

THE OBLIQUE-BANDED LEAFROLLER

Archips rosaceana Harris¹

By E. DWIGHT SANDERSON and ALMA DRAYER JACKSON

In July, 1909, our attention was called to a case of very serious injury caused by the Oblique-banded Leafroller in a large rose house at Madbury, N. H. This is one of the largest rose conservatories in the country, the two houses having a total length of nearly one-half a mile and covering three acres. The roses on one or two benches had been entirely defoliated for over 200 feet as shown in Plate 15. Brief reference to entomological literature gave practically no information of value concerning the pest, so that an investigation was commenced at once. Mrs. Jackson kindly took entire charge of the rearing work and is responsible for the account of it, while the senior author is responsible for the rest of the present article.

History

This insect is an interesting example of one of our best known and much be-written species about which there seems to be but little information. Among the sixty-eight references given in the bibliography, less than a dozen give any very original information of any importance. The great bulk of the literature is mere compilation and quotation from Harris, the original describer. Coquillett seems to have made the most observations upon the species, but not until 1903 were the eggs briefly mentioned by Hart, and no one seems to have observed the stage which passes the winter. The insect has been a common one thruout the United States and, as the bibliography shows, has been noted for over half a century wherever entomologists have been located.

Injury

Serious injury by it has, however, been only occasionally reported. In 1894 Fletcher reported injury to the foliage and young fruit of pears in Ontario. In 1895 Piper noted considerable injury to prunes in Washington. In 1896 Lintner recorded serious injury to apple foliage and by the larvæ gnawing into young apples in eastern and central New York. The same year Lugger reported that Russian apples are sometimes defoliated by the caterpillars in Minnesota. No very serious injury to roses was noted until Chittenden in 1903 mentioned a case in which roses received from Ohio at Libonia, Pa., in

¹Moths were determined for us by the courtesy of Prof. C. H. Fernald.

May, 1898, were badly infested, though Smith (1896), Davis (1897), and many others had mentioned the rose as one of the common food plants.

In the case under our observation the pest was received on some Killarney plants imported from an Ohio firm something over a year ago. The larvæ evidently increased during the summer of 1908 and by midsummer of 1909 were sufficiently abundant to cause very serious devastation, the loss from defoliation and incidental checking of blooms undoubtedly amounting to over five thousand dollars. Fortunately the infestation started in one corner of the house and though when first observed by us both houses were well infested thruout, defoliation was confined to a relatively small area and the slowness of the spread was rather remarkable. When first observed most of the terminals had been folded up by the larvæ. Subsequent observations show that where the larvæ are not numerous that they are much more common on the lower leaves than on the terminals, this doubtless being due to the fact that the eggs are always laid on the older leaves and never on the terminals. Where plants are badly infested the larvæ tie the terminal leaves together in a typical tortricid fashion, thus checking all growth of the plant, and burrow into the flower buds, so that there is no possibility of securing blooms (Plate 16).

The owner of these houses states that some twenty years ago he was troubled with the same insect in rose houses in Massachusetts, but not so seriously and it was gradually brought under control by handpicking. Upon visiting the Waban Rose Conservatories at Natick, Mass., Mr. Alex. Montgomery, the manager, informed the writer that some twenty years ago when hybrid roses were first introduced that they had had considerable trouble with the insect both in the house and on Jacqueminot roses growing out of doors, but that in recent years, though a few were always to be found in old houses, they had found no difficulty in controlling them by handpicking. Mr. Montgomery had just returned from an extensive trip among rose growers thruout the East, but had heard of no noteworthy damage by the insect in recent years, nor do the florists' trade journals give any account of injury, except that Sirrine (1900) mentions it as a carnation pest, where carnations are with or follow roses, implying that it a common rose pest. It is evident, therefore, that serious injury to roses is sporadic as on the apple, and other common food plants.

