specimens, but as the pupa matures the imaginal eyes appear as two reddish spots in the cephalic region.

The pupæ are greenish white in color, wiith yellow bodies present in the basal abdominal region as in the previous instars; the empty pupa cases are white.

The length of the pupa varies from .66 to .88 mm.; the greatest width from .396 to .55 mm.; average length about .76 mm.; average width about .49 mm.

Adult. (Plate IV, Figs. 17–20; Plate V, Figs. 21–27.)

Female. The length of the body of the adult female varies from 1. to 1.3 mm., the average being about 1.14 mm. The color of the head and thorax is pale yellowish buff, and of the abdomen pale lemon yellow. The tip of the rostrum* is black; the legs and antennæ are pale yellowish, sometimes slightly tinged with dark white. The vasiform orifice and the base of the ovipositor may be more or less dark colored. In specimens mounted in balsam the thorax is deep orange in color, due to muscles within; the abdomen is bright lemon yellow, showing bright orange or orange red ovaries and egg nuclei. Soon after emergence from the pupa case the whole body becomes covered with a white amorphous waxy secretion. This first appears in the form of very fine threads exuded from extremely numerous and minute pores in the integument.

The head is transverse; seen from the front, sub-triangular, rounded above. Two pairs of reddish eyes are borne on each extreme side, the upper pair of which is wine colored, being a little lighter in color than the lower pair. There are about forty-eight pigmented facets to each of the upper eyes, surrounded by about ten unpigmented ones. The lower eyes are each composed of about thirty pigmented facets, larger in size than the facets of the upper eyes. Both the upper and lower eyes are sub-circular in outline, separated by a narrow strip of integument. Directly above each upper eye is a single unpigmented ocellus. Each antenna arises a short distance in front of the upper eye of its respective side. It consists of seven

* I have here used "*rostrum*" in the sense of *beak*. Some writers follow Maskell in designating this organ the *mentum*. As Maskell gives no evidence in support of this view, and as I have been unable to find any reference to a study of the homology of the mouth parts of this group of insects, I prefer to retain for the present the word "rostrum," as used by the older writers.

segments (Plate V, Fig. 24.); the first sub-rotund; the second club shaped; the remainder slender. The following is the usual formula of the comparative length of the segments:*

2—5—10 1-2—4—6—4—4.

The following formula shows the range of variation observed, omitting the two basal segments, which are fairly constant and which can seldom be measured accurately in mounted specimens:

(9–11)—4—(5–6)—(4–5)—(4–5).

The entire length of the antenna is about one-third the length of the body. The second segment bears a few short spines, and the apical segment bears a short spine at its tip. The third, fourth, fifth and seventh segments have one or more sense organs near their outer ends. These seem to be always absent on the sixth segment. The third to seventh segments, inclusive, are annulated.

Immediately below the eyes is a short sub-conical structure (rostrum of Maskell), from the apex of which the mouth setæ appear to arise. The rostrum (mentum of Maskell) consists of four free segments and a basal apparently immovable portion, which is attached to the body seemingly to the prothorax between the bases of the fore legs. The basal portion reaches about to the tip of the conical structure (rostrum of Maskell), and the four following segments show the following proportionate lengths: 4—7—5—12. The rostrum bears a few scattering hairs, which are more numerous on the terminal segment. The labrum, which is very slender at the tip, reaches to the outer end of the first movable segment of the rostrum.

The thorax is rather short, compact and well rounded above. The prothorax is slightly smaller than the metathorax, which in turn is smaller than the mesothorax. The sclerites which compose these divisions of the thorax are well fused. The two anterior pairs of legs are of about equal length. The fore coxæ are slightly longer than the middle coxæ; the trochanters are short; the femora about two-thirds as long as the tibiæ and about equal to the two tarsal segments together; the first tarsal segment is about one-fourth longer than the second. The hind coxæ are very stout, with a prominent infolding anteriorly. The hind trochanters are short, each bearing a single spine at the bottom of a groove-like cavity on the caudal

* Measurements made with 1 in. eyepiece and 1-2 in. objective; tube length 145 mm.

side. The remaining segments of these legs are longer than in the two anterior pairs, but their relative lengths are about the same. All three pairs of legs, more particularly the last two pairs, bear numerous spines on the femora, tibiæ and tarsi. These spines are rather scattering, with the exception of a row of about fifteen on the inner side of the hind tibia, an oblique row of four or five spines on the outer sides of the middle and hind tibiæ, a little beyond the middle of the segment, and about a half dozen spines near the tip of the tibiæ of all three pairs of legs. From the upper side of the tip of the last tarsal segment (Plate IV, Fig. 17) a long slender spine arises from a common tubercle. The two curved tarsal claws apparently unite at their bases, and articulate on the lower side of the tip of this segment; between the two claws there is a short knife-blade-like process, pointed at the tip and bearing on the under side a fringe of very delicate hairs.

The fore wings arise far back on the sides of the mesonotum. They are about as long as the entire length of the body when the abdomen is fully extended, or about 1.15 mm. long and .44 mm. broad at the widest part. The hind wings arise from the sides of the metanotum anteriorly, and are smaller than the anterior pair. Both wings are provided with a single median vein, that of the posterior wing being nearly straight; that of the anterior wing being bent toward the posterior margin of the wing at a point slightly beyond the middle. A fold in the fore wing, appearing like a branch of the median vein, is frequently seen arising near its base and extending obliquely toward the posterior margin. The wings are beaded on the margin (Plate IV, Fig. 18), each bead consisting of a minute globule, from the outer side of which two or three minute setae arise. Three or four slender spines arise near the base of the hind wing on the costal margin.

The abdomen (Plate IV, Fig. 20; Plate V, Figs. 21–23) is more or less spindle-shaped, and consists of eight segments. The basal segment is small and transverse, sharply separated from the remainder of the abdomen, in which the segmentation is difficult to distinguish except in freshly emerged specimens. The dorsal and ventral plates of the second to the seventh segments inclusive are separated by a pleural membrane, which is capable of considerable extension. In specimens mounted in balsam the ventral plates of the third and fourth segments are clearly outlined, the remaining plates being indistinct. The eighth segment is quite large, and is terminated by a short conical ovipositor. This organ (Plate V, Fig. 27) consists of three pieces, and is surrounded near its base by about eight tactile hairs. Near the base of the eighth segment above, is the vasiform orifice, which is sub-circular in outline. The operculum is sub-quadrate, the caudal margin being concave. The lingula protrudes caudad beyond the orifice; is strap-shaped, narrowing toward its base, and is minutely setose. The ovipositor is usually bent upward when not in use, and sometimes appears to be held in a vertical position by a projecting fold of the eighth segment. A pair of minute spines is borne on the under side of the second abdominal segment near its base; a minute pair is present on the dorsum of the fifth, sixth and seventh segments; two pairs on the dorsum of the eighth segment, and a few spines on the sides a little anterior to the base of the ovipositor. These minute spines are all, as a rule, indistinguishable in specimens mounted in balsam.

The writer has not been able to positively locate the spiracles.

Male. The male (Plate IV, Fig. 19; Plate V, Figs. 25 and 26) differs from the female only in size, and in the form of the genitalia and of the abdomen. The length varies from .9 to 1.1 mm., the average length being about .95 mm. The number of abdominal segments is nine, the vasiform orifice and the genitalia being upon the ninth instead of the eighth segment as in the female. The third to sixth ventral plates of the abdomen, inclusive, are quite prominent in outline, especially in specimens mounted in balsam. Genitalia (Plate V, Figs. 25 and 26) forcipate, consisting of two side pieces or claspers and a median penis, the former being provided with tactile hairs. Either the right or left clasper, differing in different individuals, appears to have a dorsal swelling near its base, which shows only in a side view. From the side the penis is large at the base, gradually tapering toward the tip. There is a marked upward curve near the base and another less marked upward curve near the tip. From above, the penis appears barrel-shaped at its basal fourth, outwardly becoming flattened laterally; the outer half or two-thirds is thin, the sides being nearly parallel. The opening at the tip of the penis is circular. It is usually bent upward, and consequently is not seen in its full length from above, but a side view (Plate V, Fig. 28) shows that it is about as long as the claspers.

Tracheal System of the Immature Insect.

The diagram on Plate VI (Fig. 32) illustrates the main branches of the tracheal system of larval and pupal Aleyrodes, based on a study of the two species, vâporariorum and packardi. Prof. C. W. Woodworth has worked out more in detail the tracheal system of A citri.* It will be seen that the diagram here given differs from his description only in a few minor details. What he has called "dorsal girdles" I find to be ventral, and his "ventral trunks" I find to be dorsal in the species examined. I have not found the branches which he describes as arising from the transverse connections between the longitudinal trunks and the third pair of spiracles. The following is the explanation of the letters used in the diagram:

$\overset{\text{I}}{\text{V}}\ \overset{\text{II}}{\text{V}}\ \overset{\text{III}}{\text{V}}$	Ventral loops.
D D D	Dorsal trunk.
$\overset{\text{I}}{\text{T}}\ \overset{\text{II}}{\text{T}}\ \overset{\text{III}}{\text{T}}\ \overset{\text{IV}}{\text{T}}$	Position of spiracles.
L L L	Vestigial legs.
R	Rostrum.
E E	Eyes.
A A	Antennæ.

NOTES ON LIFE HISTORY AND HABITS.

Egg. The mechanical condition of the leaf seems to have some influence on the vitality of the eggs, for if a leaf upon which the eggs have been deposited within five or six days is allowed to wither and become dry, the eggs will not hatch. Those eggs which are nearly mature are not so affected. As a rule, the eggs hatch in from ten to twelve days, though this period may be prolonged by low temperature. On hatching, the egg splits longitudinally from apex to base and the larva slowly frees itself. The egg shell collapses at the same time that the larva escapes, the free edges of the shell curving inward.

Larva. The newly hatched larva is quite active and may

* Can. Ent., vol. xxxiii, p. 173.

crawl some distance before settling down, or may remain quite near its place of birth. Its rate of locomotion on a leaf is between one and two millimeters per minute, equivalent to about one-half an inch in ten minutes. The larvæ rarely crawl in a straight line, however, as they double on their own tracks and change direction at every little obstruction such as a hair or a particle of dirt on a leaf, so that it is a rare accident if one finally reaches a distance of one-half inch before settling down, where it remains until it reaches the adult condition. Everything considered, there seems to be little chance of an Aleyrodes in this instar getting from plant to another, or even to another leaf, unless the leaves are in actual contact. The young larva usually settles down within twenty-four hours and gradually loses the use of its legs.

The duration of the first instar is from five to seven days, of the second and third instars from four to six days each, and of the fourth or pupal instar from thirteen to sixteen days. At moulting, in the first three instars, the skin splits apparently around the anterior margin of the body, and is then gradually moved back, aided by up and down movements of the abdomen, and usually drops off entirely unless entangled by the hairs of the leaf. Moulting appears to be a slow process, from two or three hours to a whole day being required before the change is entirely completed. As each portion of the body becomes freed from the skin it spreads out over the surface of the leaf and immediately assumes the form and horizontal dimensions which continue throughout the instar.

If the ventral surface of a freshly moulted insect of the second, third or pupal instars be examined, it will show a large fleshy projection arising on each side between the bases of the first and second legs. These structures are concave at the tip, and are probably adhesive in function, serving to keep the insect attached to the leaf during the process of ecdysis, as they disappear soon after. A specimen in the second instar, placed on its back on a glass slide, was observed to withdraw these almost completely within five minutes.

Changes in position of the Aleyrodes in the second, third and pupal instars are very slight, if any, and these occur only at the time of moulting, or immediately afterward. In one instance, one of these insects in the third instar was observed to move in the course of a few minutes so that its long axis formed an angle of ninety degrees to its original position.

Between the moults in all the immature stages—considering hatching from the egg as a moult—lateral growth of the body is not appreciable, increase in size seeming to result almost entirely from growth in thickness.

During the last few days of pupal life the insect does not feed or perceptibly increase in size, and the developing imaginal characters can be more or less distinctly seen within. It is at this time only that the Aleyrodes is a true pupa in the sense the word "pupa" as used in other Holometabola, or insects with complete metamorphosis; thus what is known as the *pupa case* is in reality the last larval skin.

In all the immature stages there is exuded from the vasiform orifice at intervals a colorless liquid similar to the honey dew of aphids. Sometimes this excretion collects in large viscid globules immediately below the insect secreting it, apparently suspended either by the hairs on the leaf or by the dorsal spines of the insect. The cause of the insects feeding almost exclusively on the under surface of the leaves is apparent. If they should attack the upper surface of the leaves in large numbers they would cause their own destruction, for in this case the honey dew, instead of dropping to the leaves below, would spread out over their bodies and serve as food for fungi, the mycelia of which readily penetrate the tender skins of the insects themselves.

Adults. The adults emerge through a T like opening in the pupa case. The integument splits along the middle of the dorsum from the anterior end of the body to the base of the abdomen, where it joins a transverse split which follows the line of segmentation, reaching nearly to the lateral margin of the case on each side. A newly emerged adult is devoid of wax secretion, the wings are folded up like crumpled paper, and the legs are delicate and much twisted. In a short time secretion of wax appears, the wings unfold and the legs straighten. The wings are rarely used unless the insect is disturbed, and then only for short, more or less erratic flights. It is probable that the wind plays an important role in their distribution out of doors. In the laboratory single specimens on isolated plants have been observed to remain for days at a time on a single leaf.

The adults are frequently seen in coitu, but probably many eggs are unfertilized. Before pairing, there seem to be certain preliminary movements. The male takes a position alongside of the female, intermittently flaps its wings and at the same time continually strokes with its own antennæ the nearest antenna of the female. Their position is well illustrated by Davis (17). Frequently two males, one on each side, thus court a female. If the suit is successful, the female slightly raises the tip of the abdomen, at the same time the male taking a position of about thirty or forty degrees with the body of the female, with its inner wings arising above those of the female, bends the tip of its abdomen upward, and clasps the genitalia of the female from below.

Egg Laying. The female seems to have no choice of position on a plant for deposition of eggs, but leaves them wherever she may happen to be feeding. Eggs are not uncommonly found on the upper surface of the leaves, on the petioles and even on the stems of the plant, though the great majority are found on the favorite feeding place of the adults—the under surface of the leaf. The adults prefer the youngest leaves, and there is a slow but continual migration upward to keep pace with the unfolding of the leaf buds, the majority of the freshly laid eggs being found, therefore, on the upper leaves of a plant. The female frequently, as has been observed by previous writers, uses her rostrum as a pivot, and deposits her eggs in a more or less complete circle about her. From ten to twenty eggs are often found in one of these circles, which are about 1.5 mm. in diameter. Eggs are also deposited singly, this being the case especially on hairy leaves. The writer has observed as many as twelve thousand eggs per square inch on the under surface of a *Salvia* leaf with more being constantly added. The eggs, however abundant, never touch one another, it being probably impossible for the female, on account of the conformation of the ovipositor and the end of the abdomen to deposit eggs so close to one another that they are actually in contact.

Observations on the duration of adult life, parthenogenesis, etc. Adult females have been isolated on plants previously free from Aleyrodes in any stage, for the purpose of determining the duration of adult life, the number of eggs laid by each female, whether or not parthenogenesis occurs, and if so, its character. The females isolated for the purpose of these observations were seen to emerge from their pupa cases, and consequently there was no possibility of their having been fertilized. The plants upon which these females were kept were growing in small pots covered with lantern chimneys, which were closed at the top with cheese cloth. Four trials were made:

1. April 3, 1902, an unfertilized female began egg laying, and on April 17 three eggs were observed to have hatched.

2. April 17, 2902, an unfertilized female began egg laying, and on April 29 several eggs had hatched.

3. Dec. 8, 1902, a female emerged, was isolated on a tomato plant, and began egg laying Dec. 12 (females usually begin egg laying on the second or third day after emergence), and continued, averaging four per day for eleven days. Personal observations were here discontinued, but E. A. Back, an undergraduate student at the Entomological Laboratory, noted that the adult died Jan. 1, 1903. On Jan. 7 I found the plant dead, apparently from cold, and on examination of the leaves I found that about three-fourths of the eggs had hatched, and that some of the larvæ were in the second instar at the time the plant died. Quite a number of eggs were found that had certainly been laid during my absence, but they were not counted.

4. March 17, 1903, a female emerged from its pupa case, and was isolated on tomato and chickweed growing in the same pot. Egg laying began March 18. Eggs were deposited on the stems and upper and lower surfaces of the leaves of both plants, making it impossible to count from day to day all the eggs that had been laid. On April 2, forty-nine eggs were counted, and on April 22 eighty more were known to have been added to this number. There were about eight days altogether when the female was in such a position on the plant that no attempt was made to count the eggs for fear of disturbing her. At a very low estimate, twenty-five eggs were laid during these days, The offspring of this female began to emerge as adults on April 22, and the original female was transferred to a chickweed plant growing in another pot. By an accident I lost on the same day the positive identity of this insect, but I am quite sure that she produced the forty-nine eggs which I counted on April 29, after which observations on this insect were discontinued. So far as

observed, all the eggs laid by this female hatched and the young reached maturity, the adults being males without exception.

To summarize these observations, unfertilized eggs hatch and the larvæ develop into adults of the male sex. Two females were known to lay forty-four and one hundred and twenty-nine eggs respectively, and in both cases many more were undoubtedly laid. These same insects lived in the adult condition for twenty-three and more than thirty-six days respectively.

I have tried several times to isolate a female which had certainly been impregnated, but was unsuccessful. It is not impossible to do this, however, and I suspect that when this is done the young produced from fertilized eggs will all develop into females, giving us a condition similar to that which is generally believed to occur in the honey bees, and known as arrhenotoky.

In regard to the length of adult life, I might further add that in greenhouses where there are millions of live adults on the plants, it is difficult to find a single dead specimen on the benches, providing they have not been killed by artificial means. This is a further indication that natural deaths among adults are rare, and that the adult life of each individual may extend over many weeks.

Should it prove true that unfertilized eggs of this insect produce only males and fertilized eggs only females, then the number of adult males and females will be in direct proportion to the number of unfertilized and fertilized eggs. In Psyche (April, 1903) I gave an estimate of the proportion of the two sexes of Aleyrodes in nature, based on actual count of eighty-five specimens of adult Aleyrodes taken at random, representing four different species. The figures given were twenty males to sixty-five females. For the purpose of obtaining a more exact idea of the proportion of the sexes in the present series I counted one hundred adults taken at random, and found twenty-three males to seventy-seven females.

The spreading of the adults from greenhouses probably accounts for the presence of this species on out of door plants in most cases, but there is no reason to suppose that it cannot pass the winter out of doors in the egg state as do other species of the genus in this region.

IDENTITY OF THE INSECT.

