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THE DOCK FALSE-WORM: AN APPLE PEST.

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CONTENTS.

INTRODUCTION.

The dock false-worm is the larva of an allantine sawfly (*Ametastegia glabrata* Fallén) which may be called the dock sawfly. It has long been known, both in Europe and America, as an enemy of dock, sorrel, and knotweed, all common and sometimes troublesome plants which are to be found growing in moist places everywhere. Its acquired habit of boring into mature apples on the tree, to hibernate, thereby destroying their market value, brings it into prominence as an economic pest and has been noted by several observers in this country. Fletcher, in 1903 (30, 31)[1] and 1904 (33), reported finding the larva of a sawfly, which proved to be this species, boring into apples in Ontario in rather large numbers, and R. L. Webster (36) mentions the presence of these green worms in apples from New York, in 1908. Prof. A. L. Melander, of the Washington Experiment Station, in a letter to the Bureau of Entomology, under date of November 1, 1912, reports having known of the fruit-burrowing habit of this larva in British Columbia and since 1903 in Washington, particularly at Lynden, Whatcom County, where the injury amounted to about 10 per cent.

[1] Figures in parentheses refer to Bibliography, p. 38-39.

In the fall of 1914 the writer's attention was called to a number of apples which had been perforated in one or more places, the holes being round, about 2 millimeters in diameter, and similar in appearance to those caused by an apple stem or by the apple falling on alfalfa stubble. These holes, however, were evidently the work of an insect. On cutting open these apples, one or more bright-green worms were found in each, in the burrows extending from the entrance holes. These larvæ were not feeding but were lying dormant, as though intending to pass the winter here. They appeared to be the larvæ of a sawfly, and, on looking up the literature, it was found that the larvæ of the dock false-worm were known to bore into apples occasionally. Adults were secured the following spring and definitely determined by Mr. S. A. Rohwer as *Ametastegia glabrata* Fallén. A visit on September 30, 1914, to the orchard from which these apples came, which is situated along the Entiat River, a tributary of the Columbia River in north-central Washington, showed that the injury from these larvæ was of some importance, about 2 per cent of the early apples, Jonathans and King Davids, being injured. This amounted to considerably more than the injury caused by the codling moth, which is as yet uncommon in this valley. Dr. A. L. Quaintance, entomologist in charge of Deciduous Fruit Insect Investigations, suggested that a study of the insect be made, and accordingly a number of infested apples were kept over the winter. Early in the spring the orchard was again visited, and several hundred hibernating larvæ, which had burrowed into the alfalfa stubble on the ground, were collected. With this abundant material a study of the life history and habits of this insect was begun, and the results form the subject of this paper. The writer is indebted to Mr. S. A. Rohwer, of the Bureau of Entomology, for suggestions and information regarding this species, and to Mr. Frank E. Knapp, of Entiat, Wash., for permission to carry on observations and control experiments in his orchard.

HISTORY.

The dock false-worm has been known for more than a hundred years, the adult having been originally described in Sweden by Fallén (1), in 1808, as *Tenthredo glabrata*. It was subsequently described under several names and placed in several genera in Europe, as shown in the synonymy below. The larva appears to have been first recognized by Kaltenbach (6) in Germany in 1859. The adult insect was originally described in America in 1862, by Norton (8), as *Taxonus nigrisoma*, and this name has been generally used in this country, although the name *Strongylogaster abnormis* was also applied to the species by Provancher (22) in 1885. The larva was first noted here by Jack in 1893. In a recent paper by Rohwer (37), it is considered that the European and American species are identical, and therefore, according to the laws of priority, the specific name *glabrata* Fallén should be used, and the species belongs in the genus *Ametastegia*. The synonymy, as worked out by Rohwer, is given below:

AMETASTEGIA GLABRATA (Fallén).

Tenthredo glabrata Fallén, Svensk. Vet.-Akad. Handl., p. 108, 1808.
Tenthredo (Allantus) agilis Klug, Magaz. Ges. Naturf. Fr. Berlin, viii, p. 208, 1814.
Tenthredo (Allantus) rufipes Lepeletier, Monog. Tenthred., p. 81, 1823.
Ametastegia fulvipes A. Costa, Rendic. Acad. Sc. Napoli, xxi, p. 198, 1882.
Taxonus nigrisoma Norton, Proc. Boston Soc. Nat. Hist., ix, p. 119, 1862.
Strongylogaster abnormis Provancher, Addit. Faun. Can. Hym., p. 10, 1885.

DISTRIBUTION.

The dock false-worm is widely distributed in both Europe and America. In Europe it has been found as far north as Lapland, in northern Russia, and as far south as Italy. It is also recorded in the literature from Scotland, Sweden, Russia, northern Germany, southern Bavaria, Holland, and France.

In America the dock false-worm appears to be confined to Canada and the northern part of the United States. Provancher and Fletcher have observed it in Ontario, the latter having found the larvæ burrowing into apples. Norton's description of *Taxonus nigrisoma* is from specimens taken at Dorchester, Mass., and Jack found the larvæ at Jamaica Plain, both just south of Boston. From the other articles which have appeared concerning this species, and from the specimens in the National Museum collection, the following additional localities are taken: Stratford, Conn. (Walden), New York City and Flatbush, L. I. (Dyar), Seacliff, L. I. (Banks), Sherbrooke, Quebec, Harrisburg, Pa. (Myers), Menominee, Mich. (Chittenden and Titus), Ames, Iowa (Webster), and Minnesota (Ashmead collection). In the West the writer has found it very abundant in north-central Washington, at Wenatchee and Entiat, in Chelan County, and Prof. Melander reports it from Lynden, Whatcom County, Wash., from Kittitas County, Wash., and from British Columbia. It is very probable that the species has an almost continuous distribution in America from the Atlantic to the Pacific. It has never been recorded south of 40° north latitude, either in Europe or America, although some of its food plants are found farther south.

It is probable that the dock false-worm is distributed chiefly when in the prepupal or pupal stage in the dry stems of plants, for it is well protected here and during the winter season is to be found in these stems for a period of six months or more. The stems and stalks are very likely to be carried about in hay, packing materials, etc. In the egg and active larval stages the insect is greatly dependent on the fresh leaves of its food plant, and the adults, though active, are not strong flyers; thus it is not possible for the insect to travel far in these stages.

FOOD PLANTS.

The dock false-worm probably confines its feeding almost entirely to plants belonging to the buckwheat family (Polygonaceæ), including the numerous docks and sorrels (Rumex), the knotweeds and bindweeds, or wild buckwheat (Polygonum), and others. It has been recorded from *Polygonum bistorta* in Scotland, and from *Polygonum* sp., *Persicaria* sp., and *Rumex* sp. in Germany. In America it has been recorded from the common knotweed (*Polygonum lapathifolium* and *P. muhlenbergii*), and from a yellow dock (*Rumex patientia* or *brittanicus*). The writer has taken it on *P. lapathifolium*, on bindweed or wild buckwheat (*P. convolvulus*), on sheep sorrel (*Rumex acetosella*), on curly dock (*R. crispus*), bitter dock (*R. obtusifolius*), and willow dock (*R. salicifolius*). It was also found by Chittenden and Titus (34) feeding on the leaves of the sugar beet (Chenopodiacceæ), in a field where it had evidently consumed all of the dock and was forced by hunger to feed on this plant. The common cultivated buckwheat and rhubarb belong to the Polygonaceæ and may very well be food plants of this insect, though it has never been recorded from them and the writer has not had the opportunity of testing them.[1]