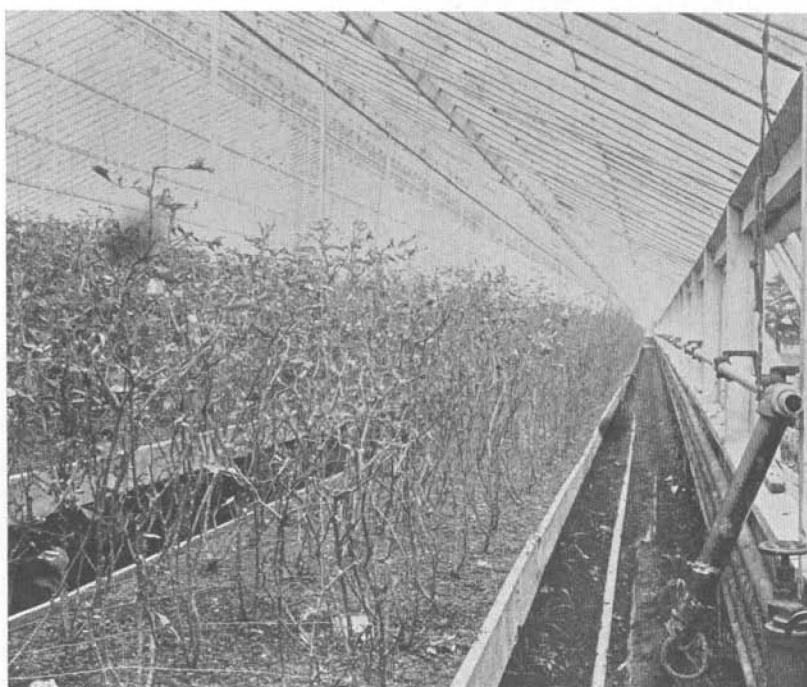


PLATE 15.—Injury in rose house by the Oblique-banded Leaf-roller. The upper view shows the complete defoliation of the plants on the benches seen in the lower view. Photos by W. S. Abbott.

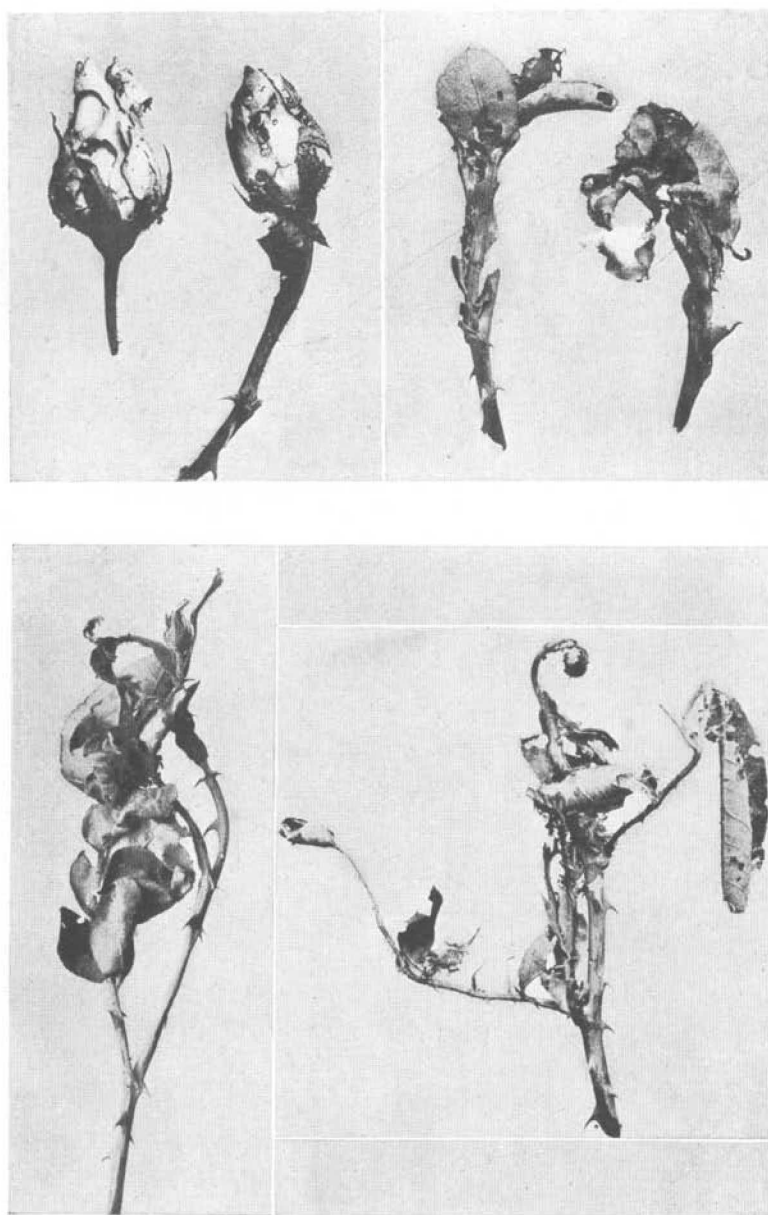


PLATE 16.—Showing injury to terminals and buds of rose by the Oblique-banded Leaf-roller. Photos by W. S. Abbott.