In regard to the specific identity of this insect, there seems little room for doubt that it is the *Aleyrodes vaporariorum* of Westwood. Although Westwood's description (1) may not be sufficient for identification, Signoret's description (2) is quite complete, and the correctness of the latter's determination has never been challenged by later European writers. On the contrary, J. W. Douglas (7), who was later the best authority on this group of insects in Europe, speaks of Signoret's work in such a manner as to leave no doubt that the species described by Westwood and re-described by Signoret were the same.

Signoret's drawings and description of the pupa differ from those of the present writer only in minor details. His determination of the limits of the second and third abdominal segments differs slightly from mine; consequently, according to his drawing and description of the pupa a pair of wax rods arises from the second abdominal segment, whereas I found the corresponding rods on the third abdominal segment. His drawing of the ventral side of the first instar is obviously inaccurate in many respects, but it probably resembles the first instar of *Aleyrodes vaporariorum* quite as much as of any other species.

ORIGIN AND DISTRIBUTION.

This insect was first described in 1856 by Westwood (1), who supposed it to have been imported into England from Mexico. Signoret, in 1868 (2), intimated that the species might have been introduced into Europe from Brazil. Whatever its origin may have been, it is at present widely distributed in greenhouses in Europe and in the Northeastern United States, and has also recently been reported from Canada (27).

FOOD PLANTS.

The list of food plants of the Greenhouse Aleyrodes is so extensive that it would seem almost advisable to list only those plants which the adults reject and upon which the immature stages cannot subsist. Westwood (1) in his description of the species says in regard to its food plants: "It especially attacks the leaves of Mexican species of *Gonolobus*, *Tecomia velutina*, *Bignoniæ*, *Aphelandræ*, *Solamnus* and other similar soft-leaved plants." Signoret (2) found it on *Salvia splendens* and *Taneana camara*, and Douglas (7) speaks of its injuries to cucumbers and tomatoes. Quaintance (19) reports "what appears to be this insect" on *Fuchsia*, *Pelargonium* and *Oxalis* from various parts of the Eastern United States. Britton (23 and 27) lists fifty-eight food plants in Connecticut upon which the insect was observed in its immature stages. It has recently been recorded on violet (26).

It is sufficient to say here that the Greenhouse Aleyrodes is a very generous feeder, its food plants representing several families and orders. The following food plants deserve especial emphasis on account of their economic importance either as ornamentals or fruit producers: Chrysanthemum, *Salvia*, *Lantana*, heliotrope, geranium, *Fuchsia*, *Coleus*, *Ageratum*, roses (17), egg plant, bean, tomato, lettuce, cucumber and melons. Tobacco, when grown in a greenhouse, shows itself to be especially attractive to the insect, but there is no indication that this plant grown out of doors will ever be seriously troubled by it as far north as Massachusetts. I am informed by Mr. Francis Canning, head gardener at the Massachusetts Agricultural College, that in his experience the Greenhouse Aleyrodes has been a serious pest of Primula obconica, a plant grown quite extensively by some florists.

ECONOMIC IMPORTANCE OF THE GREENHOUSE ALEYRODES.

From an economic standpoint the most serious injury caused by this species of Aleyrodes is to cucumbers and tomatoes in greenhouses. J. W. Douglas (7) speaks of cucumber and tomato plants in England being ruined by the agency of this insect. Among the more recent accounts of its injuries Britton (23 and 27) says: "For eight years the most serious insect pest affecting forcing house tomatoes at the station has been the "white fly," "mealy wing," or plant house Aleyrodes. Were it impossible to hold the insect in check, the crop each winter would be nearly a total failure."

Within the last two years there have been several inquiries received at the Hatch (Mass.) Experiment Station concerning this insect, and in at least three cases serious loss to the owners resulted from its attacks. The most noteworthy of these was the total loss of a crop of cucumbers and tomatoes of an estimated value of four thousand dollars at Pittsfield, Mass., during the Spring of 1901. Dr. H. T. Fernald, who visited these greenhouses about the first of June, found every plant either dead, or nearly so, with none of the crop ready for harvesting. Myriads of the white flies, which were seeking in vain to obtain liquid food from the dried leaves, would fly up in clouds when the plants were disturbed. Many other instances of the destruction caused by this insect in this state and elsewhere might be cited, but enough has been said to show that growers of vegetables in greenhouses cannot afford to ignore it whenever it makes its appearance in noticeable abundance.

This species of Aleyrodes may also require treatment in conservatories used for private ornamental or commercial purposes. Its importance here is largely due to its very general feeding habits. Still another class of plants upon which injuries are frequently reported are house plants, such as geraniums, heliotrope, etc.

Cucumbers and tomatoes are among the most delicate of the plants which are liable to require treatment from the attacks of this insect, as well as those upon which the attack is most liable to result in serious financial loss. The treatment of these two plants has therefore been given special prominence in this paper. The general principles for the treatment of plants in florists' establishments are the same as for the forcing pit, while as for the treatment of house plants they are so comparatively unimportant that but a few words need be said.

PREVENTIVES.

In dealing with this insect, preventives are of prime importance. Owners of greenhouses which are subject to its attacks can well afford to insure their plants against total or partial destruction by a very small expenditure of time and money. The axiom, an ounce of prevention is worth a pound of cure, applies here as well as to all other human troubles. Moreover, the cure, unless one is constantly on the lookout for insect pests, is in this case liable to be applied when too late and the destruction has been already accomplished.

Greenhouses in which vegetables are grown are liable to become infested in two ways. First, there may be weeds, such as chickweed or other food plants of the species, growing in the house, under the benches or other out of the way places, and on these the insects may live during the summer months when the house is unused, and in the fall spread to the new crops. Again, adults which have developed out of doors may fly into the houses. This is especially liable to occur where there are infested plants in the vicinity.

To prevent the first method of infestation, before starting a crop in the fall, all weeds and vegetation of every kind should be removed from the house. Eggs, larvæ and pupæ of the insect are thus provided for. Adults may be killed by burning sulphur at the rate of 6 oz. to 1000 cu. ft. of space, or by hydrocyanic acid gas from .2 gram of Potassium cyanide (KCN) per cu. ft. of space, leaving the house closed over night. The rate for the use of the cyanide, as given above, is much greater than is absolutely necessary to destroy adult Aleyrodes, in order that it may also be effective against thrips and other pests. The effect of sulphur on other insects than Aleyrodes is unknown to the writer.

Whenever a first crop is entirely removed, the house should be fumigated by one of these methods before starting a new crop. This, of course, will not be possible where there is only one house, and the new crop is under way before the old one is removed.

To prevent the Aleyrodes from spreading into the greenhouses from plants growing out of doors, little can be done except to see that no infested plants are growing in the vicinity. Aleyrodes found on strawberry plants, as will be seen later, need not be considered in this connection. After the first few frosts in the fall there is little danger of the insect getting into greenhouses from out of doors.

REMEDIES.

Various insecticides have been recommended and used for the destruction of this insect. Ravenscroft (10), who was the first, as far as I am aware, to recommend a specific treatment, says that " the best remedy is to syringe with a solution of Calvert's Soft Soap." Among the later recommendations are: Tobacco fumes in greenhouses, whale oil soap and kerosene emulsion out of doors (16); any of the soap and oil washes (17); hydrocyanic acid gas from one ounce of potassium cyanide for each one thousand cubic feet of space, left in the house over night (18); common laundry soap, one pound to eight gallons of water (23 and 27); nicoticide (24); kerosene and resin washes (26); and hydrocyanic acid gas (for adults), using 1 oz. of potassium cyanide for each 400 cu. ft. of space, exposure of nine minutes (29).

The experiments carried on at the insectary of the Massachusetts Agricultural College by the writer consisted of both spraying and fumigation. The details of the experiments are first given, followed by a discussion of results. When aphids or red spiders have been present in noticeable abundance, the effect of the various insecticides on them has been incidentally noted, thereby showing the comparative susceptibility of the Aleyrodes and other pests to the same treatment.

Contact Insecticides.

Lemon Oil Insecticide. Mnfg. by S. I. Pollexfen, Baltimore, Md. Cost: 11 to 25 cents per half pint, according to amount purchased. Strength recommended: One-half pint in from 4 to 12 quarts of water.

1. One-half pint in 4 quarts of water. Plants treated: Tomato, dipped in solution 20 sec.; Petunia and Eupatorium, sprayed. Results: Plants uninjured. About 50 per cent of immature insects (excluding eggs) killed on Petunia and Eupatorium, and about 60 per cent on tomato plant. All adults hit by spray were killed, but a large proportion escaped by flying away. Eggs not affected.

2. One-half pint in 1 quart of water. Plant treated: Tomato, dipped 20 sec. Results: Plant badly injured; all insects killed except eggs.

3. One-half pint in 1.5 quarts of water. Plant treated: Tomato, dipped 20-25 sec. Results: Plant injured, though not as badly as in previous experiment; all stages of the insects killed except the eggs.

4. One-half pint in two quarts of water. Plants treated: Single leaf of large tomato plant, dipped 10 sec. Lantana, sprayed. Results: Tomato leaf slightly injured; leaves of Lantana slightly

injured; practically all of larvæ and pupæ and two-thirds of adults killed. Eggs unaffected.

5. One-half pint in 4 quarts of water. Plants treated: Tomato leaf nearly dead from effect of insects' attack, and another slightly infested healthy leaf, dipped 10-12 sec. Results: Leaves uninjured; for some reason much more effective than in Expr. 1; 95 per cent of larvæ and pupæ killed; eggs unaffected.

Laundry Soap (Welcome). Cost 6⅔ to 5½ cents per lb, according to amount purchased. Strength recommended by Britton, 2 ounces to 1 gallon of water.

1. 2 ounces to 1 gallon of water. Plants treated: Salvia, Lantana and Geranium. Results: Plants, as a whole, uninjured (a few leaves slightly); about 95 per cent of larvæ and young pupæ killed, and about 25 per cent of old, nearly mature pupæ; about two-thirds of adults killed; eggs unaffected.

Stott's Fir Tree Oil Soap. Cost 30 to 50 cents per lb., according to amount purchased. Strength recommended: One tablespoonful to a gallon of water.

1. One tablespoonful to a gallon of water. Plants treated: Various greenhouse plants. Results: Plants uninjured; only a few larvæ and apparently no pupæ killed; about one-half of adults killed; eggs unaffected.

2. One ounce to a gallon of water. Plants treated: Tomato, geranium, Petunia and Salvia. All except a geranium and Petunia plant were syringed about one-half hour later with clear water. Results: Plants not afterward syringed with clear water were slightly injured; about 95 per cent of larvæ and young pupæ, and about 25 per cent of old, nearly mature pupæ killed; a smaller proportion killed on those plants afterward syringed with clear water. About two-thirds of adults killed; eggs unaffected.

Kerosene Emulsion. One-half lb. soap, 1 gallon water and 2 gallons kerosene. Usually recommended for soft bodied insects: one part of emulsion in 9 of water.

1. One part in 6 parts of water. Plants treated: Salvia and tomato (sprayed); Salvia syringed with clear water about one-half hour later, tomato syringed the following day. Results; Leaves of

tomato plant badly spotted by the emulsion, Salvia leaves uninjured; practically all of larvæ and about 95 per cent of pupæ killed; about two-thirds of adults killed; eggs unaffected.

2. One part in 3 of water. Plants treated: Arbutilon and tomato (sprayed). The first was afterward syringed with clear water. Results: Tomato leaves badly spotted; practically all of larvæ and pupæ and about two-thirds of adults killed; eggs unaffected.

3. One part in 9 of water. Plants treated: Salvia and tomato (sprayed), also a single leaf of Salvia (dipped), afterward washed in clear water one-half hour later. Results: On single leaf every larva and pupa, of which there were hundreds, were killed, and leaf showed no injury, being kept for several days in a tightly stoppered bottle with damp cotton; on the Salvia and tomato plants practically all of larvæ and pupae were killed, but the foliage was slightly spotted; two-thirds of adults killed; eggs unaffected.

4. One part in 11 of water. Plants treated: Salvia, Lantana and tomato (sprayed); all three syringed with clear water one-half hour later. Results: Plants uninjured except for a few spots where emulsion was not washed off; practically all larvæ and about 75 per cent of pupæ killed; about two-thirds of adults killed; eggs unaffected.

Permol Kerosene Soap, mnfg. by Poole & Bailey, New York City. Cost 14 to 25 cents per lb., according to amount purchased.

1. One ounce in 1 gallon of water. The soap did not entirely dissolve in a quart of boiling water, and the insoluble scum clogged the nozzle somewhat. In later experiments with this material, this difficulty was obviated by straining through cheese cloth. Plants treated: Geraniums, heliotropes and callas. Results: Plants uninjured; on heliotrope practically all of larvæ and pupæ killed, on geraniums results not quite as good, while on callas, where all of the immature insects happened to be in pupal stage, only a very few were killed. This difference in results on the different plants appears to be due to the character of the under surface of the leaves in regard to leaf hairs; the heliotrope, being best provided with these, retained the liquid the longest and gave the best results; about two-thirds of the adults killed; eggs unaffected.

2. Three ounces in 1 gallon of water. Plants treated: Ger-

anium, Arbutelon and tomato. Results: Plants slightly injured; practically all of larvæ and pupæ and about two-thirds of adults killed; eggs unaffected. Plant lice on calla and red spider on tomato apparently all killed.

3. Two ounces in 1 gallon of water. Plants treated: Salvia, Arbutelon and tomato (sprayed). Results: Plants uninjured: practically all of larvæ and young pupæ, 50 per cent of old, nearly mature pupæ, and about 50 per cent of adults killed; eggs unaffected.

Bowker's Tree Soap, mnfg. by Bowker Insecticide Co., Boston, Mass. Cost, 6 to 8 cents per lb., according to amount purchased.

1. One ounce in 1 gallon of water. Plant treated: Tomato. Results: Practically all of larvæ and young pupæ and at least 90 per cent of old, nearly mature pupæ killed; about two-thirds of adults killed; eggs unaffected. While the plant was practically uninjured, on a few leaves little areas surrounding the dead larvæ and pupæ were slightly affected by the application, showing that the limit had been reached at which the solution could be used with safety to the plant.

Good's Potash Whale Oil Soap, mnfg. by James Good, Philadelphia, Penn. Cost, $3\frac{1}{4}$ to 5 cents per lb., according to amount purchased.

1. One ounce in a gallon of water. Plant treated: Tomato. Results: Plant uninjured; practically all larvæ and young pupæ killed; old, nearly mature pupæ apparently unaffected; about two-thirds of adults killed; eggs unaffected.

2. $1\frac{5}{16}$ ounces in 1 gallon of water. Plants treated: Tomato (dipped and left in shade), and a badly infested leaf on another tomato plant (dipped 10-12 sec. and left in bright sunlight). Results: Plant and single leaf uninjured; practically all larvæ and young pupæ and two-thirds of adults killed; about 75 per cent of nearly mature pupæ killed; eggs unaffected.

Fumigants.*

Nicoticide, mnfg. by The Tobacco Warehousing and Trading Co., Louisville, Kentucky. Cost, $2.50 per lb. Strength recommended, one ounce to 2000 cu. ft. of space.

* Unless otherwise stated, these experiments were made in a fumigating box containing 15 cu. ft. of space, and estimated to be of about the same tightness in proportion to its size as an ordinary well built greenhouse.

1. One ounce evaporated in a greenhouse containing 1888 cu. ft. of space. Time of exposure, 6 P. M. to 7.30 A. M. Plants treated: Various—tomato, cucumber, Salvia, Lantana, heliotrope, geranium, etc. Results: Plants uninjured; a small percentage of larvæ and young pupæ killed; adults appeared as though intoxicated, and in the course of two days, a few, perhaps 5 or 10 per cent. recovered; the rest finally died. No live plant lice could be found, although they became abundant again in the course of a few weeks, showing that a few must have escaped.

2. Rate: One ounce per 2000 cu. ft. of space. Time of exposure, 6 P. M. to 7.30 A. M. Plant treated: Tomato. Results: Plants uninjured; adults stupified in a few minutes, but 75 per cent fully recovered by the next morning; larvæ and pupæ unaffected.

3. Rate: Two ounces per 2000 cu. ft. of space. Time of exposure, 3 hours. Plant treated: Tomato. Results: Plant uninjured; adults began to drop from leaves in about 3 minutes, and in 10 minutes none showed signs of life; 24 hours later, 50 per cent of adults dead; the remainder recovered.

4. Rate: Two ounces per 2000 cu. ft. of space. Time of exposure, 10 hours. Plant treated: Tomato. Results: Plant uninjured; adults killed; a few larvæ and young pupæ killed.

5. Rate: One ounce per 2000 cu. ft. of space. Time of exposure, 23 hours. Plant treated: Cucumber. Results: Tender leaves killed; all adult insects killed.

6. Rate: Five ounces per 2000 cu. ft. of space. Time of exposure, 7 P. M. to 8 A. M. Plant treated: Tomato. Results: Plant uninjured; all adults and about 50 per cent of larvæ and young pupæ killed; eggs and nearly mature pupæ unaffected.

7. Rate: Fifty ounces per 2000 cu. ft. of space. Time of exposure: One hour. Plant treated: Tomato. Results: Plant uninjured; all adults killed; larvæ and pupæ unaffected.

Buck's Best Brand Fumigating Compound, mnfg. by W. W. Bush & Co., Ltd., London, England. Cost, $4.75 to $8.00 per lb., according to amount purchased. Strength recommended, one ounce to 2275 cu. ft. of space.

1. Rate: One ounce to 2275 cu. ft. of space. Time of ex-

posure: 6 P. M. to 8 A. M. Plant treated: Tomato. Results: Plant uninjured; adults slightly disturbed.

2. Rate: Two ounces to 2275 cu. ft. of space. Time, 3 hours. Plants treated: Tomato and geranium. Results: Plants uninjured; adults began to drop from leaves in about 2 or 3 minutes; in the course of 3 days, however, all but about 5 per cent fully recovered.

3. Rate: One ounce to 2275 cu. ft. of space. Time of exposure, 22 hours. Plant: Tomato. Results: Plant uninjured; a few adults showed signs of life when door of fumigating box was opened, but at the end of the third day after fumigation all adults were dead; a few larvæ and pupæ killed.

4. Rate: Two ounces to 2275 cu. ft. of space. Time of exposure, 6 P. M. to 8 A. M. Plant treated: Tomato. Results: Plant uninjured; a few larvæ and young pupæ and 95 per cent of adults killed.

Thripscide, mnfg. by E. H. Hunt, 76 Wabash Ave., Chicago, Ill. Cost, 16½ to 25 cents per lb., according to amount purchased. Strength recommended, One lb. for an ordinary 100 foot greenhouse for a light fumigation, or 5 lbs. for an ordinary 300 foot greenhouse for a heavy fumigation.