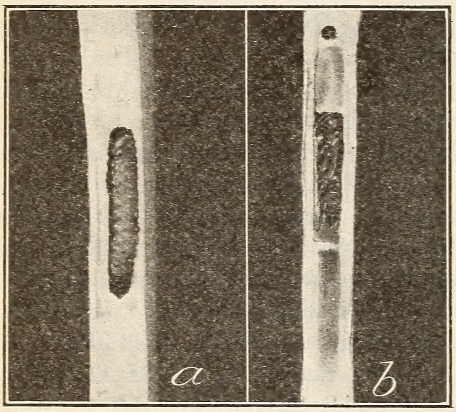
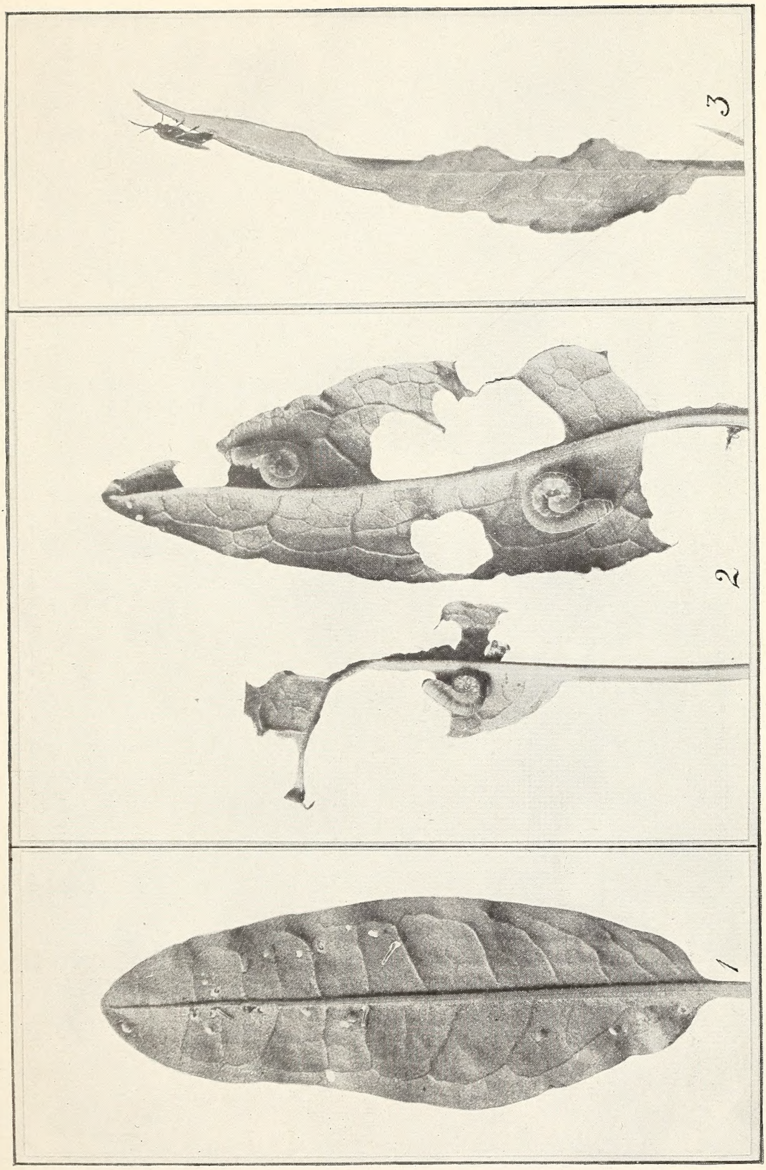


FIG. 1.—The dock false-worm (*Ametastegia glabrata*): *a*, Larva in hibernation cell in stalk of the dock plant; *b*, pupa of dock false-worm in larval hibernation cell. Enlarged. (Original.)

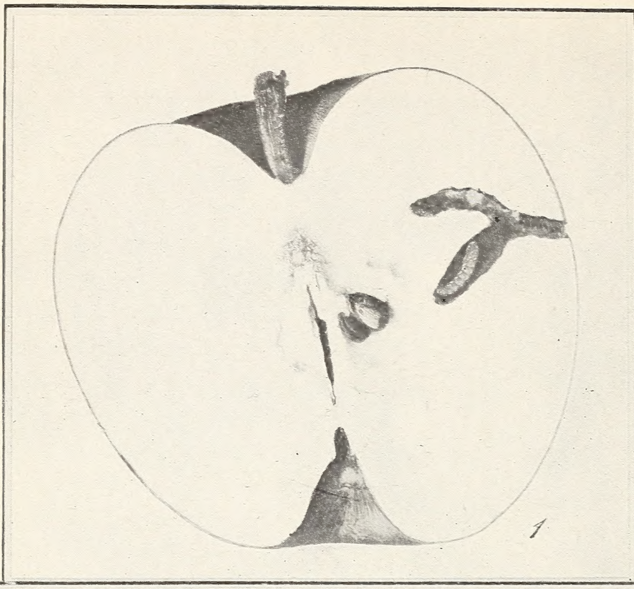
Several European writers have recorded a number of plants, not belonging to the buckwheat family, as food plants, but most of these are doubtful. Brischke (21) mentions loosestrife (*Lythrum salicaria*), and the common pansy (*Viola tricolor*). He was probably mistaken about the latter, in view of the fact that the larvæ of several related sawflies are known to feed on both the pansy and the violet. Kaltenbach (14) mentions goosefoot (*Chenopodium album*) and Laboulbène (16) mentions a reed (*Arundo phragmites*), but a careful reading of their papers shows that they merely found the prepupal larvæ in the stems of these plants, which does not necessarily indicate that they are food plants, as the full-grown larva will bore into any suitable stems, or even rotten wood or soft bark. Kleine (35) found

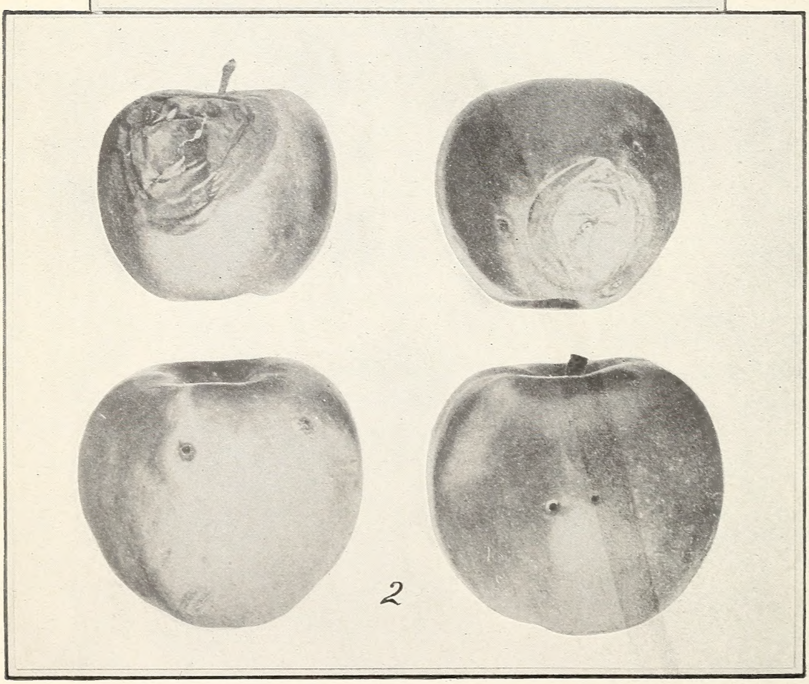
[1] In the summer of 1916, leaves of the common rhubarb and those of a wild species of Eriogonum were tested as food for the false-worm larvæ. A number of larvæ of different ages were provided with these leaves, and fresh food was supplied daily. The larvæ fed to some extent, but in a few days all had died, and it seems apparent that the leaves of these plants do not form a suitable food for this insect.