Food Plants

The list of food plants on record comprises over fifty species, as follows:

Gnaws rinds of apples (Walsh & Riley); currant (Perkins); oak (Hart); cotton (Glover, Mally); rose, apple blossoms and leaves, peach, cherry, yellow birch, plum, clover, honeysuckle, beans, strawberry, *Acer negundo*, *Crataegus*, *Cornus stolonifera* (C. H. Fernald); *Betula populifolia* (Packard); ash (Forbes); celery (Davis); pear,—leaves and fruit, gooseberry, black currant, garden geranium, silver maple seeds (Fletcher); plums and prunes (Piper); apple—foliage and young fruit (Lintner); Russian apples defoliated (Lugger); roses (Smith, Davis); blackberry (Chittenden); carnations (Sirrime); basswood (Gibson); bred from apple, cherry, Siberian crab-apple, lilac, horsechestnut, raspberry, wild strawberry, wild rose (*Rosa blanda*), burdock (*Lappa officinalis*), thistle (*Cirsium lanceolatum*), red clover, ragweed, smartweed, knot grass (*P. aviculare*), and found on burr-oak, poplar, hazel, sumac, wild raspberry, wild blackberry, horse radish, wild sunflower (*Helianthus grosseserratus*) and blue vervain (*Verbena hastata*)—Coquillett; elm, beech (C. H. Fernald, mss.).

Distribution

C. H. Fernald gives the distribution as from Maine to California. Dyar gives Northern United States and Colorado. It undoubtedly occurs thruout the United States as the following records indicate. Maine (Harvey, Packard); Massachusetts (Harris); Ontario (Fletcher et al); New York (Lintner); Pennsylvania, Florida, Texas (Robinson); Kansas (Snow); Nebraska (Bruner); Michigan (Cook); Illinois (Coquillett); Minnesota (Lugger); Washington (Piper); Texas (Mally).

Life History

The larvæ appear in spring and attack the young foliage of the apple as soon as it opens, and later the blossoms and young fruit, as originally described by Harris and by numerous subsequent writers. In the northern states the larvæ mature during June. Coquillett is the only writer who has recorded the length of the pupal stage and gives five to sixteen, average nine days, in Illinois. The moths emerge from May 30 in Delaware, as observed by us, until early July in New England. Dates of emergence of moths as recorded are as follows:—Massachusetts, end of June (Harris); Maine, last of July (Harvey); Vermont, early July (Perkins); New York, July 1 (Fitch), at light June 13 (Lintner); Michigan, mid-June (Cook);

Illinois, late June, early July (Hart, Coquillett). Chittenden secured pupæ and moths from Libonia, Pa., May 3, 1898, but these were from greenhouse roses.

The eggs have been mentioned only by Hart, who states that the eggs overlap in flat masses. Emmons stated that on plum the eggs were laid in patches on the bark in June and July and remain there until the next spring, but as he expresses a doubt as to whether the species was really *rosaceana*, there seems no good reason to give credence to this observation, which probably refers to *A. cerasivorana* which has such habits.¹ A second brood undoubtedly occurs throughout the range of the species. Cook mentions a second brood of larvæ in autumn, observing a larva as late as October 5, and Harvey and Hart mention a second brood of larvæ in August. Coquillett reared moths of a second brood in late July and until mid-August in Illinois, Packard reared a moth September 1 in Maine and Harvey states they occur the last of July. Moffat found moths abundant at London, Ont., in late July and early August, and Snow in Kansas on August 9.