1. One-fourth lb. in a greenhouse 16 feet long containing 1700 cu. ft. of space. Time of exposure, 7 P. M. to 8 A. M. Plants: Hibiscus and Eupatorium. Results: Plants uninjured; adult Aleyrodes stupified, but all recovered; apparently all plant lice killed.

Carbon Bisulfid. Ordinary commercial carbon bisulfid was used in these experiments. This costs about 25 cents per lb. Fuma Bisulfid is manufactured by E. R. Taylor, Penn Yan, N. Y., and costs 10 cents per lb.

1. Rate: One lb. per 1000 cu. ft. of space. CS_2 was poured on to cotton in this and later experiments. Time of exposure, one hour; sun shining, 8.45 A. M. Plant treated: Tomato. Results: Adults began to drop from leaves in about 25 minutes, and showed but slight signs of life when fumigating box was opened; all recovered in course of 2 hours; plant uninjured.

2. Rate: Two lbs. per 1000 cu. ft. of space. Time of exposure, 1 hr., 15 min.; sun shining. Plant treated: Tomato. Results: Adults began to drop from leaves in about 15 minutes; apparently dead when box was opened, but all recovered in the course of three hours; plant uninjured.

3. Rate: Two lbs. per 1000 cu. ft. of space. Time of exposure, 6 P. M. to 8 A. M. Plant treated: Tomato. Results: Adults apparently killed, but about 25 per cent recovered in the course of two days; plant uninjured.

4. Rate: One and one-half lbs. per 1000 cu. ft. of space. Time of exposure, 7 P. M. to 8 A. M. Plant treated: Tomato. Results: Plant uninjured; adults apparently killed, but in the course of two days about 20 per cent. recovered; about 10 per cent of young larvæ killed.

5. Rate: Five lbs. per 1000 cu. ft. of space. Time of exposure, 7 P. M. to 7.30 A. M. Plant treated: Tomato. Results: Plant uninjured; adults all killed; 50 per cent of larvæ and pupæ killed; eggs unaffected.

Hydrocyanic Acid Gas. Cost of Potassium cyanide (KCN) about 50 cents per lb.; of Sulphuric acid (H_2SO_4) from $2\frac{1}{2}$ to 10 cents per lb.

1. Rate: .1 gm. KCN per cu. ft. of space in a practically air tight fumigating box containing 30 cu. ft. of space. Time of exposure, 10 minutes, daylight. Temperature, 40° F. Plant treated: Tomato. Results: Tender leaves killed and older leaves injured at the tips; all larvæ were killed; no pupæ or adults present; eggs unaffected.

2. Rate: .05 gm. KCN per cu. ft. of space in the same box that was used in Expr. 1. Time of exposure, 10 minutes, daylight. Temperature, 48° F. Plant treated: Tomato. Results: Plant very slightly injured; very few larvæ killed; eggs unaffected; no other stages present.

3. Rate: .0016 gm. KCN per cu. ft.: 3 gr. in greenhouse containing 1888 cu. ft. of space. Time of exposure, 6 P. M. to 8 A. M. Plants treated: Various greenhouse plants. Results: Plants uninjured; adults were found to be stupified and fluttered about on the benches; all but about 5 per cent. recovered during the day.

4. Rate: .01 gm. KCN per cu. ft. of space (see footnote page 41). Time of exposure, 30 minutes, daylight. Plant treated: Tomato. Results: Extreme tips of some of larger leaves showed injury; growing tips of stems and the tenderest leaves uninjured; all adults killed, many being left suspended to the under surface of the leaves by their rostral setæ and tarsal claws; none ever showed signs of life after box was opened.

5. Rate: .01 gm. KCN per cu. ft. of space. Time of exposure, 30 minutes, cloudy day. Plant treated: Tomato nearly dead from the effects of the insects' attacks, and a sprig of Eupatorium infested with plant lice. Results: After a few days the young and tender leaves of the plant appeared injured, (perhaps due to the fumigation; all adults killed; eggs, larvæ and pupæ apparently unaffected. Plant lice stupified, but recovered during the day after the fumigation.

6. Rate: .007 gm. KCN per cu. ft. of space. Time of exposure, 30 minutes, after sunset. Plants treated: Tomato and cucumber. Results: Plants not injured in the least, the cucumber plant being in full bloom two days later; many of the adult Aleyrodes continued to show signs of life during the next day, but 36 hours later all were dead; eggs, larvæ and pupæ unaffected.

7. Rate: .01 gm. KCN per cu. ft. of space. Time of exposure, 25 minutes, cloudy day. Plants treated: Tomato and cucumber used in experiment 6 and another tomato plant never before treated. Results: Plants uninjured, even blossoms and flower buds of cucumber escaping; all adults killed; eggs, larvæ and pupæ unaffected.

8. Rate: .01 gm. KCN per cu. ft. of space. Time of exposure, 20 minutes, cloudy day. Plants treated: Tomato and cucumber used in experiments 6 and 7, and a cucumber plant never before treated. Results: One leaf of tomato slightly injured, plants otherwise unaffected; all adults killed; eggs, larvæ and pupæ unaffected.

9. Rate: .01 gm. KCN per cu. ft. of space. Time of exposure, 20 minutes, after sunset. Plants treated; Tomato, badly infested with Aleyrodes and red spider, and sprig of Eupatorium infested with plant lice and Aleyrodes. Results: Plants uninjured; all adult Aleyrodes killed; red spider unaffected; plant lice all stupi-

fied and apparently killed, but all recovered in the course of 12 hours.

10. Rate: .01 gm. KCN per cu. ft. of space. Time of exposure, 15 minutes, cloudy afternoon. Plants treated: Cucumber and tomato. Results: Plants uninjured; about 50 per cent of adults were dead when box was opened, but the remainder showed signs of life, and some of these finally fully recovered.

11. Rate: .005 gm. KCN per cu. ft. of space. Time of exposure, 30 minutes, after sunset. Plants treated: Cucumber and tomato, and a sprig of Eupatorium infested with plant lice. Results: Plants uninjured; all adult Aleyrodes killed, though many showed slight signs of life for a few honrs. Plant lice stupified, but recovered within twelve hours.

12. Rate: .005 gm. KCN per cu. ft. of space. Time of exposure, after sunset, 6 to 9 P. M. Plants treated: Tomato and cucumber, the latter badly infested with red spider. Results: Plants uninjured; all adults killed, a few showing signs of life for a few hours; two-thirds of larvæ and pupæ killed; eggs unaffected.

13. Rate: .007 gm. KCN per cu. ft. of space in a loose greenhouse containing 1700 cu. ft. of space. Time of exposure, after sunset, 6.45 to 9.45 P. M. Plants: Tomatoes, with many of leaves nearly dead from results of insects' attack, and cucumber infested with red spider. Results: Plants uninjured; all adult Aleyrodes killed; 90 per cent of larvæ and young pupæ killed, and 2 or 3 per cent of old, nearly mature pupæ killed; eggs unaffected; red spider unaffected.

14. Rate; .01 gm. KCN per cu. ft. of space in same greenhouse used in last experiment. Time of exposure, after sunset, 6.45 to 9.45 P. M. Results: Plant uninjured; all of adults, all larvæ and young pupæ and about 75 per cent of old, nearly mature pupæ killed; eggs apparently unaffected.

15. Rate: .02 gm. KCN per cu. ft. of space (in fumigating box). Time of exposure, after sunset, 7.30 to 10.30 P. M. Plants: Tomato and cucumber, the former being small plants, showing the effects of improper nutrition, the latter being badly infested with red spider. Results: The smaller and less vigorous of the two tomato plants used showed slight injury to some of the tenderest leaves; the

other plants showed no injury; on the contrary, a cheek cucumber plant, which was practically a duplicate of the one fumigated in respect to size, vigor and infestation, was dead two days later, while the fumigated plant rapidly improved in health. Of the Aleyrodes, all the adults, larvæ and pupæ were killed; eggs apparently killed. The red spiders on the cucumber plant were all killed.

DISCUSSION OF RESULTS.

Contact Insecticides. Few contact insecticides were used, but these were varied enough to indicate that in general they are destructive to larvæ and young pupæ, and more or less so to nearly mature pupæ. They proved useless, however, for the eggs, and not practical for use against the adults of this insect. The statements of those who have had practical experience with Aleyrodes in greenhouses shows that syringing the plants does not seem to lessen the numbers of the adults. In these experiments especial attention was given to the destruction of the adults, but not more than two-thirds of them were killed in any case. At the most, one could not expect to kill more than one-half the adults by an ordinary syringing, which would be sufficient to destroy 90 per cent of the young. The most expert growers of tomatoes in greenhouses tell us that these plants should not be syringed except when it is absolutely necessary, for a damp atmosphere promotes rot and interferes with pollination. It is desirable, therefore, to depend as much as possible on fumigation for the control of the greenhouse Aleyrodes, at least on those plants which are liable to be injured in any way by the application of a contact insecticide. These latter, however, may be used to advantage in many cases.

The following comments will aid in showing the relative value of each of the contact insecticides used in the experiments:

Lemon Oil Insecticide.—The cost of this material precludes its use on a large scale, but it is easy to prepare, has a not unpleasant odor, and the experiments show it to be effective on the larvæ and pupæ when the plant is dipped in a solution of one-half pint in one gallon of water. Chiefly commendable for the treatment of house plants.

Laundry Soap.—Cheap; fairly effective on the insects when used at the rate of two ounces in a gallon of water: liable to injure foliage slightly.

Stott's Fir Tree Oil Soap.—Altogether too expensive for use against the insect, even though it were effective.

Kerosene Emulsion.—Cheap; troublesome to prepare; effective as an insecticide, but requires syringing the leaves afterward to prevent injury, at least in greenhouses when used on tomato plants.

Permol Kerosene Soap.—Too expensive; fairly effective when used at the rate of two ounces in a gallon of water.

Bowker's Tree Soap.—Cheap; most effective of all contact insecticides used in these experiments; has advantage over the others in requiring but one ounce in a gallon of water, making it less liable to interfere with the respiration of the plants by forming a film over the surface. While the odor of the soap itself is unpleasant, it is not very objectionable when used in such a weak solution.

Good's Potash Whale Oil Soap.—Cheaper by weight than Bowker's Tree Soap, but when an amount is used which equals the latter as an insecticide, the cost is about the same for the two soaps. One and one-third ounces per gallon of Good's Soap is nearly as efficient for use on the insect as one ounce of Bowker's Soap. More efficient than laundry soap or Permol Kerosene Soap. The same may be said of the odor as of Bowker's Tree Soap.

Fumigants. The resistance of the greenhouse Aleyrodes to the action of tobacco fumes is well known. The young, as might be expected from their mode of life, are entirely unaffected, while the adults are only temporarily stupified by the same treatment with tobacco that destroys most of the plant lice. The experiments with Nicotocide and Thripscide show that these, also, are much more effective on plant lice than on the adult Aleyrodes, while the experiments with hydrocyanic acid gas show the remarkable susceptibility of adult Aleyrodes to its action as compared with plant lice, the latter being only stupified in the same atmosphere which was fatal to the former Small amounts of the fumigants with a long exposure seem to be more effective on the larvæ and pupæ than large amounts with short exposures.

Nicoticide.—The difference in the results of experiments 1 and 2 may be accounted for by the fact that in experiment 1 the tomato plant was a small one, and the pot rested on the floor of the fumigating box. It was observed that the fumes were very thin near the bottom of the box, and in later experiments the pots were set on a board raised about a foot from the floor. This insecticide is inexpensive to use, and some who have had experience with it against the insect claim that it is ineffective even for the adult. My own experiments show that one or two ounces to 2000 cu. ft. of space, according to the tightness of the house, should result in killing the adults. The cost of fumigating a house containing 20,000 cu. ft. of space at one ounce per 2000 cu. ft. of space would be $1.56. According to experiment 6 it would cost five times this amount to kill one-half of the larvæ and pupæ in a house of the same size. There are many insecticides on the market which are used as fumigants which have tobacco extracts as the active principle. Nicoticide may be considered as a fairly representative type of the best of this class.

Bush's Best Brand Fumigating Compound.—Nearly as effective, ounce for ounce, as Nicoticide, but much more expensive.

Thripscide.—The single experiment indicates that this material is no more effective on the adult Aleyrodes than ordinary tobacco.

Carbon bisulfid.—Long exposure necessary for good results; too expensive for ordinary use. In a greenhouse containing 20,000 cu. ft. of space, the adults and a small percentage of the young could be destroyed for $6.00, and the adults and about 50 per cent of the immature insects for about $10.00.

Hydrocyanic Acid Gas.—Safe to use only by careful and intelligent persons who appreciate its properties. Far cheaper and more effective than any other fumigant known for use against the greenhouse Aleyrodes. Cost for a house containing 20,000 cu. ft. of space, using KCN at rate of .01 gm. per cu. ft., between 25 and 30 cents for each fumigation. Even plants as tender as tomatoes can be fumigated without injury with the extremely small amounts of the cyanide required.

RECOMMENDATIONS.

Fumigation. Bearing in mind the cost, labor involved and effect on plants and Aleyrodes of the various materials used in these experiments, hydrocyanic acid gas is pre-eminently the most deserving of recommendation. From the fact that no two greenhouses are exactly alike in regard to tightness, it is impossible to give specific directions to cover all cases, but it is safe to recommend the use of an amount of potassium cyanide varying according to the tightness of the house from .007 to .01 gm. per cu. ft. of space, for three hours' time after sunset. No injury to tomato or cucumber plants would result from using the larger amount, but it is believed that the smaller amount in a tight house will prove as effective as the larger amount in a loose house. Even .02 gm. per cu. ft. of space, as shown by Experiment 15, can be used without injury to cucumber and tomato plants in a reasonable state of vigor. For tender plants like tomatoes it is advisable to keep well below the danger limit of the tenderest leaves and use the potassium cyanide at rates not greater than .01 gm. per cu. ft. of space.

It is not within the scope of the present paper to give the minute details of fumigating with this most powerful of all known destroyers of animal life.

Johnson's recent work, entitled "Fumigation Methods," is indispensable to anyone who has occasion to use hydrocyanic acid gas as an insecticide. This book can be purchased for $1.50 of the publishers, Orange Judd Company, 52 and 54 Lafayette Place, New York City. To those interested in greenhouse fumigation the following pages are especially recommended: 9–11, 118, 124–146.

Attention is here called to the fact that ventilation of the house is necessary after the expiration of the three hours of treatment, and that this is practicable only under such circumstances that no injury to the plants will result from lowering the temperature of the house. The amount of artificial heat that can be supplied, and the outside temperature must be taken into consideration. Ventilation need not be very prolonged nor very thorough immediately following the exposure; a few side ventilators opened (from the outside) for a quarter of an hour will be sufficient. A more thorough ventilation should be given before one ventures to inhale air while in the house.

In order to be most successful, fumigation should be in accordance with a knowledge of the life history of the insect. A single fumigation at the rates recommended will destroy all of the insects except those in the egg and some of those in the late pupal stage. It is desirable to fumigate again two weeks later, thus killing the few adults that have emerged in the meantime, and which at the time of the first fumigation were in the late pupal stage, and all the larvæ which resulted from the eggs present at the first fumigation. The adults killed by the second fumigation will have deposited a few eggs, the larvæ from which will be in the first, second and third instars two weeks after the second fumigation, and a third treatment at this time will destroy them. Theoretically the house will now be entirely freed from the pest. The writer's tests indicate that this is possible, but even though it is not actually accomplished, no trouble need be expected from the insect for many weeks. In badly infested houses even a single fumigation will so reduce the numbers of the insect as to prevent furthur injury for at least a month, and an occasional fumigation in slightly infested greenhouses will control the pest so as to prevent the possibility of its increasing to an injurious extent.

Fumigation Combined with Syringing. If for any reason it seems undesirable to use hydrocyanic acid gas, a systematic treatment with a fumigant and a contact insecticide should result in effectually controlling the insects. The first step in the process should be to prevent the enormous production of eggs by ridding the house of the adults. For this purpose, Nicoticide is the most effective and cheapest material, aside from hydrocyanic acid gas, which was used in the foregoing experiments. Other similar preparations may be found to be equally good for the purpose. For each two thousand cubic feet of space from one to two ounces of Nicoticide should be used, according to the tightness of the house. This fumigation should last all one night, and be followed the next day by a thorough syringing of the plants with a contact insecticide, the most desirable used by the writer being Bowker's Tree Soap, at the rate of one ounce in a gallon of water. One such combined treatment should so reduce the numbers of Aleyrodes in a greenhouse that further treatment would be unnecessary for several weeks. If it is desired to continue this treatment further, the house should be fumigated as before, one week after and then sprayed as before, two weeks after the first treatment.

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* A. vaporariorum in part.

The Strawberry Aleyrodes, Aleyrodes packardi Morrill.

This well known and widely spread insect was for many years believed to be identical with the common greenhouse Aleyrodes. Packard, who first mentioned this insect in the American Naturalist (1) as occurring in large numbers on strawberry plants at Amherst, Mass., referred it to the species " vaporarium " (vaporariorum). This was a very excusable error, as we are justified in separating the two species only after a critical study of all the stages of each, laying special stress upon the range of variation in their structure. Since this first mention the insect* has been reported several times as occurring on strawberries (in such regions) in Ohio (7), Kentucky, (4, 5, 8, 10, 12), Southeastern New York (9) and Connecticut (10, 12).

The food plants of the species, as far as known, are very limited. Besides the strawberry, pupæ of this insect have been found in small numbers on ash, spiræa and camperdown elms.

I have recently described (11) all the stages of the strawberry Aleyrodes, and have briefly tabulated the differences between it and the greenhouse Aleyrodes. I will here consider more in detail the points wherein the former species differs from the latter.

Egg. Length varies from .23 to .24 mm. ; greatest width from .08 to .094 mm.

First Instar (Plate VI, Fig. 33). Only sixteen pairs of marginal spines are present in this instar, there being none to correspond in position to the seventh and ninth pairs of A. vaporariorum. The average comparative lengths of these spines in A. packardi are about as follows :

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* I have positively identified specimens from Kentucky believed to be *A. vaporariorum* as belonging to *A. packardi*. Quaintance (9) has considered specimens from New York state on strawberries which were too poor for positive identification as "much like *A. vaporariorum*." My experience with strawberry plants growing in a plant house thickly infested with *A. vaporariorum* goes to show that while the larva of this species will grow to maturity on that plant if transferred in the first instar, the adults show no liking for it, and are almost never observed even resting on its leaves. On such a plant I once found a very few pupa cases, which were, however, too poor for identification. It is possible that they were *A. vaporariorum*. I have never found an *A. vaporariorum* on a strawberry plant out of doors. On the whole, therefore, I feel justified in considering all Aleyrodes which have been reported as occurring on strawberries in this country and taken for *A. vaporariorum* as belonging to the species *packardi*.