THE DOCK FALSE-WORM (AMETASTEGIA GLABRATA).

FIG. 1.—Leaf of dock plant (*Rumex crispus*), showing eggs of dock false-worm in situ. FIG. 2.—The dock false-worm and its injury to foliage of the dock plant; 6th instar larva on the left; on the right, 5th instar larva. FIG. 3.—Adult of dock false-worm on dock leaf. (Original.)





THE DOCK FALSE-WORM.

FIG. 1.—Larval hibernation burrow in mature apple. FIG. 2.—Injury to apples by dock false-worm, and rotting of fruit following injury. (Original.)

larvæ in the stalks of the orache (*Atriplex nitens*), and he states that the larvæ had undoubtedly fed on the pith, though he did not see them doing so, and did not find them feeding on the foliage. The writer has reared over a hundred and fifty larvæ, and has seen them bore into pithy stems, but in no case has he observed the last-stage larva feeding on the pith or on anything else. The borings are invariably pushed past the larva and fill up the burrow behind it. (Fig. 1, *a*.)

In the course of the work with the dock false-worm, larvæ and adult males and females were confined with plants of the common garden beet, with goosefoot (*Chenopodium album*), and with alfalfa, since many prepupal larvæ had been found in dry alfalfa stems. The adult females in every case died without ovipositing, and the larvæ died without feeding on any of the plants, although larvæ transferred from one known food plant to another, as from dock to wild buckwheat, readily adapted themselves to the change.

In feeding on any of these plants, the larvæ devour the leaf tissue and the smaller veins, eating out irregular holes in the leaves. (Pl. I, fig. 2). Ordinarily, the midribs and the larger veins are untouched. If forced to it, however, the larvæ will feed on these, or even on the stem, and sometimes also on the flowering parts.

The dock false-worm must not be confused with the true apple sawfly (*Hoplocampa testudinea* Cameron) of England, which has a whitish larva that lives and feeds in young apples, its feeding habits being similar to those of the related American species, the cherry fruit sawfly (*Hoplocampa cookei* Clarke).

CHARACTER OF INJURY TO APPLES.

The dock false-worm is known to injure apples only in the fall, when the fruit is approaching maturity; that is, in September and October. In orchards under observation the larvæ were present on their food plants throughout the growing season, but no evidence of injury was found that had occurred before the apples had practically stopped growing, with one exception. A single Jonathan was found on October 5, into which a larva had succeeded in burrowing some time before the apple had reached maturity. The apple had grown subsequently and had closed the entrance and squeezed the larva to death. The greater hardness of immature apples probably deters the larvæ from burrowing into them. There were no summer apples in the infested orchards, hence it is not known whether these are ever injured.

The injury to apples consists externally of the small round holes bored by the larvæ, which after a few days show a slightly sunken, brownish ring about them and occasionally may be surrounded by a larger discolored halo. (Pl. II, figs. 1 and 2.) These holes may occur anywhere on the surface, but are most numerous about the calyx and stem ends, or at a point where the apple touches a leaf or another apple, since it is easier for the larva to obtain a foothold here. Within, the injury is usually more serious, since the larva often burrows to the core and usually hollows out a pupal cell somewhat larger than itself. The burrows vary in length from those just started to holes an inch or two deep. It is quite evident that the larvæ are often not entirely satisfied with the apple as a place of hibernation and that they may begin more than one burrow. Apples frequently have three or four, or sometimes even eight, holes in them of varying depths, but contain only one or two worms, or often none at all. In making counts of apples in connection with control work a record was kept on this point, and it was found that in 207 damaged apples there were 364 holes, each apple having from one to eight holes, and that of the 364 burrows only 66, or a little over 18 per cent, had been completed and contained worms.

The burrow is more or less irregular in outline and may be curved or straight. At its end the larva hollows out the slightly larger pupal cell, turns with its head toward the entrance, and forms a plug across the end of the cell, leaving the outer part of the burrow open. This open burrow affords an easy entrance for mold spores, such as those of the blue mold (Penicillium), and the injured fruit frequently starts to rot shortly after being picked, especially if the weather is moist. The larva seems to be well protected against this mold, however, for the fruit tissue immediately surrounding the pupal cell does not rot very readily, but rather becomes dry and pithy. As long as the larva is not actually drowned in the fermenting juices of the rotting fruit it remains alive and healthy. In March, 1915, a number of healthy larvæ were taken from rotten and even mummied Jonathans which had been kept since the preceding September. These larvæ were placed on moist sand, and most of them subsequently pupated and produced adults.

ECONOMIC IMPORTANCE.

Since the dock false-worm does not feed upon any part of the apple tree, but must live upon certain succulent plants, mostly of the buckwheat family, it follows that it can become an apple pest only where these plants are growing in or around the orchard. There can be little or no danger from this insect in clean-cultivated orchards, or in orchards where the food plants do not exist. The possibility of the larvæ coming into the orchard from neighboring meadows, ditch banks, or roadsides is slight, for the larvæ are incapable of finding their way over any extent of bare, cultivated soil. The danger of the larvæ adapting themselves to the apple and feeding upon it is not to be considered. The apple foliage is so much tougher and dryer than the succulent foliage of the moisture-loving plants upon which they are accustomed to feed that the change of food plants would be practically impossible.

This insect becomes of economic importance, then, only in orchards in which its ordinary food plants are growing, and such orchards would naturally be those that, either through carelessness or because of sod or a cover crop, are not kept clean cultivated. Any orchard kept moist enough to support a cover crop is a favorable place for the food plants of the insect to grow, and since these food plants are widespread, the chances of some one of them, at least, getting into the orchard are very good.

From the description of the injury to apples given above it will be seen that individually this insect is fully as injurious to the fruit as the codling moth, for a single larva will often bore several holes in one apple, and sometimes in several apples, before forming its final burrow. This burrow, too, is often larger than that made by the codling-moth larva and is confined to the flesh of the apple. The tendency of these apples to rot seems to be greater than that of ordinary wormy apples. Collectively, these larvæ have never proved as destructive as many other insects, because they have not been as numerous. It is not inconceivable, however, that they might, under favorable conditions, become a more serious pest.

In the Entiat Valley, Washington, where this insect was chiefly studied, there was a large quantity of wild buckwheat or bindweed (*Polygonum convolvulus*) in the infested orchards, growing in the alfalfa cover crop, and this often was climbing up into the trees for some distance. It can thus be readily seen how the larvæ found their way into the trees and to the fruit. The Jonathan variety was the worst infested, since the tree is of a drooping habit, and the many heavily laden branches, extending down into the alfalfa, afforded the larvæ an easy opportunity to reach the fruit. In the fall of 1914 the extent of injury in one orchard was estimated at about 2 per cent. In 1915 actual counts were made from four representative trees in this orchard, and it was proved that more than 5 per cent of the picked fruit was rendered unmarketable by this worm. This would represent a loss in this particular case of about 16 cents per tree, since the value of the fruit from these trees, which were only 7 or 8 years old, was something over $3 per tree. This was in spite of the fact that the larvæ had been heavily parasitized the preceding spring. The loss may at times be considerably higher, and, in fact, as already noted, Prof. Melander has written of injuries running as high as 10 per cent.