A second brood of moths thus give rise to larvæ which work in the fall. Coquillett hazarded the guess that the eggs passed the winter, but this is the only statement as to the hibernation except that Harvey was candid enough to state that nothing was known of the eggs or hibernation of the species. From the fact that the larvæ occur in fall and early spring and that many species of this family pass the winter as larvæ it seems probable, though we have no definite observations on the point, that the larvæ hibernate over winter probably within folded leaves well encased in their own silk, either attached to the tree or on the ground, altho they may hibernate under or attached to the bark. It seems probable that even in a warm greenhouse the majority of larvæ do not transform in the winter, as Mr. Montgomery of Natick, Mass., states that they have never been troubled with them in winter, but that as soon as the spring sunshine warms up the houses they commence to work. We are now making observations on this point. It will be interesting to determine, as we expect to do, whether more than two generations occur in greenhouses, but our present data does not so indicate.

Observations on the Life History

The following observations on the life history were made during August and early September, 1909. The eggs are laid in round or

¹Weed. Bulletin 81, N. H. Agr. Exp. Sta., p. 17.

oval, flat, green patches, each containing an average of about 117 eggs, as shown below.

Number of eggs:	10-20.	25-50.	75-100.	100-150.	150-200.	275.	300.	360.
Number of masses:	7.	6.	5.	3.	4.	2.	3.	1.

The table shows plainly the great variance in the number of eggs in one mass, ranging as it does from a very few to over 300. A weighted average of the above gives 117 eggs as the average number laid at one time.

The total number of eggs produced by one pair of moths is an interesting as well as an important feature. For this purpose, single pairs of moths which had just emerged, were isolated and placed in glass cylinders containing fresh rose twigs. As soon as the eggs were noted they were removed and counted. The results were as follows:

Number of eggs laid by individual females: 650, 488, 80, 375, 52, 83, 200, 575, 190, 45, 400, 575.

Averaging the above gives 305 eggs to be the average number laid by one female moth at room temperature having a mean of 70°F. The masses vary considerably in size, four millimeters being a good average width. The eggs are glued together by gelatinous material and often overlap. From our observations in the infested greenhouse and in the insectary they are generally deposited on the older leaves of the plant rather than on the fresh shoots. The egg mass is usually a shade lighter than the green leaf. Oviposition usually takes place at night, although cases have been observed on very cloudy days. Practically all the eggs of a mass hatch at once, leaving the empty shells of the mass whitish in appearance. In case of parasitism the individual eggs are blackened by the pupa of the parasite. The figure in Plate 17 above E is a parasitized egg mass, while the light masses are unparasitized.

The time of incubation varies considerably according to the temperature. A number of freshly deposited egg masses were put in vials and placed in an incubator kept at 80°F. The length of the egg, larval, and pupal stages were all determined with specimens kept in a glassfront incubator kept constantly at 80°F., which is practically the mean temperature of the rose house in summer. Observations were made every morning from which were obtained the following data:

Number days' incubation.....	5	6	7	8	9
Number of egg masses.....	10	12	11	9	4

From the above experiment 6.67 days is found to be the average

length of time required for the incubation of one egg mass at what is probably an average mean temperature for a rose house in late summer. Another lot of egg masses was left in the room where the temperature averaged 70°F. From these we obtained the following results:—

Number days' incubation.....	8	9	10	11	12
Number of egg masses.....	1	6	6	6	3

At this temperature a single egg mass requires 10.18 days incubation and so takes 3.51 days longer to hatch at 70° than at 80°F.

The larvæ when first hatched are extremely minute and closely resemble the leaf in color. They crawl about for three or four days, feeding here and there and growing rapidly. At the end of this period the young larva begins to form a protection for itself by pulling two or three leaves together, or more frequently a young larva will fold over a single leaf forming a tube open at either end. The leaves are held together by silken threads. The larva feeds upon the inside of the tube or makes short excursions to adjacent leaves which are pulled down and attached to the original tube, so that as the larva increases in size it also increases the size of the nest. It was frequently observed that when all the leaves of a particular part of a plant had been destroyed the larvæ would go to another part of the plant and start new nests. This, however, seems to be dependent on food supply. The length of the larval stage may be seen from the following:—

Larval period in days...	22-25.	26-29.	30.	31-35.	36-40.	41-46.
Number of larvæ.....	11.	16.	13.	28.	14.	9.