$\frac{1}{6\frac{1}{2}}, \frac{2}{6\frac{1}{2}}, \frac{3}{7}, \frac{4}{5}, \frac{5}{5}, \frac{6}{4\frac{1}{2}}, \frac{7}{4}, \frac{8}{3}, \frac{9}{2}, \frac{10}{2}, \frac{11}{2}, \frac{12}{2}, \frac{13}{3}, \frac{14}{11}, \frac{15}{4}, \frac{16}{24}.$

The true lengths in mm. of these spines may be obtained by multiplying the lower figures by .0035.

On the cephalic region of the dorsum I have been unable to distinguish a pair of spines to correspond with those in *A vaporariorum* as well as in the later instars of *A. packardi* itself.

The length of the body in the first instar varies from .29 to .35 mm., the greatest width from .16 to .18 mm.

Second and Third Instars. In these stages the only difference in structure observed between the two species is in the comparative lengths of the first and third pairs of dorsal spines, the second pair in both species being minute. In *A. packardi* all three pairs are invariably minute.

The length of the body in the second instar varies from .41 to .45 mm., the greatest width from .21 to .26 mm.

The length of the body in the third instar varies from .56 to .62 mm., the greatest width from .32 to .38 mm.

Pupa. The most marked differences between the two species are in the pupal stage, although at a casual glance they appear alike. In *A. packardi* all three pairs of dorsal spines are minute, while in *A. vaporariorum* the third pair is very variable in its degree of development, as already described. In the former there is only a double sub-marginal series of wax rods present, none arising farther up on the dorsum. The rods of the outer series, unlike those of *A. vaporariorum*, are very variable in length, in mature pupæ being usually more than one-half the width of the body in length. The number of rods in the outer series averages much greater in *A. packardi* than in *A. vaporariorum*, there being from about sixty to one hundred present in the former and from about fifty to seventy-five in the latter species. The inner sub-marginal series of rods also differs in number in the two species, there being eighteen or twenty in *A. packardi* and but ten or twelve in *A. vaporariorum*. In both species these (the inner-submarginal series) are usually directed upward and curved inward over the dorsum of the body, but the variation in their place of origin is much less in *A. packardi*, none having been observed to arise farther mesad from the outer series than the width of their bases.

The length of the pupa of *A. packardi* varies from .748 to .88 mm., the greatest width from .407 to .54 mm.

Adult. The following formula shows about the average proportionate lengths of the segments of the antennæ in the female: 2—5—10½—3—4—3½—3½. The segments of the antennæ of the males are slightly smaller, but show about the same proportion.

The two basal segments seem to be of little systematic importance, as they can rarely be accurately measured owing to the fact that in specimens mounted in balsam their long axis is seldom perpendicular to the line of vision. I have therefore considered 2—5 their proportionate length in both species, these numbers being approximately correct. In *A. packardi* the following formula indicates the range of variation in length observed in each segment, omitting the two basal ones: (10–12)—3—(4–4½)—(3–4)—(3–5).

For convenience of comparison the following formula, representing the range of variation observed in the same segments of *A. vaporariorum*, is again given: (9–11)—4—(5–6)—(4–5)—(4–5).

The length of the fore wing of *A. packardi* is about 1.16 mm., the breadth about .48 mm.

The length of the body of the adult female varies from 1.15 to 1.20 mm.; average length of the male about .90 mm.

NOTES ON LIFE HISTORY AND INFLUENCE OF WEATHER.

This species evidently passes the winter entirely in the egg stage. Here in Amherst the adults become extremely abundant every fall, and hundreds, or even thousands, of eggs are deposited on nearly every leaf. The adults are very hardy, and egg laying may continue up to the middle of November, the larvæ and pupæ having all been killed by the frosts some weeks earlier.

In the spring a few consecutive warm days in March cause many of the eggs to hatch. The young larvæ, however, being in the most delicate stage, will, as a rule, succumb to the frosts up to the first of April, or even later. In the spring of 1902 all the eggs had hatched by the end of the first week in May. The first adults emerged about the middle of May, and from this time until November all stages could be found on the leaves. In the spring of 1903, two adults, recently emerged from their pupa cases, were found on May 4, but it was over a week later before the adults became at all common. In some seasons the strawberry Aleyrodes will be much more abundant than in others, owing to the varying weather conditions. A cold March, unfavorable to the development of the eggs, will delay the time of hatching until the larvæ will be less liable to be cut off by the spring frosts, while a couple of weeks of warm weather in March, followed by a cold snap, will cause a large number of the eggs to hatch and the resulting larvæ to die, and consequently comparatively few adults will result from the wintering over eggs.

Of those larvæ which are fortunate enough to escape destruction by the frosts only a small proportion reach maturity, as most of the old leaves upon which they feed and from which they are unable to move, are dead before the insects reach maturity. Considering, however, the enormous number of eggs which are deposited upon the leaves in the fall it is evident that if only one adult results from each one thousand eggs, the number left to continue the species will still be large.

ECONOMIC IMPORTANCE OF THE STRAWBERRY ALEYRODES.

The only serious injury thus far reported as resulting from the attacks of this insect has been from the state of New York. The following quotation from Slingerland (9) shows the amount of injury the insect may do:

"In the fall of 1897, and again in July, 1900, we received specimens of strawberry leaves which were seriously infested with a peculiar scale-like insect. The first specimens came from Sparkill, Rockland county, N. Y., and those last year from Rossville, Staten Island, or not far from the first. The following statements from letters of our correspondents will describe the insects' work:

'Our strawberry plants are full of very small white flies. They seem to suck the sap out of the leaves; they are on the under side of the leaves, and when disturbed fly away. The leaves turn black on the outer edges, where they are infested badly, and some plants are nearly or quite killed by them. Certain varieties are more infested than others.'

'The leaves I enclose were taken from plants set this spring, which have been attacked by small white insects on the under side of the leaves,' writes our Rossville correspondent in July, 1900. 'When I touched the plants, the flies, not larger than a grain of salt, but perfectly white, would rise up by the thousands in clouds. The plants started off vigorously with large healthy runners. Finally, I noticed that the plants began to look dead, leaves began to die and the runners began to wilt and dry up. Some of the plants are dead. The patches that were in bearing were also found to be badly infested later in the season. While picking the fruit the upper sides of the leaves seemed glossy like varnish, and the pickers remarked that their hands were covered with stickiness. Later on the plants had a black smutty appearance. These plants were very vigorous, but now the greater part of them have turned brown and died out entirely.' "

From my own observations I consider that the greatest injury to strawberries by these insects is in the late summer and early fall. The adults and immature insects are then very abundant, and though comparatively few leaves are actually killed, the plants are perceptibly weakened and fail to develop good vigorous crowns and roots. As a consequence, the following spring the new growth is retarded and the fruit yield reduced.

In the springs of 1902 and 1903 the insects did not become sufficiently abundant previous to the fruit harvesting season to do any appreciable damage to the fruiting vines. It seems, therefore, that whenever the insects become of sufficient importance to require treatment, that such treatment should be applied so as to prevent the injury which takes place in late summer and early fall.

TREATMENT.

In considering the treatment of the strawberry Aleyrodes we are confronted by two problems: How to prevent the insects from establishing themselves on newly set plants, and how to deal with them when once they are present in large numbers.

The amount of labor, time and money which it is expedient to spend on the treatment of the insect in strawberry fields depends in a large measure upon its abundance and the past experience of the owner. Each case must be judged on its own merits. In most cases it probably will not pay to treat the insect, but in cases as serious as those referred to from New York it demands considerable attention. When experience shows that treatment is advisable, the following recommendations will be of use.

Preventives.

1. Strawberry plants known to be infested should not be introduced into uninfested regions, unless it be at a season when the recommendations given under remedies for nursery plants are applicable.

2. In locating new fields those not adjacent to old infested fields are to be preferred. As the natural spread of this insect is due largely to winds rather than to its powers of flight the value of thus locating a new strawberry field is obvious. It has been the experience of the writer that the Aleyrodes occur in greatest abundance on those fields which are nearest to the old infested ones.

3. Plants for propagation should be grown for that purpose alone in a nursery isolated from the fruiting beds. This method not only acts as a preventive against the insect but is in accordance with the best methods of strawberry culture.

4. If plants are chosen from an infested field for setting purposes they should be taken, when possible, from the least infested parts of the field.

5. Plow under the old infested fields as soon as the fruit is harvested.

Remedies.

1. In the Nursery. When plants for setting purposes are grown in separate plots or nurseries, they should be first thoroughly treated there, as in such cases the next year's fruiting plants are confined to a comparatively small area, and the trouble and expense of treatment is proportionately less. The number of Aleyrodes on such plots can be reduced to a minimum by pinching off and removing in

the spring the old leaves which have lived through the winter. Until the adult, or winged form, appears in the spring, shortly after the first of May, the insects are confined wholly to these leaves, and there is no chance for them to spread to the new spring growth. The old leaves are usually weak and spotted with rust, and the plants are, on the whole, benefitted rather than injured by their removal. They lie close to the ground, and their dark green color contrasts sharply with the bright light green of the newer leaves. The expense of removing these old leaves will be lessened if it is done in connection with weeding, but in any case the expense will be trivial. Experienced strawberry growers advocate setting new fields as early in the spring as the ground can be worked to advantage, perhaps between the middle of April and the first of May in this latitude. Plants taken from the nursery for setting purposes will be freed from this insect in direct proportion to the thoroughness with which the old wintered over leaves are removed.

If the adults are allowed to emerge and become scattered over the leaves so that a second brood of larvæ appears, the insect should be held in check in the nursery by an occasional thorough spraying with kerosene emulsion (one part in ten of water) or whale oil soap (1.5 ounces Bowker's Tree Soap or 2 ounces Good's Potash Whale Oil Soap to a gallon of water). The spray, in order to be effective, should reach the under surface of ths leaves, and for this purpose an underspray nozzle can be used to advantage.

During the first week in May, 1902, the writer tried fumigation of growing strawberry plants in order to determine whether nurseries can be freed from the insect in this manner. While the results are apparently not of much practical value they are nevertheless interesting, as showing the effect of potassium cyanide and carbon bisulfid on the larvæ of Aleyrodes and on growing strawberry plants.

In the experiments with carbon bisulfid, the liquid was poured on to cotton and placed near the plant to be fumigated ; a bell jar with dirt tightly packed around its base was used as a cover. In the experiments with Potassium cyanide a large dry goods box, made practically air tight with putty, was first placed over the plant to be treated and made to set squarely on the ground, with loose soil all around in position to be quickly packed against the sides. The box was raised from one end and the potassium cyanide, wrapped in filter paper, was dropped into the glass vessel containing the freshly mixed sulphuric acid and water. The box was quickly dropped into position and made air tight around the base with dirt.

Experiments With Carbon Bisulfid.

No.	Rate.	Time.	Results.
1	10 gms. per cu. ft.	15 minutes.	Insects unaffected. Plant uninjured.
2	15 " "	15 "	Insects unaffected. Plant uninjured.
3	10 " "	30 "	Insects unaffected. Plant uninjured.
4	15 " "	30 "	Insects unaffected. Plant uninjured.
5	20 " "	30 "	1 or 2 p. c. insects killed. Plant uninjured.
6	25 " "	30 "	80 per ct. insects killed. Plant slightly injured.
7	30 " "	30 "	Insects all killed. Plant killed.
8	15 " "	1 hour.	Insects all killed. Plant badly injured.
9	20 " "	1 "	Insects all killed. Plant killed.
10	10 " "	1 "	20 per ct. insects killed. Plant uninjured.
11	10 " "	1¼ "	25 per ct. insects killed. Plant uninjured.
12	.2 gm. per cu. ft.	5 minutes.	Insects unaffected. Plant uninjured.
13	.2 " "	10 "	60 per ct. insects killed. Plant uninjured.
14	.2 " "	15 "	Insects all killed. Plant slightly injured.
15	.3 " "	10 "	75 per ct. insects killed. Plant slightly injured.

The eggs having all hatched at the time these experiments were made, the effect on that stage could not be observed. The conclusion to be drawn from the above is that for short exposures there is very little difference between the strength of these gases required to kill the young of this insect and the strength that will injure the growing plant. Experiments numbers 10 and 11 seem to indicate that as regards the killing of the insect without injuring the strawberry plant, a small amount of carbon bisulfid for a long time is better than a large amount for a short time.

Tests of the use of Potassium cyanide for the strawberry root louse by Powell and Sanderson of Delaware, and also by Johnson (Fumigation Methods, p. 148), show that two-tenths of a gram of KCN is satisfactory when properly handled. The plants are taken from the nursery, freed as much as possible from dirt and moisture, and loosely packed upon trays in the fumigating box or room.

To determine the effect of this treatment on the eggs of the strawberry Aleyrodes, a large number of strawberry leaves with hundreds of the insects' eggs attached to their under surfaces were treated in a fumigating box, using .2 gm. KCN for twenty minutes. The result was that none of the eggs hatched, although conditions in the laboratory were favorable, as eggs on untreated leaves invariably hatched under similar conditions. This shows that when strawberry plants are treated according to the above method for the root louse, the treatment will also be effective for the Aleyrodes when present.

2. In the Field. This is the most difficult place to treat the strawberry Aleyrodes. If they become very numerous in the fruiting or newly set beds, and require treatment, the best that can be recommended at present is to spray with an underspray nozzle as described for the nursery.

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9. Aleyrodes sp. (?), Slingerland, Bul. 19, Cornell Expr. Sta., p. 155–158 (1901).

10. Aleyrodes vaporariorum (?), Britton, Bul. 140 Conn. Expr. Sta., p. 3, 10, 14, 17 (1902).

11. Aleyrodes packardi, Morrill, Can. Ent., vol. xxxv, p. 25–35 (1903).

12. Aleyrodes vaporariorum (?), Britton, 2nd Rept. Conn. State Ent., p. 149, 156, 160, 162 (1903).

13. Aleyrodes packardi, Morrill, Psyche, vol. x, p. 80, 81, 83 (1903).

SUMMARY.

Of the sixty-five known American species of the genus *Aleyrodes*, the two herein treated, the greenhouse Aleyrodes (*A. vaporariorum*) and the strawberry Aleyrodes (*A. packardi*), together with the orange Aleyrodes (*A. citri*), are the only ones that have thus far proved of much economic importance. The orange Aleyrodes occurs only in greenhouses on citrous plants in northern climates, and at present is of no importance in this state.

The common names of the insects of this genus are: Aleyrodes, white fly, mealy wing and snowy fly.

The family Aleyrodidæ, to which the genus *Aleyrodes* belongs, occupies a systematic position between the plant lice and the scale insects, and appears to be more closely related to the latter.

The Greenhouse Aleyrodes.

The immature stages of this insect consist of the egg, three larval stages or instars and a so-called pupal stage. Of these, only the first larval instar is furnished with well developed legs and is able to crawl. The pupal stage is characterized by wax rods of variable length, which arise from the dorsal surface.

The egg hatches in from ten to twelve days, the larval and pupal stages together last from twenty-five to thirty days, and the adults may live, and as a rule probably do live, for several weeks.

Adult females are about three times as abundant as the adult males. Unfertilized eggs will hatch, and, as far as known, develop into adults of the male sex.

An adult female has been known to lay more than one hundred and twenty-nine eggs in thirty-six days.

There seems to be no reason to doubt that the common greenhouse Aleyrodes of North America is the same as that described by Westwood in 1856 as *Aleyrodes vaporariorum.*

The insect is supposed to have come originally from Mexico or Brazil, but it is at present very widely distributed in greenhouses in Europe and North America. It has a wide range of food plants, including many of such economic importance as cucumbers and tomatoes.

The insect is generally believed, by those who have had experience with it, to be the most serious greenhouse pest known at the present day.

Simple preventive measures may be all that it is necessary to use in many cases to keep the greenhouse free from the insect.

Spraying tomato plants in greenhouses is to be avoided when possible.

Hydrocyanic acid gas is the cheapest and most efficient remedy for the Aleyrodes in greenhouses. At present, it is advisable not to exceed the rate of .1 gram of Potassium cyanide per cubic foot of space for three hours' exposure after sunset. Even in a loose house this can be depended on to destroy all the insects except the eggs and a few pupæ. Twice this amount of Potassium cyanide per cubic foot of space in a tight house, with the same conditions otherwise, will not injure tomato plants in a reasonable state of vigor, while it has destroyed red spiders on a cucumber plant without injury to the plant. Three fumigations, using Potassium cyanide at the rate of .01 gram per cubic foot of space, and with an interval of two weeks between each fumigation, should practically rid the house of the pest.

When undesirable to use hydrocyanic acid gas, a combination of fumigation with Nicoticide and syringing with a solution of Bowker's Tree Soap seems to be the best substitute.

The Strawberry Aleyrodes.

This insect has been known for many years, and has been reported from various parts of the Eastern United States.

It was formerly believed to be identical with the greenhouse Aleyrodes, but it is now known to be distinct. Differences between the two species have been found in all stages except the egg.

This insect passes the winter in the egg stage on the under side of strawberry leaves. The eggs hatch in the spring and the earliest adults appear from the first to the middle of May.

Many of the larvæ are destroyed by frosts and by starvation, due to the leaves to which they are attached and from which they are unable to move, drying up before the insects reach maturity.

In some cases it proves a serious pest.

Preventive measures are necessary if the treatment is to be followed by good results. These consist in using care in the location of new fields in growing plants for propagation in nurseries, etc.

The simplest and cheapest remedies consist in treating the plants in the nursery. The old wintered over leaves should be removed not later than the first of May. As all the insects are confined to these leaves up to this time the plants will be freed from the insect in proportion to the thoroughness with which these are removed. It is necessary to combine the preventives with this remedy.

If the insect becomes so abundant in the field as to require treatment, spraying with kerosene emulsion or whale oil soap, using an underspray nozzle, is recommended.

EXPLANATION OF PLATES.

The cuts of Plate I have been obtained through the kindness of Mr. W. E. Britton, State Entomologist of Connecticut, who has used them in Bulletin 140 of the Connecticut Agricultural Experiment Station, and in his Second Report of the State Entomologist.

PLATE I.

Fig. A: Aleyrodes vaporariorum; early stages on tobacco leaf. Enlarged about four times.

Fig. B: Aleyrodes vaporariorum; adults and pupa skin on tobacco leaf. Enlarged four times.

PLATE II.

Aleyrodes vaporariorum.

Figs. 1 and 2: Eggs.
Fig. 3: Dorsum of first instar.
Fig. 4: Venter of first instar.
Fig. 5: Vasiform orifice of first instar.
Fig. 6: Dorsum of second instar.
Fig. 7: Venter of second instar.
Fig. 8: Right antenna of second instar.