DESCRIPTION.

THE EGG.

The egg of the dock false-worm is bean shaped or kidney shaped, and somewhat flattened, pearly white, and with a soft, pliable shell. It is protected by the tissues of the leaf in which it is deposited, (Pl. I, fig. 1.) The average length is 0.8 mm., and the width 0.6 mm. About a day before hatching a dark spot shows through, which is one of the eyes of the larva, the head being seen from the side. Shortly before the larva breaks through the shell the outline of the head is discernible.

THE LARVA.

The larva would not ordinarily be noticed on the plants until nearly full grown, and it appears at this time as a slender, hairless larva, with a finely wrinkled olive-green or blue-green skin and a scattering of conspicuous white tubercles. After passing the last molt, which brings it to the stage in which it bores into pithy stems or apples, the larva changes in appearance. (Fig. 2.) It is no longer velvety, but has rather a sleek, shiny appearance, though the wrinkles still persist. Its color is a brighter green—more of an apple green—and the larva seems almost translucent, since the alimentary canal is empty. The tubercles are no longer white and can not be distinguished. If an infested stem or apple be cut open, the larva within will be found to have much the same appearance as before it entered, except that it has become shrunken and curved and has lost the power of locomotion. A detailed description of the various larval stages follows:

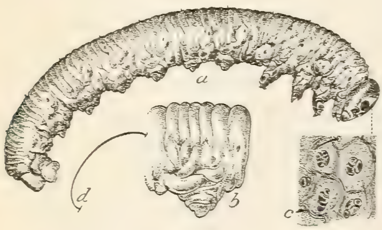


FIG. 2.—The dock false-worm: *a*, Full-grown larva, enlarged; *b*, seventh larval segment, much enlarged; *c*, portion of cranium, highly magnified; *d*, actual length. (Original.)

First instar.—Length, 2.25 mm. General color very light gray; food showing through green. Somewhat slug shaped, thoracic region slightly enlarged, body tapering gradually posteriorly, wrinkled. Head olive brown changing to dark brown, shining; eyes shining black. Just before molting the larva has a shiny, swollen appearance and is somewhat lighter in color.

Second instar.—Length, 4.5 to 5 mm. As before; body wrinkles showing plainly. Head very dark brown, nearly black.

Third instar.—Length, 6 to 8.5 mm. Dorsum greenish gray, merging gradually into the very light yellowish gray of the rest of the body. Body surface wrinkled, dull, numbers of small, sparsely-set setæ being noticeable laterally; surface minutely reticulated, these reticulations being slightly raised and gray dorsally. Head olive brown; mouth parts dark brown; eyes black; thoracic legs same as body, joints marked by dark-brown lines.

Fourth instar.—Length, 9.5 to 14 mm. Dorsum dull bluish green; remainder of body as before. Dorsal surface crossed by whitish lines formed by the wrinkles, and with a scattering of whitish setigerous tubercles. Head light brown, with a dark-brown band dorsally and another crossing the eyes and clypeus. Mouth parts tipped with dark brown.

Fifth instar.—Length, 14 to 17.5 mm.; width of thorax, 2 mm. Body of 13 segments, cylindrical, slightly enlarged in the thoracic region. Integument considerably wrinkled, and with a very finely shagreened surface, which gives the larva a velvety appearance. Dorsal region to the line of the spiracles distinct olive green or occasionally bluish green; ventral region very light yellowish, color changing abruptly at spiracular line.

The dorsal olive-green region appears to be crossed by more or less irregular whitish lines, due to the cuticular folds or wrinkles, and laterally this dark region is even darker, as the raised shagreening is black. The dorsal vessel shows through as a dark-green line. The prothoracic segment is provided with four whitish setigerous tubercles on each side, three of them being in the dark dorso-lateral region and one just above the leg. The other thoracic segments have seven tubercles on each side, having, besides those mentioned above, two near the dorsal line and one latero-ventrally, near the anterior margin of the segment. The abdominal segments, also, have seven tubercles, in slightly different positions, except the last segment, which has only one tubercle on each side of the dorsal line. The anal region is covered with small setæ.

Head narrower than thorax, minutely punctured, sparsely covered with setæ, light brown, a dorsal transverse band of dark brown, incised on the dorsum posteriorly by a triangle of light brown, at each side of which is a distinct, short, longitudinal suture. Dorsal part of clypeus, tips of mandibles, palpi, and antennæ brown. Eyes very dark brown. Abdominal legs, eight pairs, concolorous with venter; thoracic legs, three pairs, the same but somewhat more heavily chitinized, and with the joints marked by brown lines.

Sixth instar.—Length, 14.5 to 16 mm.; width of thorax, 2 mm. (length of parthenogenetic larvæ, 8 to 12 mm.). Similar to fifth-instar larva in shape and skin texture. Color of dorsal region apple green or pale green; ventral region light yellow. Dorsal vessel showing through whitish or yellowish. No dark contents of alimentary canal. The whitish tubercles have disappeared, but the setæ can still be made out in the same positions.

Head covered with small, irregularly rounded, slightly raised, smooth spots, interspersed with raised dots. The spots, when strongly magnified, seem to be made up of two or three cells, this appearance evidently being due to darker markings just beneath the surface. Color of ventral part very light brown, dorsal part, above eye, dark olive brown; clypeus olive brown; tips of mandibles, palpi, and antennæ reddish brown; eyes black.

Prepupal larva.—Length, 6 to 13 mm., average, 10 mm.; male larva smaller than female; cylindrical, somewhat curved dorso-ventrally, shrunken. Body surface wrinkled. Color unchanged.

THE PUPA.

Length, male, 7 to 8 mm.; female, 9 to 11 mm. Elongate, slim, the male smaller than the female and more slender. Sexes distinguished by appearance of tip of abdomen, the female saws being very distinct. Dorsal region apple green. Head, appendages, and ventral and lateral surfaces up to spiracular line, light translucent whitish or yellowish, sometimes with a greenish tinge. Eyes reddish brown.

After a few days the head and thorax become black-brown, and shortly before the adult emerges, the eyes, head, antennæ, thorax, and abdominal plates are jet black, the membrane between the plates being light greenish. The legs are light ferruginous, except the metatarsi, which are black, and the distal tips of the protarsi and mesotarsi, which are dark brown.

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THE ADULT.

The adult sawfly (fig. 3; Pl. I, fig. 3) is a slender, blue-black, wasp-like insect, with reddish legs. At first glance it may be mistaken for an ichneumon fly, but it will be distinguished readily by its thicker and heavier abdomen, its relatively shorter antennæ, and in the female by its lack of the usual long, conspicuous ovipositor of the ichneumon fly. The males and females are similar, the males averaging smaller. The description given for *Taxonus nigrisoma* by Norton (8) characterizes the adult very well, and is given herewith:

Blue black, the legs dark rufous; length 0.30, breadth of wings 0.60 inch. Color blue black; abdomen rather long, flattened, acute; antennæ slender, basal joint enlarged, third longer than fourth; apical joint as long as the preceding; clypeus angulate emarginate; labrum and base of mandibles pale rufous; legs rufous or honey yellow; base of coxæ and tarsi black; wings faintly clouded, stigma and costa black.