The average length of the larval stage is thus 32.69 days at 80°F. There is no doubt but that food conditions may very materially influence the length of the larval stage which is probably somewhat shorter than the above figures indicate. Before pupation the larva draws the leaves together more firmly than usual so that they practically form a cocoon, to the silk of which the pupa is attached by the hooks of the cremaster. The average length of the pupal stage may be seen from the following:—

Pupal period in days.....	5	6	7	8
Number of pupæ.....	13	23	23	9

This gives 6.41 days as the average of the pupal stage at 80°F. Out of 62 pupæ, 35 were males and 27 females. About 30% of the pupæ failed to transform.

The adults emerge during the night and if not disturbed will remain in the vicinity of the pupal cases throughout the following day. Usually the males may be distinguished from the females not only by their smaller size but also by two round black spots on the thorax (Plate 17, B). Mating occurs shortly after emergence. The length of time between emergence and egg deposition may be seen from the following:—

Days from emergence to oviposition....	1	2	3	4	5	6
Number of females.....	1	2	2	4	1	1

Thus on an average a female oviposits at the end of 3.45 days at the room temperature of 70°F. Egg deposition may not, however, all occur at once, as one moth may deposit several egg masses at different times. The average life of an individual as seen from the following is 14.6 days at 70°F:

Length of life in days.....	11	12	13	14	15	17	20
Number of moths.....	2	6	2	2	2	2	4

Summarizing the life history it is found that at a constant temperature of 80°F. the egg stage is 6.67 days, larva 32.69 days, pupa 6.41 days, and life of moth to oviposition 3 days, giving a total of 48.77 days or seven weeks. The difference in rate of development of the eggs at 70°F. would indicate that the total life cycle at 70° would require over ten weeks. This is about the temperature of a rose house in this latitude in September. After October first the houses have a mean of about 62°, running from 56° at night to 70 to 75° in the day. With this temperature the life cycle would probably require three to four months.

Description

Egg mass. (Plate 17, E.) Round or oval, flat, green patches, generally lighter green than the leaf; laid very close together, frequently overlapping; held together by glutinous material; average number in mass, 117; varying in size from a small dot to one-fourth by one-half inch.

Larva. (Plate 17, F). Generally light green in color, varying in some specimens to a reddish or brownish green; a darker green stripe generally evident along the dorso-mesal line; head round, very dark brown or black mottled with brown; mouthparts lighter brown; anterior portion of clypeus light brown; anteclypeus greenish white; labium green with the exception of the distal portion and a black triangular spot near the base; labial palpi green, first and basal segment black; antennæ of three segments; tip of antennæ dark brown,

base green; cervical shield brown or greenish brown, posterior border black, a very distinct dorsal suture lighter; two black tubercles on either side midway between ventral border of cervical shield and prothoracic legs, each provided with two long setæ; prothoracic spiracle posterior to the dorsal tubercle; thoracic legs black, first segment concolorous with body; prolegs and anal legs green; anal shield concolorous with body; spiracles circled with brown on each abdominal segment; third to sixth abdominal segments bearing prolegs; yellowish tubercles as follows,—abdominal segments one to eight bear sub-dorsal tubercles I and II, with single seta, I mesad of II, III just above spiracle and IV–V just below spiracle, VI, VII and VIII as usual; on segment nine II is nearer the meson than I and lies close to the caudal margin, and III just latero-caudad of II; anal segment bears three large sub-dorsal setæ on the caudal half, and a lateral seta on each side; meso- and meta-thorax with a sub-dorsal tubercle bearing two setæ (I), another further latero-cephalad (II), a tubercle with two setæ (III–V ?) in the usual position of the spiracle, and one just caudad of this bearing a single seta (IV); a tubercle in the same position as VI of the abdominal segments further ventrad and apparently homologous; VII and VIII as usual.

Pupa. (Plate 17, C). Light brown just after pupation, becoming much darker with age; lighter on ventral surface; a mid-dorsal dark line beginning with the thorax running the length of the body; the anterior and posterior margins of abdominal segments I to VII inclusive bear a row of short black spines or teeth on both anterior and posterior margins; yellowish setæ are scattered over the body; a decided blackish cremaster nearly twice as long as broad, about equal to the eighth abdominal segment in length, rounded at tip, bearing two strong hooked spines at the tip and one on either side near the tip.

Moth. (Plate 17, A. B.) See Robinson and Clemens (1860) in bibliography.