PLATE III.

Aleyrodes vaporariorum.

Fig. 9: Right hind leg of first instar, from below.
Fig. 10: Vasiform orifice of second instar.
Fig. 11: Venter of third instar.
Fig. 12: Dorsum of third instar.
Fig. 13: Vasiform orifice of pupa.
Fig. 14: Legs, antennæ and mouth parts of pupa.

PLATE IV.

Aleyrodes vaporariorum.

Fig. 15: Side view of pupa.
Fig. 16: Dorsum of pupa.
Fig. 17: Right hind tarsus of adult female.
Fig. 18: Margin of wing of adult.
Fig. 19: Abdomen of male from the side.
Fig. 20: Abdomen of female from the side, soon after emergence from pupa case.

PLATE V.

Aleyrodes vaporariorum.

Fig. 21 : Adult female from above.

Fig. 22 : Adult female from below.

Fig. 23 : Adult female from the side, abdomen distended with eggs, ovipositor extended.

Fig. 24. Right antenna of adult female.

Fig. 25 : Genitalia of male from the side.

Fig. 26 : Terminal segment of abdomen of adult male from above, showing vasiform orifice and genitalia.

Fig. 27. Ovipositor of female from above.

PLATE VI.

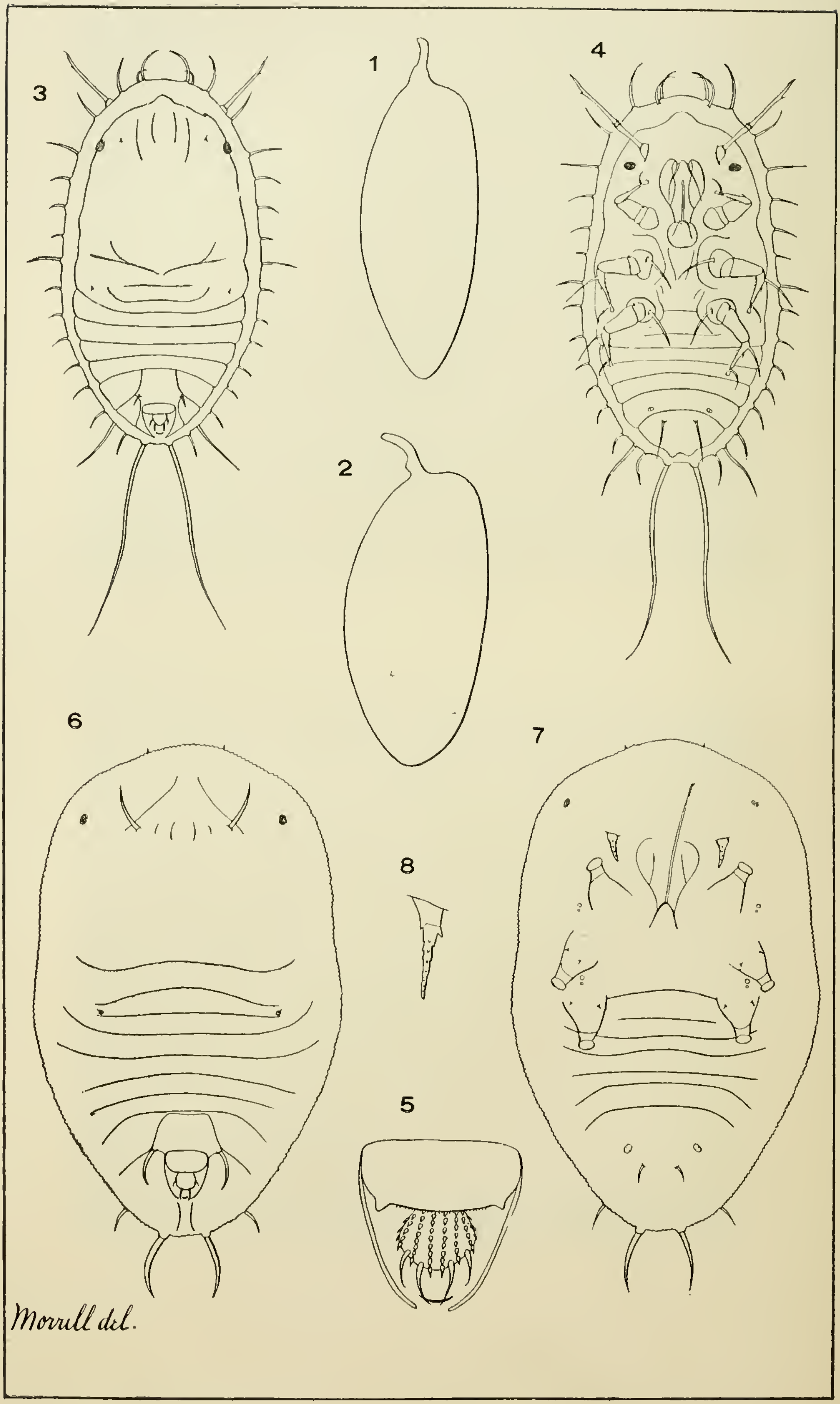
Figs. 28–31 : Diagrams illustrating variation in number and position of wax rods of the inner submarginal and dorsal series of the pupa of Aleyrodes vaporariorum.

Fig. 32 : Diagram illustrating main trunks of tracheal system of larval Aleyrodes; drawn from a larva (third instar) of A. packardi seen from below. For explanation of lettering of figures see page 28.

Fig. 33 : Dorsum of the first instar of Aleyrodes packardi.

A. Young of A. vaporariorum on tobacco leaf: enlarged about four times.

B. Adults and pupa skins of A. vaporariorum on tobacco leaf: enlarged four times.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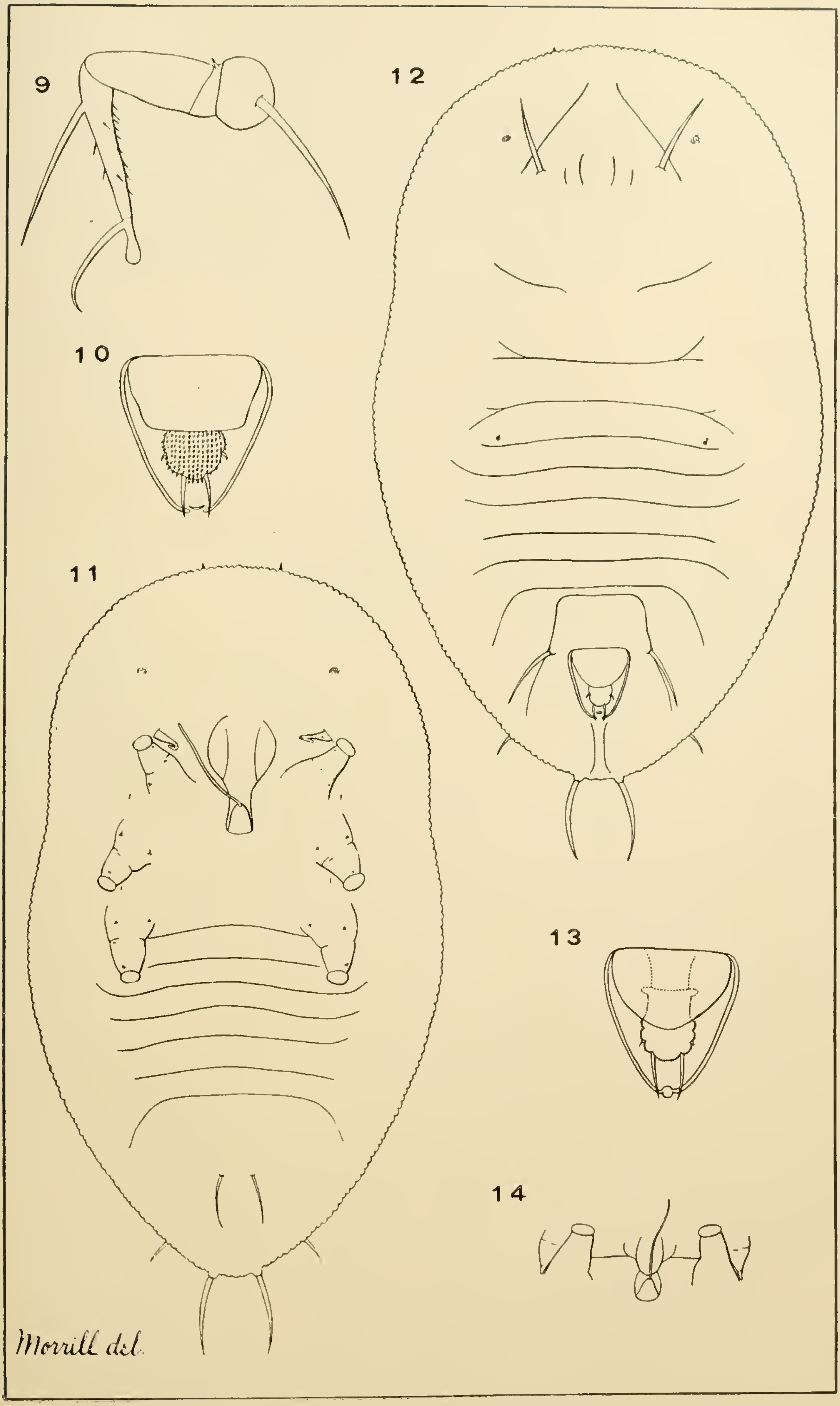
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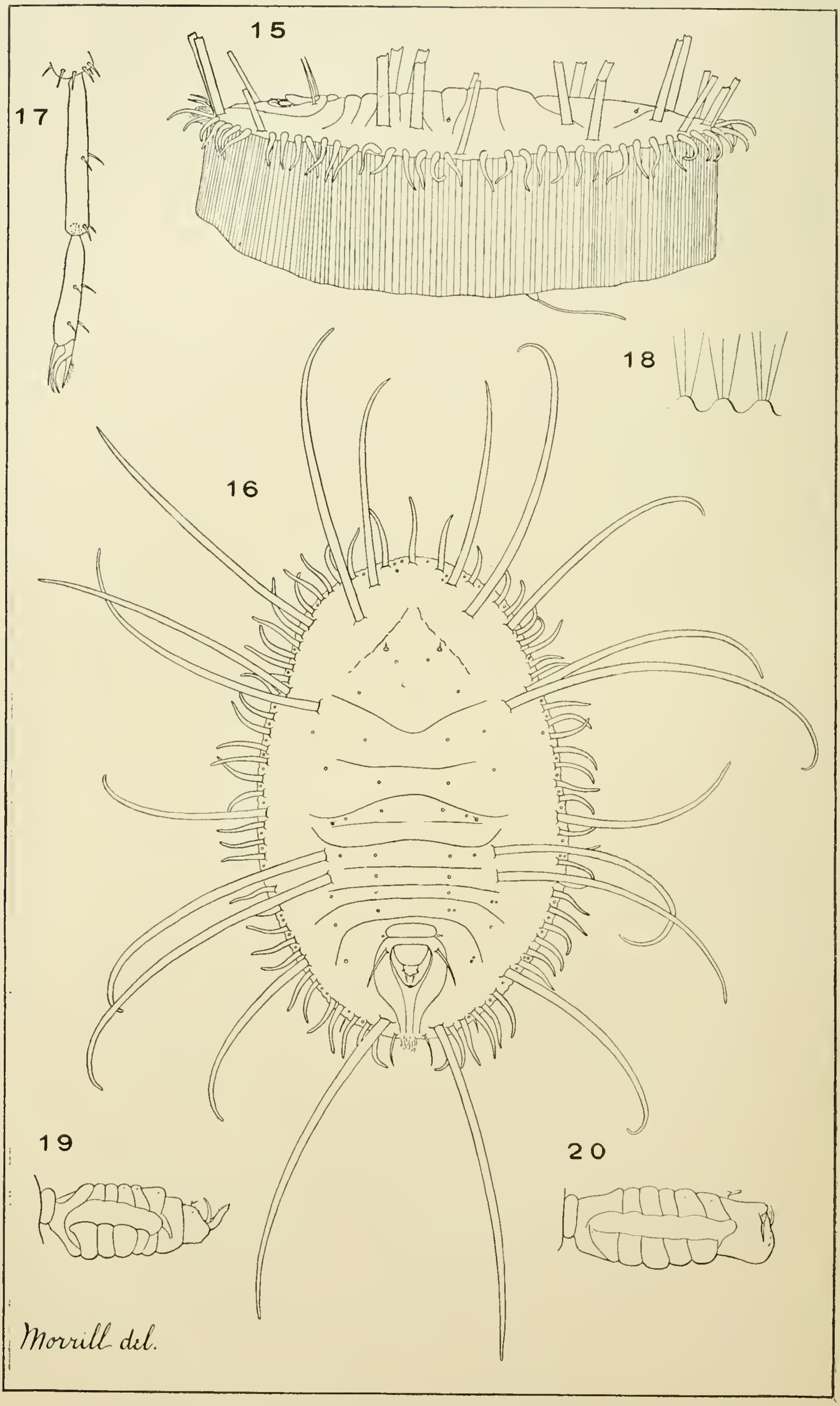
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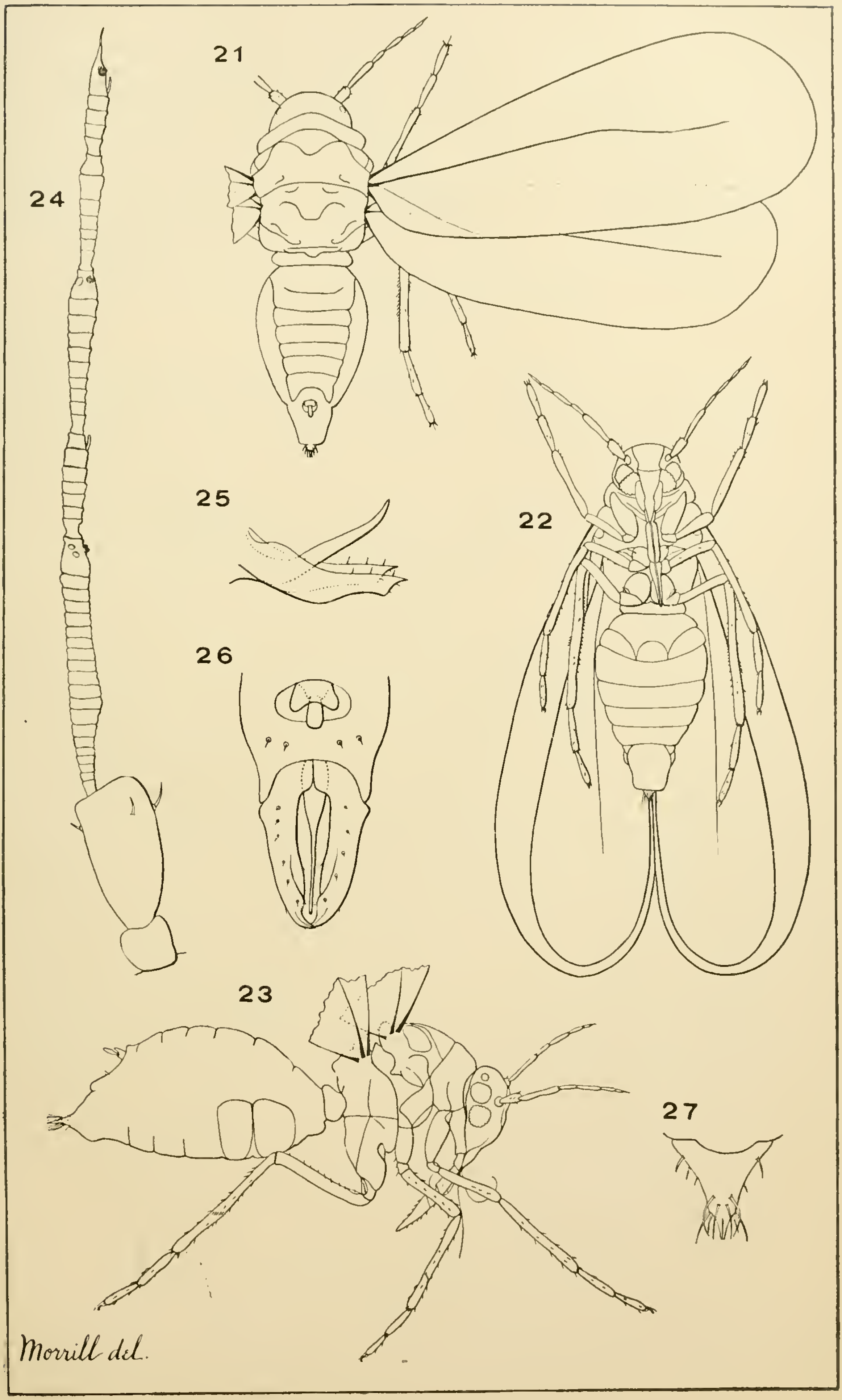
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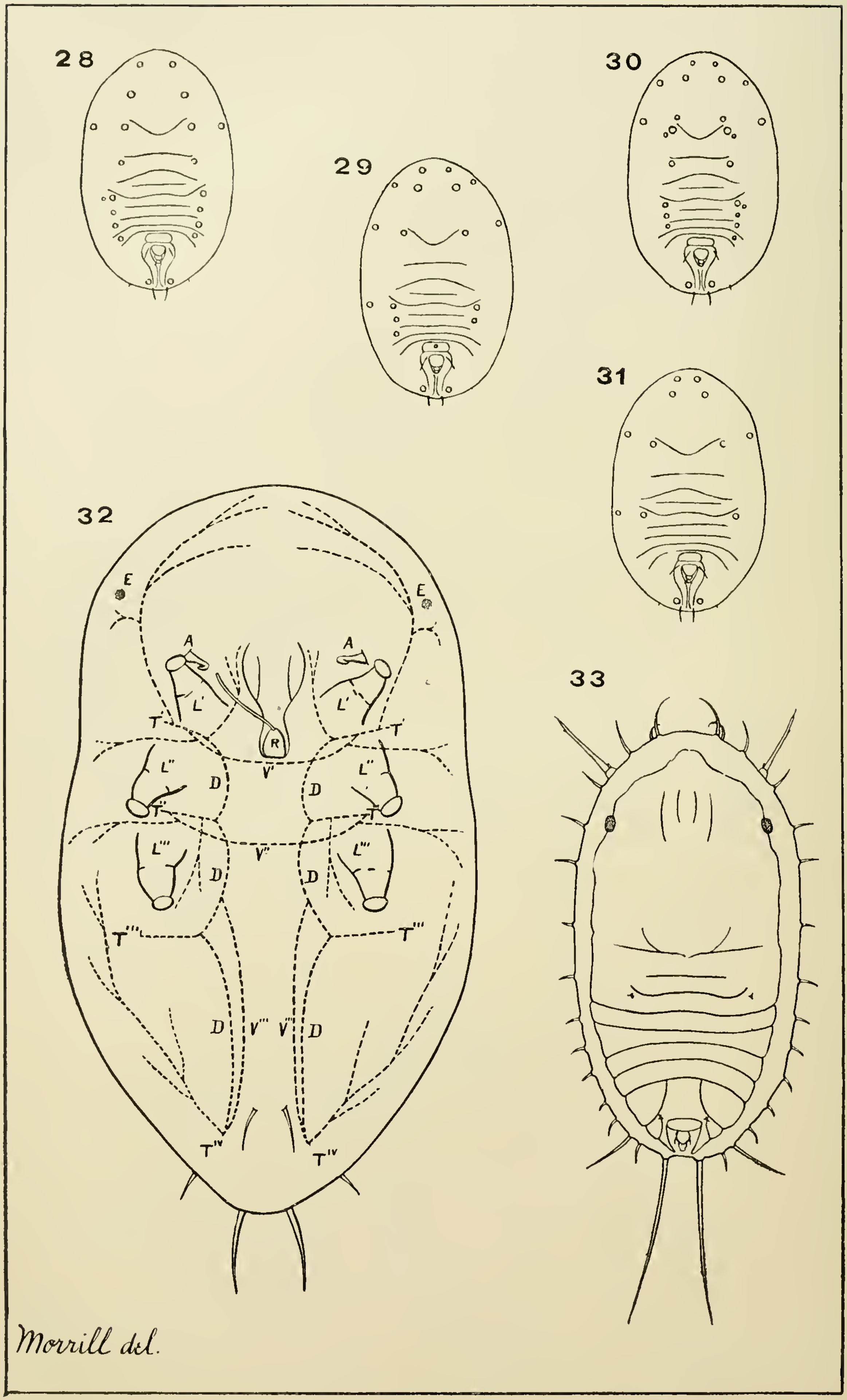
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HATCH EXPERIMENT STATION

OF THE

MASSACHUSETTS AGRICULTURAL COLLEGE.