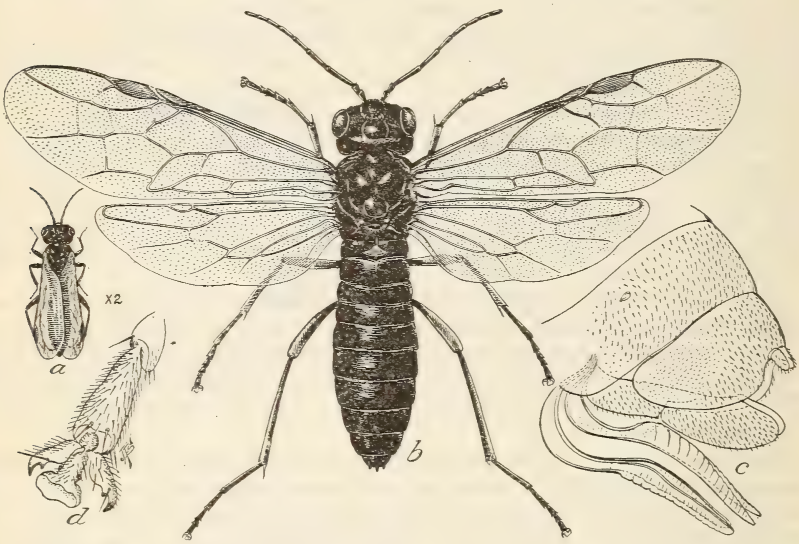

FIG. 3.—The dock false-worm: *a*, Adult fly, twice enlarged; *b*, adult female, much enlarged; *c*, anal segments of female showing ovipositor; *d*, tarsus of hind leg of female. (Original.)

LIFE HISTORY AND HABITS.

METHODS OF STUDY.

In studying the life history of the dock false-worm, rearings were made in an outdoor insectary with a roof but no sides. In order to rear the larvæ under conditions as nearly normal as possible, they were kept on living plants. Small plants of the common curly dock (*Rumex crispus*) and of the wild buckwheat (*Polygonum convolvulus*) were potted in tin cans. After being kept in a cool place for a few days, with plenty of water, these plants appeared normal and made regular growth throughout the season, some of them even producing flowering stalks. The dock plants were by far the most satisfactory, since they were more easily kept within bounds and their fewer and larger leaves made it easier to locate the larvæ. Oviposition records were obtained by confining freshly emerged adult flies, either pairs or single females, in inverted lantern chimneys placed over these plants and closed at the top by pieces of cheesecloth held in place by rubber bands. A few records, also, were obtained in larger cloth-covered rearing cages. The adults were transferred, usually every day or two, to fresh plants, in order to ascertain more exactly the incubation period of the eggs. These were examined every morning, and the larvæ, as they hatched, were transferred to other plants, or, if not required, were destroyed, because, if left on the same plant, they frequently ate into the unhatched eggs. Several larvæ were ordinarily placed on each plant, since the young ones sometimes fell off and were lost. There was a great regularity in the early molts, making them easy to keep track of, and as the larvæ grew larger they were moved to new plants, only one or two being kept on a plant. The larvæ showed little inclination to wander, and the plants were left uncovered on the shelves. As the larvæ neared the final stage, however, a lantern chimney was inverted over the plant, and several pithy stems, such as those of wild mustard, were placed in the chimney for them to burrow into. However, if the larvæ were discovered just after the last molt, they were transferred to cotton-stoppered glass vials with one of the stems, since they sometimes burrowed into the ground instead of into the stems. Pupation was observed by splitting open the stems a few days after the larvæ had entered. This did not affect them at all, except that during the hot, dry weather they showed a tendency to dry up and die, either before or after pupating. This was avoided by moistening the cotton plugs and by keeping the vials in an improvised moist chamber made of a large lard can. Experiments showed that this did not materially affect the pupal period; indeed, the presence of moisture is undoubtedly a normal condition, since the dead stems in which the larvæ naturally pupate must lie on or near the moist soil in which the food plant is growing. These careful laboratory studies were supplemented by observations in the field, covering chiefly the natural habits of the insect.

NUMBER OF GENERATIONS.

Four generations of the dock false-worm have been distinguished. The generations overlap and become somewhat confused, the reason being apparent when it is noted that the emergence from overwintering larvæ of the spring brood of adult flies in 1915 covered a period of seven weeks, namely, from April 13 to June 4, with a single emergence on June 16. In rearing this insect, it was planned to carry a genealogical series through the season. This attempt was only partially successful, since the hot, dry weather of the latter part of July cut off the adult emergence of the second generation to a great extent, and, while a number of males were secured, only a single female emerged. The offspring from this female were successfully carried through, however, to four complete generations, the larvæ of the fourth generation, of course, hibernating in their pupal cells and forming spring-brood pupæ and adults the following year. Additional records were obtained by collecting eggs in the field at the time the second-brood adults were emerging and rearing the larvæ from these eggs. It is reasonable to suppose that these eggs were deposited by second-brood adults, since they were collected after July 15, and no spring-brood adults had emerged from the overwintering material after June 16. In selecting adults for oviposition in the insectary, those emerging early and late were, if possible, disregarded, and only those emerging during the period of maximum emergence were used.

Since it was not possible to rear a sufficient quantity of the false-worms to get an adequate idea of the time when each generation occurred in maximum numbers, field observations were made from July 1 to September 8, once a week or oftener. This work was done near the field station at Wenatchee, Wash. As many worms as could be found in a couple of hours were observed, and the instar or stage in each case was recorded. From these figures the percentage of each instar for each date was worked out, thus indicating the broods. Since the infestation was not great enough near Wenatchee to afford a large number of worms for examination at each date, the number running from 20 to 100, the detailed figures are not given here. The diagram in figure 4, however, shows graphically the percentage of full-grown larvæ found on each date. As these figures do not cover the whole season, the lower line is added to the diagram to show the actual number, and not the percentage, of first and second brood larvæ passing the final molt each day, from among those reared at the laboratory. It will be seen that where these two lines overlap they correspond fairly well, and the two together show at a glance when the larvæ of each generation attain maturity. The curves are shown for the mature larvæ, since these are the only ones that ever injure fruit.

HABITS.

Since the habits of the individuals of all generations of the dock false-worm are the same, they will not be considered separately. As we have already indicated, the eggs are deposited in the leaf tissue of the food plants (Pl. I, fig. 1). The larvæ, in escaping, eat a small circular hole through the eggshell and the thin epidermis of the leaf, usually the lower, and crawl out. They begin to feed at once, finding a secure foothold on the rough lower surface of the leaf. At first they eat only through to the upper epidermis, leaving this intact as a thin membrane, but after passing the first molt they begin to eat clear through the leaf, forming irregular holes.

The larvæ molt five times, passing through six stages or instars. During the first and second instars, or until the second molt, the larvæ usually remain on the same leaf. After this they become more or less restless and find their way to other leaves, especially if the first leaf has been supporting several larvæ and is mostly eaten. The younger larvæ lie securely in the hollows they have eaten out of the leaf, clinging to the lower side of the upper epidermis, and they are not easily dislodged. The large larvæ simply lie at full length on the under surface, and if disturbed, curl up the posterior part of the body, holding to the leaf only by the thoracic legs. If the disturbance continues they loosen their hold and drop to the ground, later finding their way back to the leaves. This death feigning, if it may be so called, is a characteristic of this type

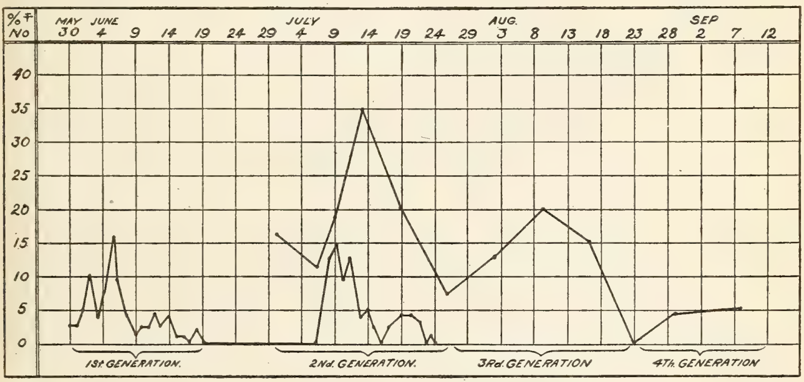

FIG. 4.—The dock false-worm: Diagram showing seasonal abundance of the generations. (Original.)

of sawfly larva, and where the larvæ are numerous a veritable shower of them will be produced by shaking the plants.