Natural Enemies

Parasites. It is evident that this species is most effectively held in check by its natural enemies or with so large a list of food plants, wide distribution, and the number of eggs laid, we should have frequent serious outbreaks. What little evidence we have points to the fact that it is held in check by parasites. Coquillett (1882) states that a species of *Glypha* emerges from the larva about the time it should pupate and spins a cocoon from which the parasite emerges 8 to 12 days later; and that in late August, fully one half of the larvæ

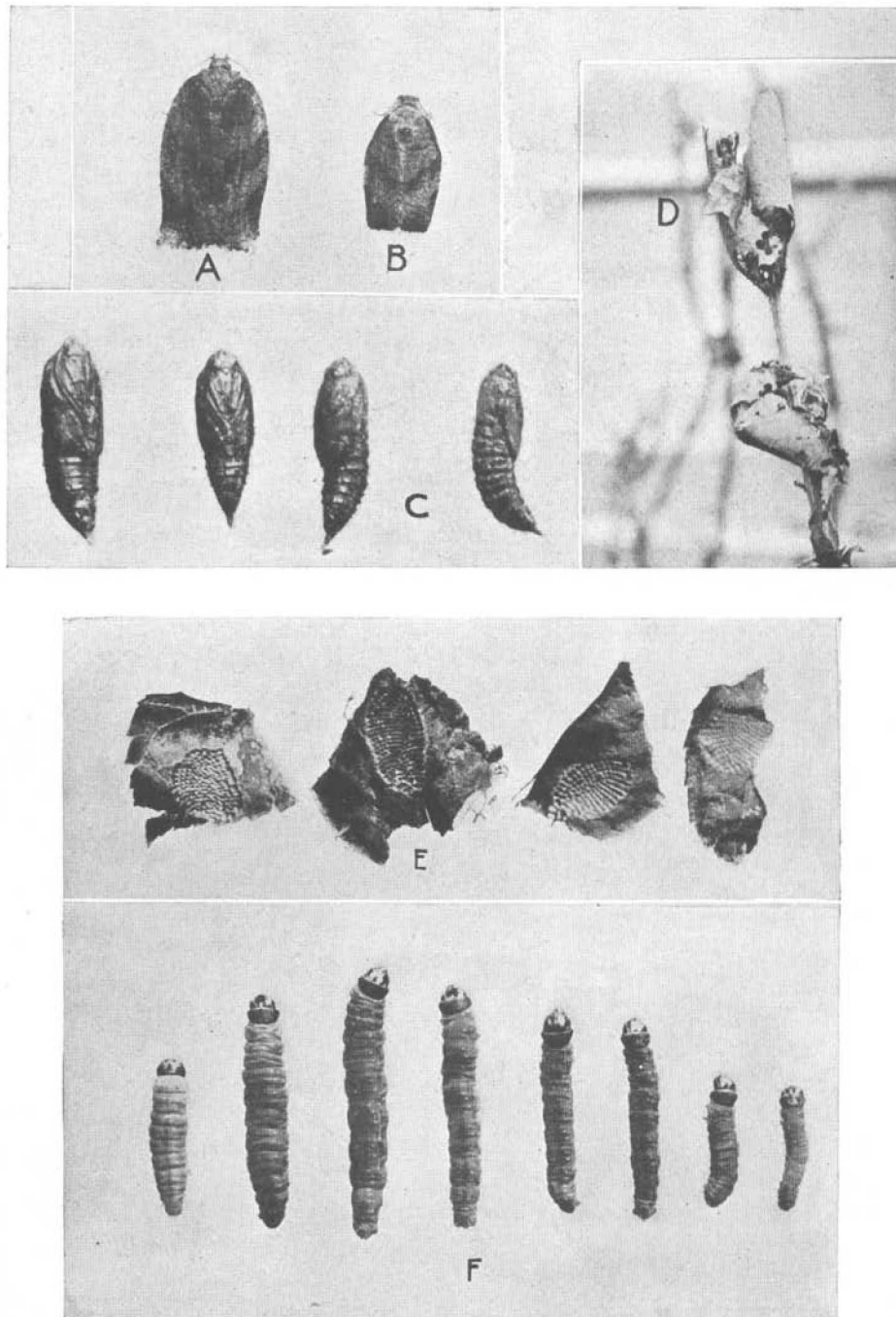


PLATE 17.—A, female moth; B, male moth; C, pupæ; D, moth at rest on foliage, natural size from life; E, egg masses, the one immediately above E full parasitized, the next partially and the one at right unparasitized; F, larvæ—all greatly enlarged. Photos by W. S. Abbott.