TECHNICAL BULLETIN NO. 2.

THE GRAFT UNION.

OCTOBER, 1904.

The regular Bulletins of this Station will be sent free to all newspapers in the State and to such individuals interested in farming as may request the same. Technical Bulletins are sent only to those persons interested in the subject treated of in each case.

AMHERST, MASS.:
PRESS OF CARPENTER & MOREHOUSE
1904.

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OF THE

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AMHERST, MASS.

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Hatch Experiment Station, Amherst, Mass.

THE GRAFT UNION.

Some Observations on the Nature of the Union Between Stock and Cion, Especially in Hard-wood Grafting.

BY F. A. WAUGH.

Grafting is one of the most important processes in horticulture. As soon as we penetrate its essential nature we find it also one of the most intricate of subjects. The importance of the practice, and the difficulties which stand in the way of a full understanding of it, must make it always the subject of much speculation and study; and anyone who contributes, even a little, to make the knowledge of graftage clearer, is doing some sort of a horticultural service. These reflections must be the writer's excuse for presenting here certain observations, the most of which seem to be so obvious and simple as hardly to deserve statement in words. Nevertheless, in spite of their obviousness, some of these simple facts have been commonly overlooked, and in disregard of them, fallacious arguments have been made and erroneous conclusions drawn.

We speak of graftage as the union of a cion with a stock. In the vast majority of cases the prime object—we might say almost the sole object—of graftage is to secure this union. The nature of this union is generally understood to determine the whole success or failure of the graft. We say that the cion unites with the stock; and we speak of good unions and poor unions. These phrases are almost the commonest in horticulture; yet their significance is generally unknown, the facts are wrongly guessed, and the whole nature of the matter essentially misunderstood.

If this statement seems too sweeping, let us wait a moment until some of the simpler facts can be stated. Doubtless there are persons who have had the wisdom to see long ago all that is here set down; but many persons, even horticulturists of experience and ability, have long overlooked the facts.

How do stock and cion unite in the growth of a graft? The short and easy answer is that the two grow together. The common idea is that the two pieces grow fast to one another, just as two pieces of bone grow together when they heal after a healthy boy breaks his leg. There is a notion further that both cion and stock produce new tissue, and that these new tissues commingle or coalesce in some way; but this speculation is even more vague than the primary one which leads to it.

In herbacious grafting (where soft growing parts are used) the union may possibly be somewhat of this sort; but even here there is usually no general commingling of the two members as has been popularly imagined. The original cion and the original stock remain to the end of their existence very largely separate and distinct.

In ordinary graftage, where the cion is a cutting of hard, ripe, one-year-old wood and the stock is a dormant stem or root, it is, on the face of the proposition, impossible that the two should unite. Disregarding for the moment the very thin (though very important) cambium zone, the stock and cion are made up wholly of dead wood and bark. With perfectly negligible exceptions the cells are all dead—totally and forever dead. It is absolutely impossible for them to grow or to unite with anything. One might as well talk of making a lead pencil unite with a pen holder or a neckyoke with a singletree. The two may be glued together, waxed together, tied together; but they can never unite.

It is said sometimes that the cambium layers of stock and cion unite. This is quite a different matter, and though in the sense in which it is usually presented, the statement furnishes no explanation of the process, it leads us in the right direction. This thin sheet of cambium, lying between the bark and the wood, is the only portion of a tree stem which is really alive, the only portion which can grow, and so, necessarily, the part to which we must look for the beginning of the graft union.

If, now, we examine a successful graft of several years' growth, we shall at once discover two important facts: First, the one already propounded, that the old cion and stock have remained totally distinct and separate, without the slightest promise of a union; and, second, that the new wood which has grown since the graft was made is *continuous*. It is in complete, continuous, unbroken annual layers, *like those in an ungrafted stem.* At any rate, the difference between these annual layers as they grow over a graft junction and as they grow on an ordinary stem is not an essential one. It may be set aside for the present, but will be examined later.

FIG. 1. Diagram of Cleft Graft 3 years old.

These statements may be better understood by reference to the accompanying diagram, Fig. 1. The black portions represent the wood of the original cion and stock. The white portions represent three annual layers of wood which have grown since the graft was made. That this is a true statement of what really takes place may be seen from the photographs, Figs. 2, 3, 4, which are taken direct from the actual specimens, and are reproduced natural size. In every case the old stock can be traced, more or less clearly, along its junction with the cion, while the annual layers may be seen completely enveloping both. We have thus demonstrated the following simple facts:

(1) Stock and cion do not unite like the two parts of a broken bone. On the contrary they remain forever separate.

(2) Neither do the annual layers produced after grafting unite, in the ordinary sense of that term. Each layer, under normal conditions, is complete and continuous.

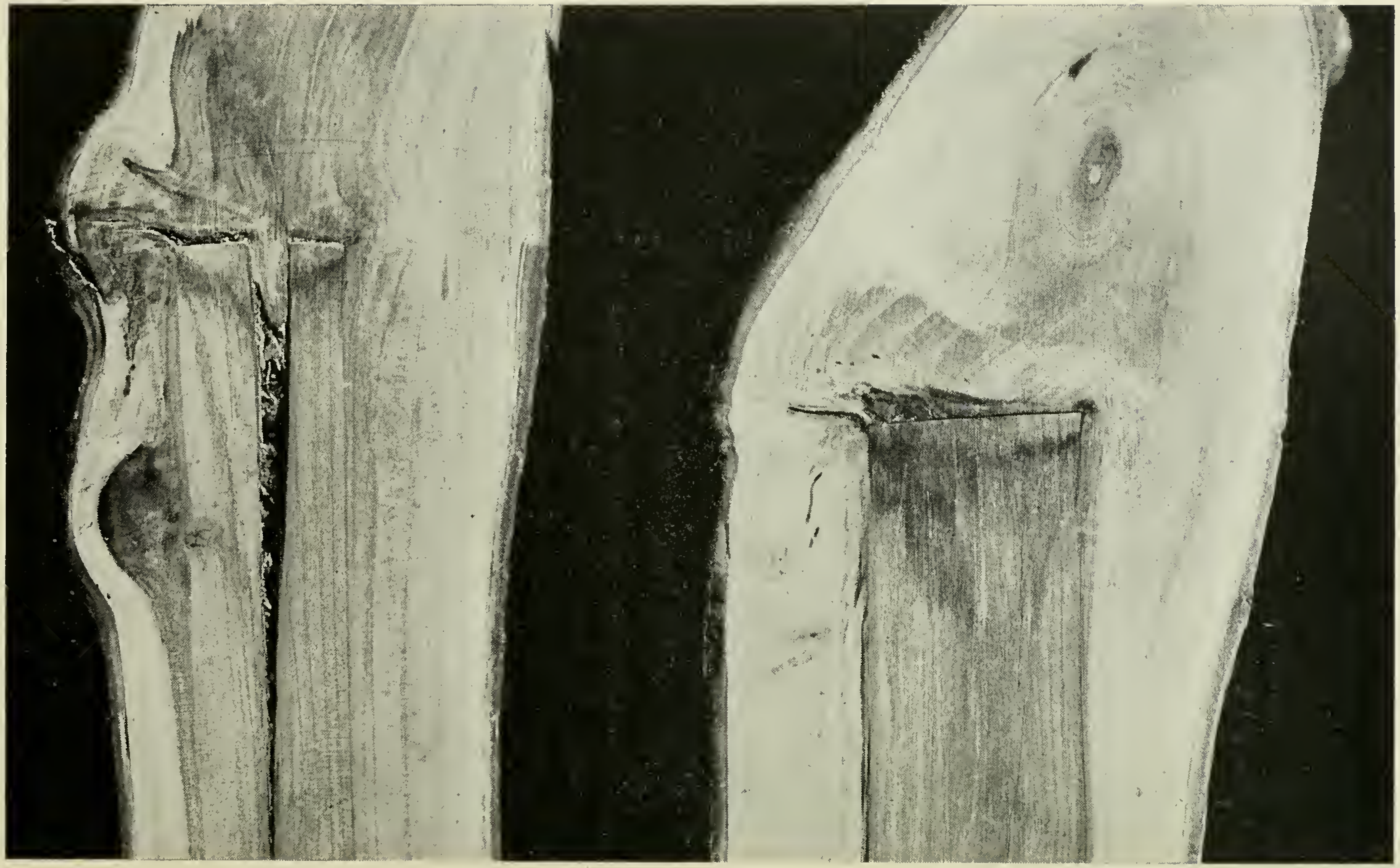

FIG. 2. Sections of Apple Grafts, the first one transverse, the second longitudinal.

(3) In hardwood graftage, therefore, the "union" of stock and cion is quite different, in its mechanical nature, from what our common speech would signify and from what it is commonly understood to be.

These conclusions are so simple and obvious that we are slow to admit their revolutionary character. Moreover, they are immediately followed in the horticulturist's mind by a train of questions and doubts which, though entirely subsidiary, do much to disguise the force of the main facts. The horticulturist knows, for instance, that the two varieties brought together by graftage retain their characteristic qualities unmodified, or only slightly changed. If a pear cion is grafted on a quince stock, then any bud above the junction will bear pears, and any bud growing from below the junction will bear quinces. There must be a division between the two kinds of wood. What is the nature of this division? How precise is it? Is it accompanied by any mechanical strength or weakness? These and other similar questions press for answer.

It cannot be said that we are yet in a position to answer all these questions. Possibly we can throw a little light on some of them. But it must not be forgotten that all these considerations are entirely above and beyond the more fundamental conclusions already reached, and that the facts already developed are not to be in any wise affected by the discussion of these questions which we now take up.

THE SEPARATION OF CHARACTERS

If we make sections of a large number of grafts, such as are shown in the accompanying photographs, we shall find that, in spite of the longitudinal continuity of the annual layers, there is sometimes, at right angles to them, a visible line of demarcation between the wood grown from the cion and that grown from the stock. The two kinds of tissue are sufficiently unlike that the difference can be noted with the naked eye. Moreover, in some cases there is a distinct line which seems to form a boundary between the two members.

FIG. 3. Plum Grafts, showing continuous layers of new wood. The old wood of the original stock and cion has been partly eaten out by ants in the specimen on the right

One would naturally expect that a microscope having a sufficient magnification to show the individual cells of which the tissues are made up would quickly exhibit the manner of their conjunction. However, after having studied a large number of such specimens under the microscope, the writer is compelled to report the results disappointing. In nearly all cases one can see less with the microscope than with the naked eye.

Fig. 4. Dyehouse Cherry on Miner Plum, showing continuous annual layers of wood.

In figure 6, which is very greatly magnified, showing the cells at something like 1000 times their natural diameter, the little knot of scar tissue near the middle does accidentally show one point on the line of junction ; but it will be seen at the same time that the vessels and the parenchyma cells run uninterruptedly from end to end.

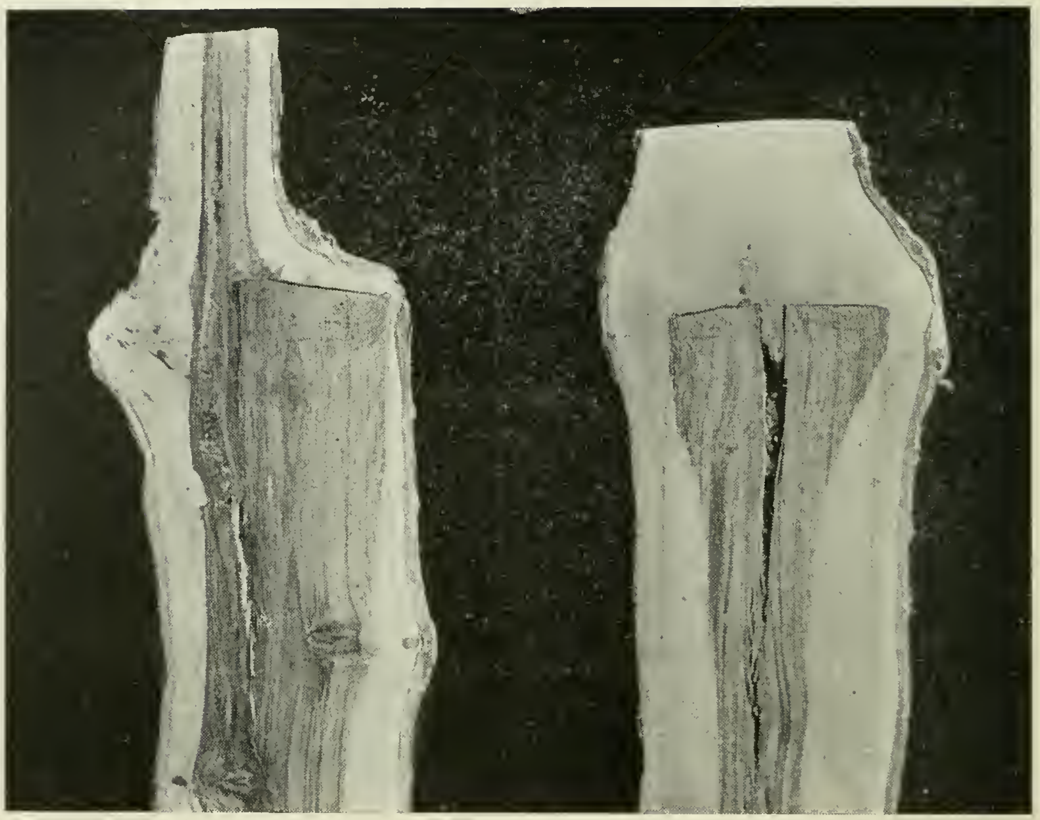

FIG. 5. Sections through Grafts of Plum.

With this photograph showing the microscopic anatomy of the tissues before us, it is harder than ever to see where a certain tree ceases to be cherry and begins to be plum. The cells are so indifferently mixed that one is tempted to believe that the specific physiological character may be blended at the same time. It has long been the dream of gardeners to produce new kinds of plants by the graft union of diverse cions and stocks. Do not our present observations show the reasonableness of such endeavors?

Certainly not. No matter how closely the two kinds of cells may lie against one another, their contents are never mingled in the production of a new cell. Each new cell is produced by the division of some older single cell, never by the fusion of two parent cells. Let us suppose that in figure 7 the black cells are those of the quince stock, while the white cells are those of the pear cion. As each

FIG. 6. Section through a young graft, greatly magnified. The round mass of scar tissue is merely accidental.

black cell divides quite independently of the white ones, it produces only black offspring; and, similarly, the white cells dividing produce only white offspring. Conversely stated, each cell is the offspring of one parent only, not of two; and it will therefore have the qualities of one parent only.

The two kinds of tissue may commingle or lap in together somewhat along the line of junction, but this mixture is only mechanical, not physiological.

The question of the mechanical strength of the graft union may be postponed for a moment until we consider the morphology of the union produced in budding.

FIG. 7. Diagram to illustrate separateness of character in stock and cion.

THE BUD UNION

Budding is simply a form of graftage in which the cion carries only one bud, with little or no wood. The form by far the most commonly used is known as the shield bud. This is the only form here considered, but other methods give strictly comparable results.

Figure 8 represents diagramatically the growth of a bud when set upon a stock. The black portion of the figure represents the

FIG. 8. Diagram of bud graft 3 years old.

wood of the stock and the shaded portion represents the bud or cion. The white portions represent three annual layers of growth which have been put on since the bud was set. In this case, as with the common graft, the layers of new growth are continuous, running from top to bottom without any break at the plane of junction.

If a successful bud graft of several years' standing is cut in two along its axis we shall find almost precisely the same conditions as we have already found in the ordinary graft. Although the annual growth layers are continuous, we may sometimes find a line of demarcation visible to the naked eye. When this is examined under the microscope, however, the distinction usually disappears to a considerable degree, and the cells are found to run together indistinguishably. There is therefore no difference, from our present point of view, between a bud graft and a long-cion graft.