The larva ordinarily molts on the leaf where it has been feeding, but sometimes it will migrate to the leaf stem or the base of the plant. It remains quiet for a time before molting, and then the usual peristaltic motion is noticeable. The integument of the head soon splits along the dorsal line to the clypeus, the split forking here and following the clypeal sutures. This frees the head of the larva, which is pushed out, followed by the thorax, and a little time elapses before the mouth parts and thoracic legs are pulled out of their old coverings. Since the posterior part of the old skin is attached to the leaf by means of the hooks on the abdominal legs, the larva is soon able to crawl out, the whole operation occupying six or eight minutes. After molting the larva rests for 10 or 15 minutes in order to allow the new integument to harden somewhat, whereupon it is ready to feed again. The molted integument is not eaten, but remains adhering to the leaf or stem.

No food is taken by the larva after passing the fifth molt and entering the sixth or last instar. The larva usually remains quiet for a time after this molt, as after the others, and then begins to search for a suitable place in which to pupate. This, as a rule, is a dry, pithy stem, such as the flowering stalk of the dock or pigweed, or a dry alfalfa stem. It will also bore into rotten wood or soft bark, if nothing better is available, and, under laboratory conditions at least, will occasionally burrow into the moist earth at the base of the plant. Upon finding a suitable stem the larva at once commences to burrow into it. If the stem has been cut, as may frequently be the case with alfalfa, the larva burrows into the pith at the cut end and soon disappears. Otherwise, it burrows directly into the side of the stem, cutting out a circular hole and then hollowing out the pith within the stem, working the pieces back to the opening with the feet (fig. 1).

The larva burrows an inch or more from the opening and hollows out a pupal cell somewhat larger than itself. When this is accomplished the larva turns around within the cell, returns to the opening, and caps it over with a regurgitated, translucent, mucilaginous substance, mixed with bits of pith. This substance is smeared around the edge of the opening, the mouth parts and fore legs aiding in the process, and the head is moved back and forth until the hole is closed. After this the larva can be seen for a time through the cap, but as the latter is thickened from within the actions of the larva become indistinguishable. The larva then gives its attention to the pupal cell, cleaning it out and often filling up the burrow behind it with pith. A specially compacted mass or plug of pith is formed at the entrance to the pupal cell, as an additional protection, and after completing this the activities of the larva are over, and it soon becomes shrunken and capable of only a slight squirming motion.

The amount of time consumed in making this burrow and forming the pupal cell naturally varies with the condition of the wood, but it usually occupies six or eight hours, unless the larva bores into the cut end of a stem, when the time is considerably shortened. One larva under observation started to bore into the side of a stem at 11.15 a. m., and began to cap the opening at 4.35 p. m. The opening was closed at 5 p. m., and the larva undoubtedly took some time subsequently to complete the burrow. Another larva started its second burrow at noon, after having worked three and a half hours on the first, only to find the stem already occupied, and completed it by 6 p. m. In the breeding cages, where pithy stems were always available for the larvæ, they almost invariably had completed their burrows within 24 hours after the last molt. The larvæ of the summer generations remain in this cell six or eight days before pupating, while the larvæ of the last generation pass the winter here, remaining in the cell six months or more.

In collecting these wintering larvæ in the spring it was observed that when a larva bored into the side of a stem it always formed its pupal cell below the entrance, unless the stem lay in a horizontal position, when it might go either way. In nearly all cases, but not invariably, the head of the larva lies toward the entrance, so that escape may be facilitated. Where the insect is common, more than one larva will frequently be found in one stem, and sometimes as many as four, or five, or even eight. It sometimes happens that a larva in forming its cell pushes the lower plug down too tightly on the larva below, with the result that the latter is killed.

The pupa is able to wriggle about in its cell to some extent but does not force its way out to the entrance when the adult is ready to emerge, as is the case with many wood-boring insects. Several hours before emerging the legs, mandibles, and labrum become somewhat freely movable, with the strengthening of the adult muscles within. After casting the pupal skin the adult sometimes lies in its cell for a day or two, especially if the weather is unfavorable (fig. 1, *b*). It escapes through the original entrance, biting a hole in the cap. If two or more adults are confined in a single vial for several days after emergence they often mutilate each other. sometimes biting off all the appendages.

The adult flies are quite active and take flight readily. They spend their time flying and crawling about over the larval food plants and the neighboring vegetation, and it is unlikely that they get very far from their birthplace, unless carried by the wind or some other agency. Copulation has not been observed, although numbers of pairs were under observation in breeding jars. No food was observed to be taken, except that the adults occasionally lapped up the little moisture that occurred on the leaves.

The female usually oviposits from the upper side of the leaf, and the egg appears below, very close to the epidermis, in a raised blister about 1.2 mm. long. The ovipositor (fig. 3, *c*, and fig. 5) is thrust into the leaf and gradually worked around to one side by a sawing motion until a nearly circular cell is cut between the upper and lower leaf epidermis. When this is completed, the ovipositor is slowly removed as the egg is deposited. In eight timed ovipositions the operation occupied from 25 to 75 seconds, with an average of 45 seconds. Frequently the eggs are laid in chains, the female after laying one merely moving forward a little and depositing another. Oviposition ordinarily begins within a day after emergence and continues for several days, the majority of eggs, however, being deposited the first two or three days.

PARTHENOGENESIS.

Parthenogenesis—that is, the production of young from unfertilized eggs—has long been known to occur among the sawflies, and the males are ordinarily less common than the females. This parthenogenesis may take one of several forms. Unfertilized females will deposit eggs which either will not hatch or will hatch and the resulting larvæ will die before attaining maturity, or the larvæ from such eggs will produce only male adults. The dock false-worm belongs to the latter class, the unfertilized females ovipositing normally and the eggs hatching and ultimately producing males.

Great care was taken in rearing the dock false-worm to ascertain the status of parthenogenesis in this species. Single pupæ were kept separate in glass vials, and females emerging from them were confined alone with the larval food plant. They appeared as eager to oviposit as those confined with males, and the average number of eggs deposited

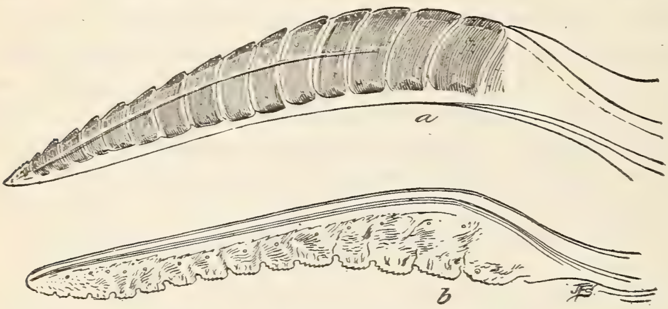

FIG. 5.—The dock false-worm: *a*, Superior saw blade of the ovipositor of adult female; *b*, inferior blade of ovipositor. Highly magnified. (Original.)

by them was greater than that deposited by mated females. The period of development of all stages, as a rule, averaged somewhat shorter than that of normal individuals, comparison, of course, being made only with normal males developing under identical conditions. The figures for parthenogenetic individuals of the various broods are given below, under the heading "Life-history studies," where they are kept separate from the figures for normal individuals. Table I compares the period of development of normal males and parthenogenetic males of the first, second, and fourth generations. No parthenogenetic individuals of the third generation were reared.