are thus parasitized. On some larvæ he observed *Tachina* fly eggs, and *Perilitus limidiatus* Cresson was reared from one pupa. Cook found that *Glypta simplicipes* Walsh was a very effective parasite of the larvæ and also reared *Microdus laticinctus* from one. Snow reared an unknown tachinid from a larva. Lugger mentions the Baltimore Oriole as a particularly effective enemy of the larvæ.

The outbreak observed by us furnished a case of the most complete parasitism we have ever seen. When first observed in late July from one third to one half of the eggs were parasitized by a species of *Trichogramma*. Two weeks later it was difficult to find an egg mass in which over 95% of the eggs did not contain the black pupæ of the parasite and in most cases 99 to 100% were affected. So effective were the parasites that the control of the outbreak was undoubtedly due to them much more than to any remedial measures.

Remedial Measures

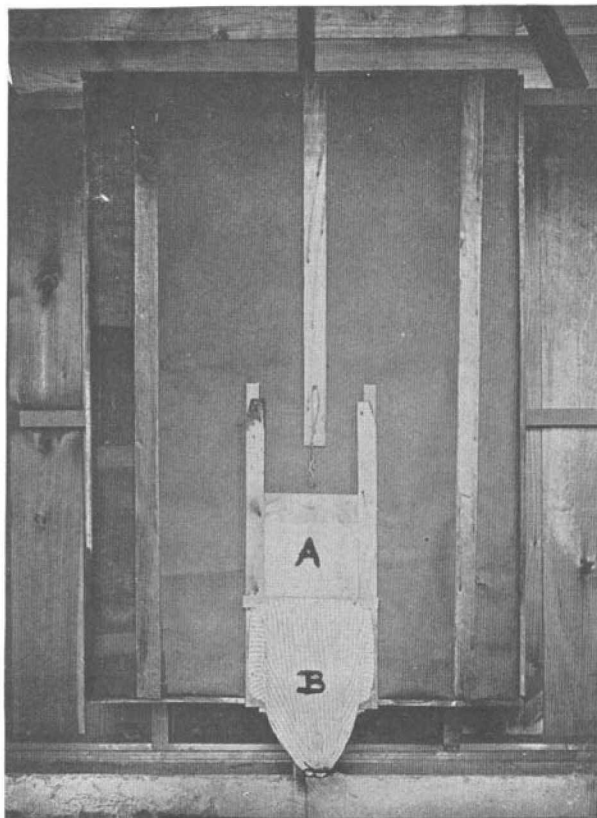
Spraying with arsenate of lead was at once advised by us in the greenhouse above mentioned. The owner hesitated to apply it, however, as it would spot the foliage so as to prevent the sale of any possible blooms, and requested that we experiment with fumigation.

Fumigation. Experiments were, therefore, made at once with hydrocyanic acid gas. For this purpose we had a large box constructed which fitted just inside a window-frame of the insectary workroom. (Plate 18.) This was fastened tightly to the frame, was covered with sheathing paper, all cracks stopped with putty, and the crack between the window sashes plugged with cotton. Thus the box was fully as tight as the average greenhouse. By raising the window from the outside, potted plants could be placed within to test the effect on them and the box could be quickly ventilated. On the inside, a tightly sliding door was fastened and over the opening to the box a canvas sleeve, which was tapered and constricted by an elastic band at the end. With this arrangement, the plants, insects, and acid could be placed in the box through the window on the outside, everything made tight, and the cyanide then poured in from the inside with no possible escape of gas. Furthermore, at any time by inserting one's arm in the sleeve, the sliding door could be raised, a tube containing insects removed, the door then shut, and the tube taken out and subsequently returned in the same way, with practically no loss of gas, thus enabling one to accurately observe the effect on the insects after different lengths of time by having several tubes of insects and taking them out at intervals. The first experiment was made with cyanide at the rate of one ounce to 1200 cubic feet, a rate