MECHANICAL STRENGTH OF THE JUNCTION

There has always been a good deal of debate amongst horticulturists as to the mechanical strength of a graft. Some have said that the graft always presents a point of weakness in the tree. Others

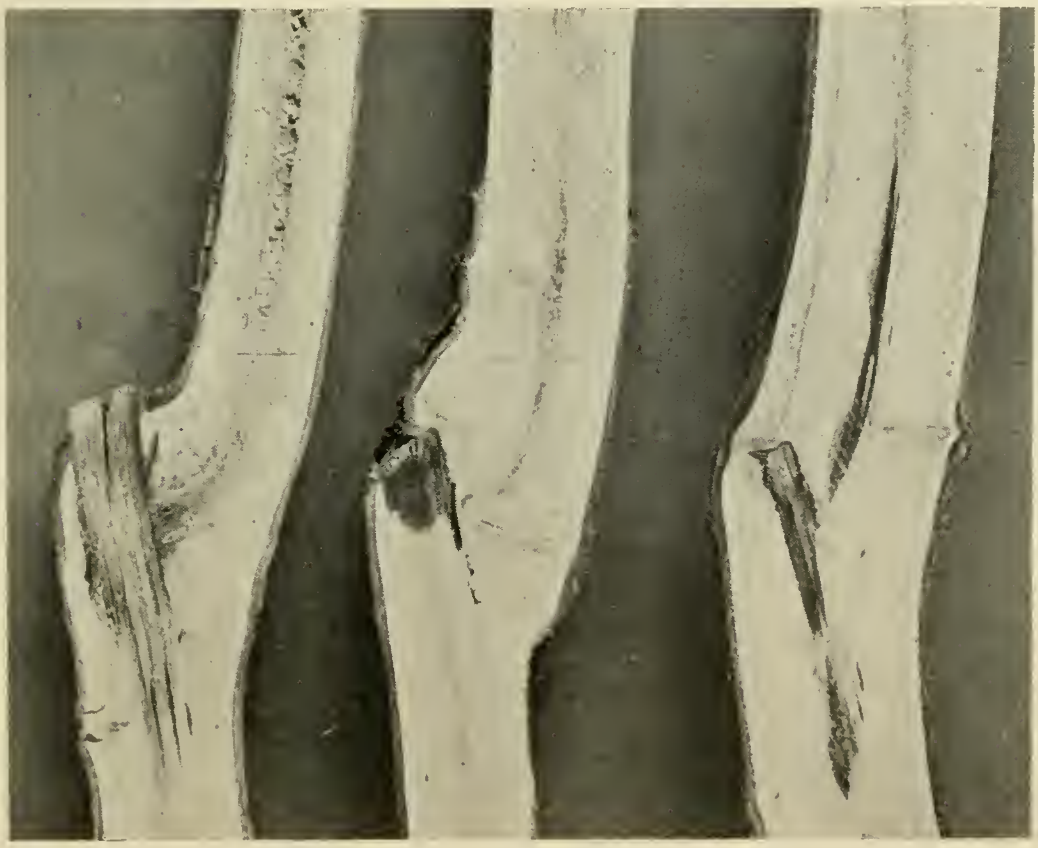

FIG. 9. Bud grafts 1 and 3 years old, showing continuous layers of young wood.

have denied this, and have even said that the place where a graft has healed successfully is the strongest point in the stem. The materials which we have here in hand enable us to put this vexed matter in its proper light.

It will be noticed that the region about some grafts is more or less swollen by the deposition of an extra amount of wood tissue (due to causes which we need not now discuss), and that the wood in this region is very close grained, as may be seen on careful examination. In some cases when grafts are cut open and dried the tissues crack or check more quickly at other points than at the graft junction, showing that the fibers are stronger in the latter region. It may also be observed when a wind breaks off branches in an old orchard that many, usually a majority, of the fractures occur, not where the grafts have been made, but elsewhere on the same stems, a fact which shows conclusively that the grafts are not points of weakness in those particular cases.

On the other hand grafts do sometime break, even after they have grown, in apparent health, for a number of years. When a branch breaks at the point of graftage it is prima facia evidence that that was the weakest point in that particular branch. Moreover there are whole classes of facts which the horticulturist has assembled here. Certain kinds of plants are known as a rule to make weak unions, the Clairgeau pear on the quince and the Domestica plum on the peach being examples. A certain nurseryman recently, on my order, sent me 100 "poor unions." These were taken from his nursery rows and were simply sorted out from his stock. In every case the cion had grown, but the union was bad, *i. e.*, mechanically weak. If the normal union of cion and stock is made by such complete and continuous cylinders of annual growth, how can we account for the unsuccessful unions?

The answer is not altogether an easy one. We may approach it by saying that, when the two members are unlike in nature and in some way physiologically incompatible (whatever that may mean), the wound does not heal readily, owing to some sort of irritation which continues to be felt at this point. In nearly all cases this is followed by the deposit of considerable quantities of loose meristematic tissue, such as is always produced by the tree for the healing of a wound. These loose and roundish cells fill the space where in a successful graft the long parenchymous cells and ducts interlace.

The whole area of the union is therefore weaker.

The constant and excessive deposits of these soft roundish cells is what causes the swellings so frequently seen at the point of union in grafts.

In some cases these round cells form a thin wall of division between the tissues of the growing stock and cion. This was the case with the bud graft illustrated in figure 9, a pear on a quince root, which, after growing three years, broke off with a cleavage almost as clean as the ball and socket of a hip joint. This articulation will be seen filling the middle half of the area of fracture. The surrounding portions, broken more roughly, are the loose corky tissue which, filling in between the wood and the bark, have formed the large swelling at the point of junction.

FIG. 10. A defective and broken bud graft. Pear on Quince.

After a close study of a large number of these defective unions, the writer has reached the opinion that they are almost always due to the incompatibility of stock and cion, as referred to above. It is a common notion among horticulturists that careless or ignorant manipulation—the defective setting of bud or cion—in the grafting will lead to these poor unions. There seems to be little ground for this opinion. If the stock and cion are of varieties which are congenial, and if the graft or bud grows at all, the union will nearly always be good. Poor manipulation will often cause the failure of a large percentage to grow, but it seldom affects permanently the strength of the union in those grafts which live at all.

GENERAL ESTIMATE

Two questions emerge from the foregoing discussion. The scientist asks what effect these observations have on the philosophy of graftage. The practical fruit grower asks how these facts bear on his work of grafting trees. The writer does not believe it is necessary for every fact to be theorized, nor yet that it should be given an immediate practical application. The notions of graft unions hitherto entertained by most horticulturists have been, for the most part, merely theories, more or less incorrect, and these incorrect theories were the less excusable because the facts were so abundant and so easily to be seen. It is hoped that the simple observations of this bulletin may help to clarify the common views of graftage. No direct application to the practice of graftage will be attempted here; but it may be said parenthetically that this department has in hand several lines of experiments bearing on the practical aspects of grafting and budding.

In conclusion we may re-state briefly the points developed:

(1) In hardwood graftage the cion and the stock never grow together.

(2) Neither do the new layers of wood grown from the cion and stock respectively unite. Instead of this, under normal conditions, they are produced in perfectly continuous layers.

(3) In the case of imperfect unions the continuity of the new growth is more or less interrupted by the deposition of a certain amount of loose scar tissue such as serves in the healing of wounds.

(4) These conditions make the graft union mechanically weak. All degrees of mechanical strength may be observed in graft unions, ranging from those (a large number) which are stronger than the adjacent parts of the same stems down to such as are incapable of even holding themselves in place.

(5) Incidentally it has been judged that weakness of unions results nearly always from physiological incompatibility of the cion and stock, and very seldom from faulty manipulation in the original setting of the graft.

Technical Bulletin No. 3. APRIL, 1907.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION.

THE BLOSSOM END ROT OF TOMATOES

BY

ELIZABETH H. SMITH, M. S.

This Bulletin gives the results of investigations pertaining to the cause of the so-called "Blossom End Rot" of Tomatoes, together with a discussion of results obtained by other investigators.

Requests for bulletins should be addressed to the
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AGRICULTURAL EXPERIMENT STATION,

AMHERST, MASS.

DIVISION OF BOTANY.

The Blossom End Rot of Tomatoes.*

ELIZABETH H. SMITH.

For several years tomatoes have been grown in one of the greenhouses of the Experiment Station, during which time what is known as "Blossom End Rot" has been present in more or less abundance. On account of the diverse results obtained by various investigators of this trouble, an attempt at a diagnosis has been made by the writer.

All the diseases of the tomato fruit now known may be summed up under the terms "Black Rot," "Blossom End Rot," and "Fruit Rot." Up to this time it has not been determined to what extent these are identical.

REVIEW OF PREVIOUS WORK.

Although Blossom End Rot has been mentioned in various experiment station bulletins, no careful investigation was made of the disease before that of Galloway[1] in 1888. He describes a "Black Rot" of the tomato as follows: "The disease, as a rule, makes its appearance at the apex or flower end of the fruit, when the latter is from one-half to two-thirds grown. At first, a small blackish spot is seen either around the remains of the style or on one side of it; this rapidly increases in size, but retains a more or less circular outline. As the disease progresses the tissues collapse quite regularly on all sides, and the berry becomes much flattened. There is usually

* These investigations on tomato rots were accepted as a thesis for the degree of M. S. The greater part of this work was done four years ago, and the manuscript in its present form was completed in June, 1905. G. E. S.

a slightly raised narrow border surrounding the diseased parts, while just outside this the cuticle retains its normal healthy color, but appears slightly wrinkled, owing to the collapsed condition of the tissues beneath. Sections through a rotten tomato at this stage show that the black discolorations extend deeply into the tissues, the depth depending somewhat on the size of the spot. As the malady progresses, the diseased parts become hard and leathery, the surface assumes a greenish black velvety appearance, and finally the entire fruit becomes dried and shriveled."

Galloway identified two species of fungi in connection with the spot, viz.: *Macrosporium tomato, Cook*, and *Fusarium solani, Mart.*, both of which he describes in detail. He finds the spores of the former exceedingly variable, the hyphæ at times long and nodulous and bearing spores which cannot be distinguished from those of the genus Cladosporium. Galloway finds that the Macrosporium grows mostly in a felty mass near the surface, while the Fusarium shows a much greater tendency to penetrate the sound tissues.

The results of Galloway's infection experiments are summed up as follows: (1) Neither the Fusarium nor the Macrosporium has the power of penetrating the sound cuticle of the tomato. (2) The Macrosporium spores, when brought in contact with the exposed tissue of either green or ripe fruit, produce the rot in a very short time. (3) The Fusarium will grow only in fully ripe tissues or tissues which have been partly disorganized through other agents.

From the publication of Galloway to that of Jones and Grout[3] in 1897, tomato rot has been often mentioned in experiment station bulletins, and *Macrosporium tomato*, or by error *M. solani*, has been given as the cause. A study of the so-called *Macrosporium solani* of potatoes by Jones and Grout resulted in the identification of two species, one an active parasite and one saprophytic. Both species were proved to be Alternaria. " When the study of the tomato rot was taken up (by the same workers) it was found that the fungus which causes the black patches on the rotting fruit was an Alternaria, not distinguishable from the one on onion and potato. It was further proved that this fungus did not cause the rot, for green tomatoes inoculated with spores from a pure culture from the tomato remained fourteen days in a moist chamber until they ripened, without showing signs of the rot, and cultures made from tomatoes just beginning to rot would not yield the Alternaria."

In an article on Blossom End Rot in the English "Journal of the Board of Agriculture," by Charles Whitehead[2], the cause of the disease is attributed to *Cladosporium lycopersici*. "This rot," it is stated, "must not be confounded with the other tomato affection known as 'Black Rot,' due to another fungus termed *Macrosporium tomato, Cook*. This is not confined to the lower part or style end of the fruit. The color of the rot is altogether much darker than the decay consequent on the attack of *Cladosporium lycopersici*." The same worker noticed another fungus in tomatoes infected with *Cladosporium lycopersici*, having a mycelium more delicate and slender than that of Cladosporium, and quite colorless. This permeated

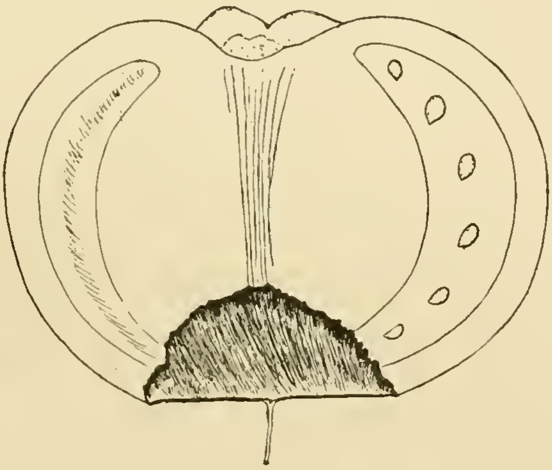

FIG. 1. Section of the natural spot showing dead cells, masses of starch and mycelium of Fusarium.

the tissues of the fruit and lived upon it, penetrating further into the healthy tissues than the Cladosporium, though the Cladosporium was "evidently the originator and main cause of the mischief."

The same writer states that Dr. Plowwright in 1881, presumably in the same journal, reported both a Cladosporium and a Macrosporium in connection with the disease, the Macrosporium being identical with *Macrosporium tomato, Cook*, of Galloway, previously quoted.

In 1900, F. S. Earle[4], of the Alabama station, published the results of work on the "Black Rot or Blossom-end Rot," as follows:

"When tomatoes are attacked by this disease in the field, the first stage to be noted is the appearance of a small, irregular, watery area, usually, though by no means always, surrounding the remains of the pistil. On making a cross section this watery condition is found to be confined to the portion immediately under the skin. It usually does not involve the tissues to any great depth, even after it has extended so as to cover a considerable surface area. Growth of the fruit over the infected area stops, so that after a few days the spot seems somewhat sunken. If the tomato is nearly ripe, maturity will be hastened and the watery spot may dry down so as to look as if the fruit had been slightly seared with a hot iron. The greater number of infections take place when the fruit is about an inch in diameter. The disease may invade the entire surface, causing the fruit to fall, or the premature ripening of the lower portion may arrest it, when the partially dried diseased portion often becomes blackened by a velvety growth of the Alternaria. In the early morning drops of sticky exudation were observed on the spots of half-grown rotten fruit. These were found to be swarming with bacteria, which were found abundantly within the diseased tissues. Sound green tomatoes under a bell-jar were inoculated with a pure culture prepared from the exudate. In all cases they showed signs of rot within twenty-four hours. When agar containing the germs was smeared on the surface of sound tomatoes, no rotting took place even after a number of days. The disease cannot be contracted through the flowers, as is the case in pear blight. The stigmas of many open flowers were smeared with cultures of the germ without inducing a single case. In no case were inoculations successful where the fruit was less than one centimeter in diameter. It grows on ripe tomatoes, but less readily than on green ones. It seems to be strictly ærobic."

From the abundance of thrips on the fruit, he concluded that insects may be the means of dispersal of the germ.

William Stuart[5], of the Indiana station, reported a tomato disease in 1900, which, he says, " resembles in many respects that caused by *Macrosporium solani*." He attributes the rot to a motile bacillus found in the tissue. He is doubtful, however, of having isolated it, as inoculated fruit developed a watery rot with an offensive odor, which soon decomposed the fruit completely. The natural " spot " was perfectly clean, and is described as a watery discoloration, which afterward dried down.

FUSARIUM ROT.

Work on the tomato fruit rot was begun by the writer in the spring of 1902. A diseased condition of the fruit was observed at once on the maturing of the crop, the appearance of which agreed in a general way with that of Galloway[1] and Whitehead[2], previously quoted. The spot was always around or at one side of, and contingent with the style, slightly sunken, with regular boundary, and clearly defined by a slightly raised ridge, beyond which the tomato was perfectly healthy. The tissue was dry and leathery, a light greyish brown, showing more or less of the shriveled vascular bundles beneath. On the larger spots rings of a darker color were sometimes barely visible near the boundary. Small, dark spots were sometimes present on the rotten area. The longitudinal section through a spot showed the interior boundary to be as clearly defined as the outer. The depth of the rotten area was about equal to the surface radius in the most extreme cases, and often extended not more than half that distance.

A microscopic examination of the spot showed nothing which could be distinguished as a fungus until a careful search had been made. The tissue was dry and blackened, the cells disintegrated. Finally a small tuft of delicate, colorless, mycelial threads was observed along the inner border, and by careful searching this characteristic form was found in every spot, most easily at the interior margin of the rot. The tufts protrude from intercellular spaces between the blackened walls into the still healthy tissue. (See Fig. 2.) Tufts were also found in the interior of the rot, but in most cases were shriveled beyond recognition.

A study of the spots on ripe fruit showed the same characteristics as on the green fruit, but it was found that some of the large starch grains so abundant in the green fruit had been retained in the cells, while the healthy tissue, as usual, gave no reaction with iodine for starch.

Particular attention was paid throughout to the detection of any bacteria which might be connected with the disease. The spot, when first opened, was in all cases perfectly dry and apparently free from bacteria. After remaining in a moist chamber for a day or two, a dense growth of Fusarium developed on the cut surface, often accompanied by putrefactive bacteria. Repeated attempts to inocculate with these bacteria failed, and several attempts to obtain cultures from the fresh spot were unsuccessful.

An examination of the fungus showed it to be a species of Fusarium. Spores were produced abundantly and proved to be the characteristic Fusarium type—club-shaped in the young stage ; more or less elliptical when mature ; usually four-celled, varying to six ; size varies from 32—38.4 μ in length, and the conidiophores are short and thick. (See Fig. 3.) In none of the rot examined was there the slightest trace of any other fungus.

Pure cultures of the Fusarium were obtained on stewed tomatoes, and these were used to inoculate green fruit. Inoculations were tried both around the style without penetrating the epidermis, and through a wound. The Fusarium placed around the style did not take effect, except in one case in which a small, quite characteristic spot was obtained in this way on the green fruit.

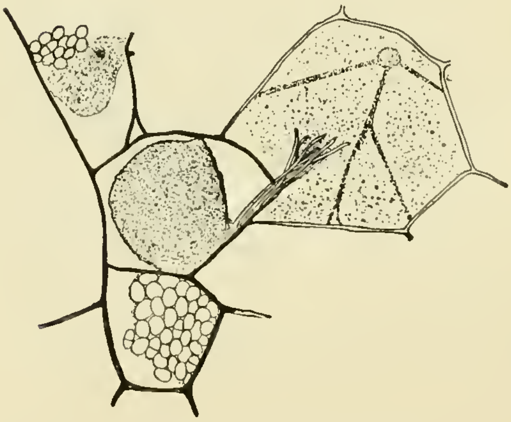

FIG. 2. Mycelium from infected cells penetrating healthy tissue.

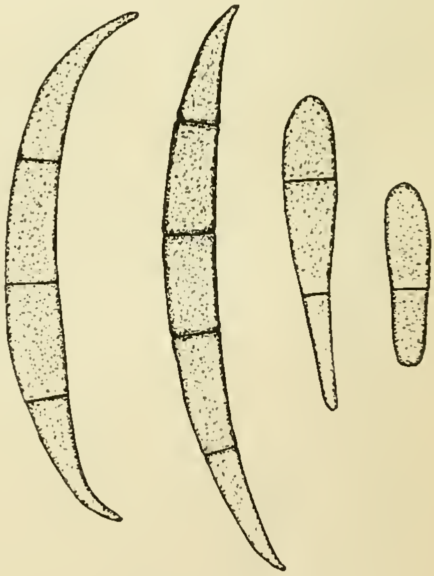

FIG. 3. Conidia of Fusarium.