TABLE I.—*Comparison of life cycle of normal and parthenogenetic males of the dock false-worm, Wenatchee, Wash., 1915.*

Generation.	Origin of males.	Average number of days in—			
		Egg stage.	Larval stage.	Pupal stage.	Total life cycle.
First	Normal	11.5	33.6	5.5	50.7
	Parthenogenetic	11.2	29.7	5.2	46.1
Second	Normal	6.0	20.9	5.4	32.3
	Parthenogenetic	4.2	20.6	6.3	31.1
Fourth	Normal	4.8	27.8	....	32.6
	Parthenogenetic	5.8	26.8	....	32.6

LIFE-HISTORY STUDIES.

The life-history records given below include records of both normal and parthenogenetic individuals. Where both records occur, these are kept separate, since the normal proportion of individuals of parthenogenetic origin in nature is not known. Records of normal males and females are also kept separate in the complete life-cycle tables, except in the table referring to the fourth generation, the individuals of this generation being still in the larval stage at the time of writing.

SPRING BROOD OF PUPÆ AND ADULTS.

Pupal period.—The pupation records of the spring brood of pupæ and the subsequent emergence of the adults were obtained from the overwintering material collected in the Entiat Valley, Wash., on March 17, 1915. Table II gives the length of the pupal period of 40 males and 71 females of the spring brood of pupæ. The average pupal period for males of this brood is 10.2 days, and for the females 10.6 days.

TABLE II.—*Length of pupal period of spring-brood pupæ of the dock false-worm, Wenatchee, Wash., 1915.*

Males.

Number of individuals.	Date of— Pupation.	Date of— Emergence.	Days— Each.	Days— Total.
1	Mar. 31	Apr. 13	13	13
1	...do.....	Apr. 14	14	14
1	Apr. 5	Apr. 18	13	13
1	Apr. 6	...do.....	12	12
1	Apr. 7	...do.....	11	11
2	Apr. 8	Apr. 19	11	22
2	Apr. 9	...do.....	10	20
2	Apr. 10	...do.....	9	18
3	Apr. 11	...do.....	8	24
1	Apr. 12	...do.....	7	7
4	...do.....	Apr. 21	9	36
1	...do.....	Apr. 23	11	11
3	Apr. 13	...do.....	10	30
2	...do.....	Apr. 24	11	22
1	Apr. 14	Apr. 23	9	9
2	...do.....	Apr. 24	10	20
1	...do.....	Apr. 25	11	11
1	Apr. 15	Apr. 26	11	11
2	Apr. 16	...do.....	10	20
3	Apr. 17	Apr. 27	10	30
1	...do.....	Apr. 28	11	11
2	Apr. 19	Apr. 29	10	20
1	Apr. 23	May 5	12	12
1	Apr. 24	May 6	12	12
40				411

Average length in days.............. 10.2
Maximum.......................... 14
Minimum.......................... 7

Females.

Number of individuals.	Date of— Pupation.	Date of— Emergence.	Days— Each.	Days— Total.
1	Mar. 31	Apr. 14	14	14
2	Apr. 7	Apr. 18	11	22
1	Apr. 8	...do.....	10	10
3	Apr. 10	Apr. 19	9	27
1	Apr. 11	...do.....	8	8
2	Apr. 12	Apr. 20	8	16
1	...do.....	Apr. 21	9	9
1	Apr. 13	Apr. 22	9	9
7	...do.....	Apr. 23	10	70
1	...do.....	Apr. 24	11	11
5	Apr. 14	Apr. 23	9	45
4	...do.....	Apr. 24	10	40
1	...do.....	Apr. 25	11	11
2	Apr. 15	...do.....	10	20
3	Apr. 16	...do.....	9	27
4	...do.....	Apr. 26	10	40
4	Apr. 17	...do.....	9	36
7	...do.....	Apr. 27	10	70
1	...do.....	Apr. 28	11	11
1	Apr. 18	Apr. 27	9	9
2	...do.....	Apr. 28	10	20
3	...do.....	Apr. 29	11	33
2	Apr. 19	...do.....	10	20
2	...do.....	May 2	13	26
1	...do.....	May 4	15	15
1	Apr. 20	...do.....	14	14
2	Apr. 21	May 5	14	28
1	Apr. 24	May 6	12	12
1	Apr. 26	May 8	12	12
2	Apr. 27	...do.....	11	22
1	May 4	May 18	14	14
1	June 9	June 16	7	7
71				758

Average length in days.............. 10.6
Maximum.......................... 15
Minimum.......................... 7

Emergence of spring-brood adults.—Table III gives the time of emergence of 201 adult male and female sawflies of the spring brood, including those hibernating both in stems and in apples. The emergence covers a period of over seven weeks, disregarding the single female that emerged on June 16, but the maximum emergence occurred on April 23, only 10 days after the first emergence.

TABLE III.—*Time of emergence of spring-brood adults of the dock false-worm, Wenatchee Wash., 1915.*

Date.	Number of—		Total number.	Date.	Number of—		Total number.
	Males.	Females.			Males.	Females.	
Apr. 13	1	0	1	May 2	1	2	3
Apr. 14	1	1	2	May 4	2	2	4
Apr. 15	1	0	1	May 5	1	5	6
Apr. 16	1	0	1	May 6	1	1	2
Apr. 18	3	3	6	May 7	1	5	6
Apr. 19	14	4	18	May 8	0	3	3
Apr. 20	6	10	16	May 18	0	1	1
Apr. 21	5	1	6	May 19	1	2	3
Apr. 22	4	1	5	May 20	1	0	1
Apr. 23	12	17	29	May 21	0	1	1
Apr. 24	7	6	13	May 24	0	1	1
Apr. 25	2	10	12	May 27	1	1	2
Apr. 26	7	14	21	June 4	0	3	3
Apr. 27	3	11	14	June 16	0	1	1
Apr. 28	2	7	9				
Apr. 29	3	7	10	Total	81	120	201

Length of life of spring-brood adults.—Table IV gives the length of life of 7 males and 11 females confined in lantern chimneys placed over the larval food plant.

TABLE IV.—*Length of life of spring-brood adults of the dock false-worm, Wenatchee, Wash., 1915.*

Males.					Females.				
Number of individuals.	Date—		Days—		Number of individuals.	Date—		Days—	
	Emerged.	Died.	Each.	Total.		Emerged.	Died.	Each.	Total.
1	Apr. 23	May 8	15	15	3	Apr. 23	May 8	15	45
1	...do....	May 9	16	16	3	Apr. 24	May 5	11	33
1	Apr. 24	Apr. 28	4	4	1	Apr. 28	May 8	10	10
2	...do....	May 5	11	22	1	...do....	May 9	11	11
1	Apr. 28	May 8	10	10	1	...do....	May 13	15	15
1	Apr. 29	May 21	22	22	1	...do....	May 15	17	17
					1	May 2	May 14	12	12
7				89	11				143
Average number of days				12.7	Average number of days				13.0
Maximum				22	Maximum				17
Minimum				4	Minimum				10

There is little difference between the length of life of the males and females, the average being 12.8 days, and it is probable that adults in the open would average about the same. Thirty-five adults were confined in the glass vials in which they emerged, with no food or moisture, and these lived an average of only 8.3 days.