often used against aphides by allowing the gas to remain in the house over night, during which time it usually leaks out. In each case several tubes, each containing several specimens of all stages of the insect were used. Though one or two moths and occasionally a larva were killed after three hours exposure, many were alive the next morning, the gas having been generated about 6 p. m. The strength was then doubled to one ounce cyanide to 600 cubic feet, then doubled again, and finally doubled again to one ounce to 150 cubic feet without killing the majority of the larvæ or moths in an hour's exposure, but seriously injuring the plants at the latter strength. Mr. H. F. Hall, formerly horticulturist of this station, who has had extensive experience in greenhouse fumigation, tried similar experiments in a small greenhouse in Massachusetts with the same results. All further experiment with fumigation was therefore dropped.

Arsenate of Lead. Arsenate of lead was then applied to all the plants in the affected houses at the rate of three pounds to the barrel. Many of the worst infested plants were first cut back. This was applied in a novel, but exceedingly effective and practical manner. The tank in which manure water is mixed and the pipes leading from it to all parts of the houses, were flushed out. The arsenate of lead was then mixed up in the tank, hose was attached at each outlet in the houses and when all was ready a score of men commenced spraying, and in an hour and one half the three acres of plants had been thoroughly sprayed without the use of a pump. The application was repeated about a week later. Inasmuch as the eggs are laid on the old foliage and the young larvæ feed upon it, there can be no doubt of the efficacy of arsenate of lead, but its effect was obscured in this case by the almost total parasitism of the eggs. Nevertheless, it probably aided greatly in killing off larvæ and those which hatched from the few unparasitized eggs, for on November 17 larvæ could still be found in some numbers on individual plants here and there. It is questionable whether spraying with arsenate of lead would be desirable on roses except in cases of serious infestation, owing to the spotting of the foliage, but this might be avoided by dusting with dry arsenate of lead. Paris green, dry and sprayed, with and without lime, has been tried by growers in the past, but there is always danger from burning the foliage.

Handpicking. There seems to be no reason why the pest cannot be entirely controlled in rose houses by reasonable diligence in handpicking. This has been practiced for years in some houses where the insect occurs but has never become numerous enough to cause trouble. From our observations we feel that there can be no doubt that hand-



A, sliding door, and B, sleeve over opening to box.

PLATE 18.—Fumigation box seen from inside workroom.

picking so that the insect is never allowed to become abundant enough to warrant spraying or dusting, is by all means the most practical method of control in rose houses. With the removal of the plants and thorough fumigation of the empty houses the pest may thus be easily controlled.

Trap Lights. When the injury was worst, the moths were flying about the house by hundreds, could be picked up beneath every plant, and could be found beneath the benches in the shade in large numbers, often several within a few inches of each other. The owner having observed their attraction to lights, trap lanterns set in pans of water were placed thruout the houses and very large numbers of moths were caught. These lights have been continued during the fall and by the middle of November, fifteen to twenty moths per night were usually caught in the larger house. There can be no doubt of the efficacy of trap lights for this insect in a greenhouse.

For the control of the insect upon apples and other orchard trees, cane and small fruits, and its numerous other food plants, there would appear to be no reason why a thorough application of arsenate of lead to the young foliage and again in midsummer at the time of the emergence of the second brood, should not control it entirely. The determination of its hibernating habits and measures to destroy it in hibernation might also be of value.

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THE GEOGRAPHICAL DISTRIBUTION OF AMERICAN TICKS

By W. A. HOOKER, Washington, D. C.

In the fourth part of the last memoir of his revision of the ticks, published in 1901, Prof. L. G. Neumann considers their geographical distribution, the species being brought together under the various political divisions of the world in which they are known to occur. The North American species listed are largely based upon the Marx collection of the United States National Museum and the collection of the Bureau of Animal Industry of the United States Department of Agriculture.

Since this account was published there has been an increased activity in the collection of ticks in this country which has resulted in the discovery of many new forms and of a wider distribution of the species recorded than was then known. In Neumann's "Notes sur les Ixodidés," which have followed the "Memoirs," new records have been given which include data on American species. With the appearance of Banks' Revision of the ticks of this country, several new species were described and a number of names were relegated to synonyms through the recognition of Say's and Packard's species. In preparing his "Revision," Mr. Banks examined the collection of the Museum of Comparative Zoölogy, which contains Packard's types,