Inoculations through punctures in the epidermis grew with varying vigor. When deep punctures were made the mycelium grew rapidly until nearly the whole fruit became involved. The tissues affected were softer, more collapsed and lighter in color than in the case of natural infection, as was to be expected from the vigor of the growth. Here, also, the tissues were perfectly dry. The surface of the rot became covered with white concentric rings. The mycelium in this case permeated the tissues in all directions, especially in strands between the cells. Spores were produced throughout, especially in the intercellular spaces, (See Fig. 4.) The concentric rings proved to be spore clusters developed in dense, conical tufts on the surface. (See Fig. 5.) Macroconidia have not been observed in connection with this species. By inoculations of varying depths, gradations in development between the natural rot and that just described were obtained, showing that the fungus is ærobic.

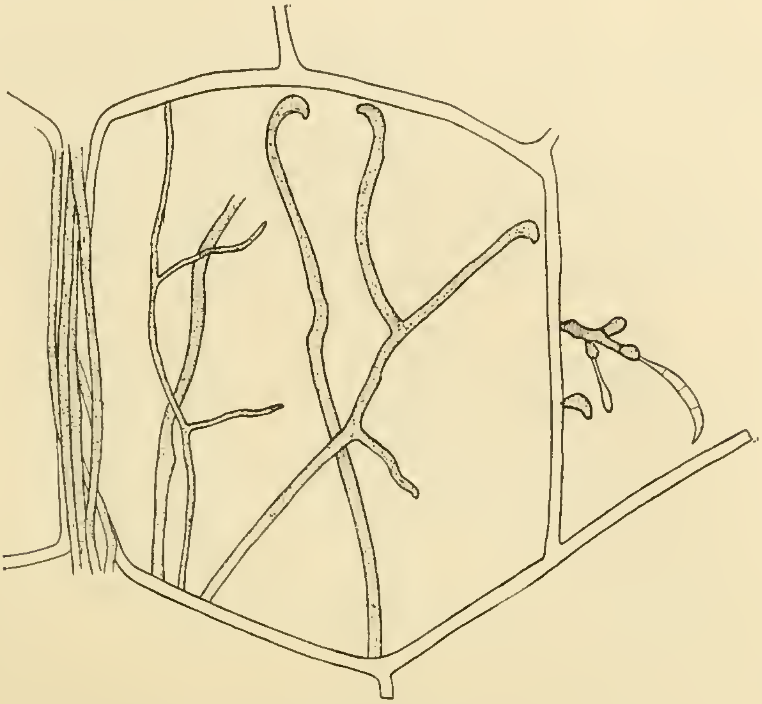

FIG. 4. Mycelium of Fusarium in deeply inoculated tomato, showing conidia.

Spotted tomatoes were left on the vines for weeks after ripening, but no further growth of the spot took place. The first indication of decay was the usual watery softening of the tissue, leaving the spot as dry as previously. As before stated, the rot appeared with the first fruits. It continued for about eight weeks, and then disappeared entirely. It was then about the middle of May, and the plants were on the decline. Galloway states that, "however long continued, the rot always begins on the first fruit." This is the only previous observation made as to duration.

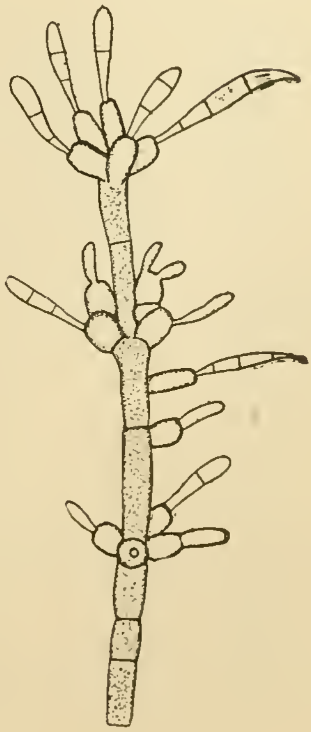

FIG. 5. Filaments from a conidial tuft from surface of inoculated tomato.

The smallest infected fruit found by the writer measures three-fourths of an inch in diameter, and inoculation experiments with fruit under this size have been unsuccessful. These results agree in a general way with those of Galloway and Whitehead. In the former case the fruit was one-third to one-half grown, in the latter the size of a horse-chestnut. Ten inoculations of Whitehead were not successful where the fruit was less than one centimeter in diameter.

CULTURAL RELATIONS OF THE FUSARIUM.

Following as far as practical the method of Prof. R. E. Smith[6] in his work on Botrytis, cultures of the Fusarium were made on media of such vegetable substances as it was likely to meet with during its growth on the fruit. The mineral stock solution used was as follows :

Potassium nitrate,	5.0 grams
Magnesium sulphate,	2.5 grams
Potassium phosphate,	2.5 grams
Calcium chloride,	1.0 gram
Water,	1000 c.c.

More nitrogen was supplied in the form of peptone. Each of the following substances was added separately to 200 c.c. of the stock solution in the proportion indicated :

Malic acid, .5%, 3%, 10% ; oxalic acid, .5% ; tartaric acid, 2% ; tannic acid, 2% ; cellulose, small quantity ; corn starch, 2% ; glucose, 2% ; cane sugar, 2%. As usual, duplicate flasks were prepared in each case which were left uninoculated for comparison.

Malic acid. This was the first acid tried, and as some species of Fusarium are known to grow best on an acid medium, a variety of strengths were tested. The acid of the tomato has been stated to be approximately .5% malic. Contrary to expectation, there was no growth in the two stronger solutions, very slight and long deferred growth in the .5%.

Oxalic acid. Growth fairly good. Slow in starting.

Tartaric actd. No growth for a week or more, then very slight growth.

Tannic acid. A little slow in starting, but finally a vigorous growth. After the surface was covered, a darkening of the solution took place from the top downward, turning from a light yellow to a deep wine color.

Glucose. Growth vigorous from the start.

Cane sugar. (Commercial.) Growth similar to that in glucose.

Cellulose. (Pure cellulose filter paper was used in sufficient amount to soak up the liquid.) Growth vigorous at the start, though on the whole not quite as vigorous as on glucose and cane sugar.

Starch. (Commercial corn starch.) The best growth from the beginning. The undissolved starch in the bottom of the flask was observed to decrease materially, while the mycelium seemed to grow down into it in a compact mass. It is evident from this result that starch is easily available to the Fusarium as food, probably, it was thought, by a rapid conversion of the starch into glucose by the means of diastase excreted by the fungus.

To investigate this matter more fully, a concentrated solution of starch was made by taking a small amount of starch and allowing it to stand in water for a day. A mycelium extract was then prepared by grinding a considerable amount of the mycelium in a mortar with a small amount of clean sand. Water was then added, the whole poured off the sand and allowed to stand for a day or more. The liquid was then decanted and used. Five cubic centimeters of the extract was added to twenty cubic centimeters of the starch. In one flask the extract was boiled, and in another unboiled. After a number of days two cubic centimeters of a very dilute solution of iodine was added to each flask. In each case a deep blue color was obtained, if anything lighter in the unboiled flask. As it was evident from cultures that starch is readily utilized by the fungus, some of the starch solution was inoculated with the Fusarium. After a week's growth, the iodine test was again tried. In this case, there was no reaction, showing that all the starch had been converted and utilized by the fungus.

One of the reasons for the preceding cultural experiments was to ascertain, if possible, why the fruit became infected at an early stage only, while the rot failed in every case to increase after the tomatoes were more than about 1¼ inches in diameter.

The result of the starch experiment would seem .to throw some light on the subject. If *Fusarium solani* grows particularly well on starch, it would naturally develop while the starch is present in greatest abundance. However, this does not explain why the rot never appears on fruits nearly or fully grown, but which have not lost their chlorophyll. The malic acid experiment suggested a possible clew to this. If, as shown by the experiment, the acid, when present in quantities as great as 3%, checked the growth of the Fusarium it was thought that a determination of the relative acid in green fruits would be valuable. Fruits of three sizes were selected and tested, with results as below :

ACIDITY OF JUICE IN TERMS OF MALIC ACID.

Fruit Diameter.	Amount of Acid.*
¾ inch,	0.42%
1¼ inch,	0.51%
2½ inch,	0.63%

The minimum size at which the fruit becomes infected is three-fourths of an inch in diameter, while 2½ inches was the maximum in these fruits before changing color. The acid, then, increases in proportion as the fruit grows. We may certainly consider this as a significant fact in explaining the arrest of the fungus.

To ascertain the effect of any possible excretion of the mycelium upon green tomato tissue, microscopic sections of the tomato were treated with the mycelium extract. No immediate change took place in the tissues. After about six hours, however, the cells were killed, the protoplasm becoming slightly yellowed, shrunken and curled up at the edges, and later the walls became blackened.

The Fusarium was grown in Petri dishes on the following cooked vegetables: Potato, carrot, beet, parsnip; and corn in the form of meal. The growth was quite uniform in all, though perhaps a little more vigorous on potato than on carrot and corn, while that on beet and parsnip was slightly retarded. In all cases the tissues were blackened after becoming permeated by the fungus. The fungus is doubtless the *Fusarium solani, Mart.* of Galloway.

OBSERVATIONS ON OUTDOOR TOMATO CROPS.

During the summers of 1902 and 1903 some work was done by the writer on outdoor tomato crops. Here there was no difficulty in finding all of the fungi recorded by writers previously quoted. In many cases the spot was entirely covered almost from the first with a dense growth of *Macrosporium solani*, but almost as often the

* These results were furnished by the department of Foods and Feeding of the Experiment Station.

black growth of Macrosporium was confined to a portion of the spot, the remainder being covered with a lighter green growth, which proved to be Cladosporium. Chains of apical spores characteristic of Alternaria were also found. In all three cases the mycelium grew in a felty mass near the surface, agreeing in every respect with that described by Galloway and others previously quoted. The average size of the outdoor spot was perhaps larger than that in the greenhouse. Cultures were made of these fungi and from them green fruit was inoculated, both on the vine and under a bell-jar, but all inoculations failed to infect.

BACTERIAL ROT.

In the late spring of 1904, another crop of greenhouse tomatoes was set out for the same work. The spot was present in abundance from the first and lasted through August, viz., until the plants were on the decline, as before. Out of more than a hundred diseased tomatoes which were cut up and placed in a moist chamber, only ten showed signs of Fusarium growth, and none of these were covered with the vigorous felty mycelium which always developed in 1902. In only one case was a pure growth obtained, the Fusarium being slow to appear and accompanied by various molds, as well as bacteria. Again a pure culture of the Fusarium was obtained and twelve inoculations made, all of which produced characteristic spots. The constant and early appearance of the bacteria led to a trial of these for inoculation.

CULTURAL CHARACTERISTICS.

The various Petri dish cultures taken from the rotting tomatoes were inoculated by piercing the tissue just beneath the skin with a flamed needle, after cutting through the spot with a sterilized knife. Out of two hundred or more cultures made during the season one characteristic organism was isolated. The deep and surface colonies showed different forms as described below:

Description of the colonies in agar plate cultures:

Deep colonies—Round—fusiform, often elliptical, entire, porcelaneous changing to butyrous, refraction strong, homogeneous, coarsely granular, size .17—.05 millimeters after twenty-four hours.

Surface colonies—Round, convex, refraction weak, grumose, entire, butyrous, with nucleus.

The growth of the organism in various media is as follows:

Agar-Agar—Comparatively slight growth, white.

Gelatin—Liquification, crateriform changing to stratiform in three days.

Litmus gelatin—A band of yellow through the center of medium after four days; after nine days, white with bluish ring at top.

Litmus lactose agar—Heavy cream colored growth; medium blue after three days.

Milk—No coagulation.

Litmus milk—A slightly alkaline reaction.

Potato—In three days a thick, firm, tawny growth; slight growth after.

Slices of green tomato—Dense growth of a tawny color, darkening with age.

From pure cultures of the above organism, sixty-seven inoculations were made during August, and many which were unrecorded before that time. Out of the sixty-seven, fifty inoculations produced a well developed and characteristic spot within a few days. (See Fig. 6.) Of those made in July a larger percentage was successful, and there was also more rot by natural infection. From the spots artificially produced, the organism was isolated repeatedly.

The position and general appearance of the spot during this season were identical with that of 1902. The boundaries were clear cut, and the surface, until late in the season, free from fungi. In several cases, however, late in August, the fungi occurred as on the outdoor crop, and again unsuccessful attempts were made to inoculate with these. There were slight differences to be noticed in the color, consistency and markings of the rot in the two crops under consideration. In 1904, the average spot was darker, there were practically no concentric rings or veins visible on the surface, and the tissue was often tender rather than leathery.

The successful inoculations with two organisms led to the idea of trying others not taken from the spot. As work on soil bacteria was going on in the laboratory at this time, three of these cultures were used for inoculation. Six inoculations were made from each culture. The inoculations made with two of these were unsuccessful, but those in which the third was used produced a rot which was not to be distinguished from that by natural infection. After this, several clean punctures were made in tomatoes on the vine by means of a flamed needle. No rot set in for a week or more, after which a very characteristic spot developed in two of the tomatoes which were close to the ground. It cannot be definitely inferred in either of these experiments that the rot was caused by an organism other than the one studied, as no attempt was made to isolate an organism either in the case of the soil bacteria or the clean punctures.

FIG. 6. Photograph of three tomatoes: One diseased by natural infection, one by inoculation with bacteria and one uninfected.

DISCUSSION OF RESULTS.

From the investigations recorded, we draw the following conclusions:

First, That *Fusarium solani*, *Mart.*, is the initial and in all probability the only active parasitic fungus connected with the fruit rot of tomato. The reasons for this may be summed up as follows:

1. Both Galloway[1] and Whitehead[2] determined a Fusarium in connection with the disease. In both cases it is described as pene-

trating the healthy inner tissues, while the accompanying fungus remained more or less on the surface.

2. Galloway's record of the inoculation of green tomatoes with Macrosporium is considered doubtful by Jones and Grout[3], who state conclusively that this fungus, called by them Alternaria, will not grow on green tomatoes.

3. Whitehead[2] states that Cladosporium is "evidently" the cause of the disease, without apparently having attempted a proof by inoculation experiments.

4. Having found a Macrosporium, a Cladosporium and an Alternaria in connection with the rot of tomato, the writer has thoroughly tested all by inoculation experiments, but was unable to induce any of these fungi to grow on green tomatoes.

5. The writer, in a crop of tomatoes free from surface fungi, has found Fusarium in the rotted tissue, which, when used for inoculating green fruit, in every case produced a more or less natural spot. No previous record of inoculation experiments with Fusarium has come to the notice of the writer.

6. Starch is the best medium for the growth of Fusarium found by the writer, it occurring in great abundance in green tomatoes.

Second, That the tissue of green tomato is a medium easily utilized by fungi as food. That a number of fungi are instrumental in producing rots which are often hardly to be distinguished from each other. This conclusion has been reached from a study of the following facts:

1. Both Earle[4] and Stuart[5] report tomato rots which they find to be caused by bacteria. In the former case surface Macrosporium is reported, but in the latter no fungus of any kind was detected. The descriptions of the two rots are very similar, though one is apparently more "watery" than the other. In both cases the organism is partially described, but the work is insufficient for comparison.

2. The writer has studied a bacterial rot of tomato in which the organism has been isolated and infection induced by repeated inoculation experiments.

3. Inoculations were made with three bacterial organisms taken at random by the writer, from one set of which a rot developed which

was not to be distinguished from the characteristic "Blossom End Rot."

Third, That the organisms causing the tomato rot are present in the air and come into contact with the inner tissues of the tomato, probably through cracks in the epidermis which occur about the pistil. This seems to be the prevailing opinion in regard to the infection of the fruit. Galloway advises a restriction of barnyard manure as fertilizer, as he considers that it tends to increase the cracking. Certainly the epidermis has become more tender with the cultivation of the plant, and that certain varieties show this characteristic more than others has been observed by the writer.

A number of infection experiments have been tried by spraying the fruit with the bacterial organism grown in bouillon. Two or three spots occurred which may have been caused by this treatment, but the numbers were not sufficient to give conclusive results.

Fourth, That the quality of the fruit may affect the size, appearance and position of the spot. This is demonstrated very nicely in a greenhouse crop now under observation. On normal fruit the rot is of slight depth, with collapsed tissue and clear boundary, as found in 1902. However, the fruit in this crop is very largely lobed and corrugated, and the rot in these cases extends almost to the calyx before the surface begins to collapse, or even to change color. On cutting open the tomato it is found that the carpels are imperfectly united at the pistil. In some cases quite a considerable opening has been detected, through which the organism has reached the watery and air exposed pulp. The pulp is often entirely dried and blackened before the pericarp begins to be affected.

This may account for some differences in the records of previous writers. The "seared" spot of Earle[4] has been described by him as occurring only on nearly matured fruits, to the ripening of which he ascribes the arrest of the rot. (The spot referred to extends through the epidermis only, turning it a light brown color.) We have had many cases of the kind, which occurred quite as often on the small as on the large fruit, but always on smooth, normal specimens with no crack visible to the naked eye. Cases of entire rotting have been found by us only on irregular fruit, as was also often found by Earle and Galloway.

In several cases during this season a small spot has appeared on very abnormal tomatoes at some distance from the style. This position has been mentioned in previous literature, but had not before been observed by us. In these cases the rot was found to have started from the pistil and in the pulp of one or more carpels, whence it had spread to the pericarp at the point where the spot appeared. Similar spots in this position were found to have been caused by bruising of the fruit.

SUMMARY OF RESULTS.

1. *Fusarium solani, Mart.*, may occur in connection with tomato rot, unaccompanied by any other fungus.

2. A tomato rot with the same characteristics may be produced artificially by inoculation with the Fusarium.

3. The same may be produced by placing Fusarium about the style. (This occurred in only one case.)

4. Fusarium grows readily on most of the substances found in green tomatoes, but less readily on sugar than starch, and not at all in malic acid above 3%.

5. Starch is converted by the fungus in direct absorption rather than by excreted diastase.

6. *Fusarium solani* will grow readily on all of our root vegetables, but most vigorously on potato.

7. Mycelium extract from Fusarium has the power of killing protoplasm and blackening the cells of green tomatoes.

8. Tomato rot may occur free from fungous growth, but containing a characteristic bacterial organism.

9. The same may be reproduced both by inoculation and by spraying with the organism in bouillon culture. (The latter was successful in two cases only.)

10. The organism isolated is an ærobic, spore-producing, monotrichic, oval form, producing a yellowish color on most media.

In the first part of the work here recorded much assistance was received from Prof. R. E. Smith, now of the University of California. The work on bacterial rot was done under the direction of Prof. G. E. Stone, by whom many of the experiments have been duplicated.

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