Oviposition of spring-brood adults.—Spring-brood adults begin ovipositing within a day of emergence. The maximum period observed was 9 days, with an average of 2.9 days, figuring from date of emergence to date of deposition of each egg. Six mated females of the spring brood deposited an average of 103.6 eggs, the maximum being 117 and the minimum 89; five single females deposited an average of 109.4 eggs, with a maximum of 125 and a minimum of 102.

FIRST GENERATION.

Incubation period of first-brood eggs.—Table V gives the length of the egg stage for 446 fertile eggs and 301 parthenogenetic eggs deposited by spring-brood females in living plants. The fertile eggs of this brood have an average incubation period of 10.7 days, as against 9.9 days for the parthenogenetic eggs.

TABLE V.—*Length of the incubation period of first-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.

Number of eggs.	Date— Deposited.	Date— Hatched.	Incubation period.	Total days.
28	Apr. 25–26	May 7	11.5	332
5	......do	May 8	12.5	62.5
98	Apr. 25–27	May 7	11	1,078
44	......do	May 8	12	528
7	......do	May 9	13	91
43	Apr. 28–29	May 8	9.5	408.5
102	......do	May 9	10.5	1,071
6	......do	May 10	11.5	69
25	Apr. 29	May 9	10	250
4	......do	May 10	11	44
2	......do	May 11	12	24
1	......do	May 13	14	14
12	Apr. 30–May 5	May 11	8.5	102
8	......do	May 12	9.5	76
50	......do	May 13	10.5	525
9	......do	May 15	12.5	112.5
1	May 5	May 16	11	11
1	......do	May 17	12	12
446				4,800.5
Average incubation period				10.7
Maximum				14
Minimum				6

Parthenogenetic eggs.

Number of eggs.	Date— Deposited.	Date— Hatched.	Incubation period.	Total days.
86	Apr. 29	May 9	10	860
10	......do	May 10	11	110
1	......do	May 11	12	12
1	......do	May 12	13	13
1	......do	May 15	16	16
12	Apr. 29–May 5	May 13	11	132
9	......do	May 14	12	108
16	May 5–9	May 15	8	128
1	......do	May 16	9	9
6	......do	May 17	10	60
5	......do	May 18	11	55
2	......do	May 19	12	24
12	May 5–8	May 14	7.5	90
31	......do	May 15	8.5	263.5
8	......do	May 16	9.5	76
21	......do	May 17	10.5	220.5
16	......do	May 18	11.5	184
8	......do	May 19	12.5	100
4	May 9	...do	10	40
3	......do	May 21	12	36
2	......do	May 24	15	30
38	May 25	June 3	9	342
5	May 26	June 4	9	45
3	......do	June 5	10	30
301				2,984
Average incubation period				9.9
Maximum				16
Minimum				6

Length of life of first-brood larvæ by instars.—Seventy larvæ from fertile eggs were reared, at least to the third instar, but of these only 31 were carried to the pupal stage. A partial record was obtained of 19 parthenogenetic larvæ, and a complete record of 8. Table VI gives a summary of the length of larval life by instars, of all larvæ reared.

TABLE VI.—*Summary of larval life of first generation of the dock false-worm by instars, Wenatchee, Wash., 1915.*

Normal larvæ.

First instar.

Number of individuals.	Number of days each.	Total days.
21	4.5	94.5
3	5	15
1	6	6
8	6.5	52
11	7	77
2	7.5	15
3	8	24
12	8.5	102
3	9.5	28.5
1	10	10
2	10.5	21
2	11	22
69	......	467
Av.		6.7
Max.		11
Min.		4.5

Second instar.

Number of individuals.	Number of days each.	Total days.
1	2	2
4	3	12
16	4	64
2	4.5	9
21	5	105
2	5.5	11
19	6	114
2	6.5	13
2	7	14
1	8	8
70	......	352
Av.		5
Max.		8
Min.		2

Third instar.

Number of individuals.	Number of days each.	Total days.
1	2	2
7	3	21
28	4	112
20	5	100
6	6	36
5	7	35
2	8	16
1	12	12
70	......	334
Av.		4.7
Max.		12
Min.		2

Fourth instar.

Number of individuals.	Number of days each.	Total days.
4	2	8
5	3	15
30	4	120
18	5	90
3	6	18
3	7	21
1	8	8
1	10	10
65	......	290
Av.		4.4
Max.		10
Min.		2

Fifth instar.

Number of individuals.	Number of days each.	Total days.
1	1	1
1	2	2
2	3	6
4	4	16
12	5	60
16	6	96
9	7	63
6	8	48
1	9	9
4	10	40
3	11	33
3	12	36
62	......	410
Av.		6.6
Max.		12
Min.		1

Sixth instar.

Number of individuals.	Number of days each.	Total days.
5	5	25
7	6	42
6	7	42
3	8	24
5	9	45
1	11	11
1	12	12
1	13	13
1	17	17
1	23	23
31	......	254
Av.		8.2
Max.		23
Min.		5

Parthenogenetic larvæ.

First instar.

Number of individuals.	Number of days each.	Total days.
1	2.5	2.5
2	4	8
1	5	5
2	6	12
2	6.5	13
2	7	14
6	7.5	45
2	8	16
1	8.5	8.5
19	......	124
Av.		6.5
Max.		8.5
Min.		2.5

Second instar.

Number of individuals.	Number of days each.	Total days.
4	3	12
10	4	40
5	5	25
19	......	77
Av.		4
Max.		5
Min.		3

Third instar.

Number of individuals.	Number of days each.	Total days.
1	3	3
16	4	64
1	5	5
1	6	6
19	......	78
Av.		4
Max.		6
Min.		3

Fourth instar.

Number of individuals.	Number of days each.	Total days.
2	2	4
6	3	18
4	4	16
4	5	20
16	......	58
Av.		3.6
Max.		5
Min.		2

Fifth instar.

Number of individuals.	Number of days each.	Total days.
3	1	3
3	2	6
3	3	9
4	5	20
1	8	8
14	......	46
Av.		3.3
Max.		8
Min.		1

Sixth instar.

Number of individuals.	Number of days each.	Total days.
1	5	5
2	7	14
5	8	40
8	......	59
Av.		7.4
Max.		8
Min.		5

Length of life of first-brood pupæ.—Records of the pupal period were obtained from 10 parthenogenetic pupæ, 9 normal male pupæ, and 22 female pupæ, and a summary of these records is given in Table VII.

TABLE VII.—*Summary of pupal stage of first generation of the dock false-worm, Wenatchee, Wash., 1915.*

Parthenogenetic males.			Normal males.			Females.		
Number of individuals.	Days— Each.	Days— Total.	Number of individuals.	Days— Each.	Days— Total.	Number of individuals.	Days— Each.	Days— Total.
2	4	8	1	4	4	1	4	4
5	5	25	2	5	10	9	5	45
2	6	12	6	6	36	10	6	60
1	7	7				1	7	7
						1	8	8
10	....	52	9	....	50	22	....	124
Average 5.2			Average 5.5			Average 5.6		
Maximum 7			Maximum 6			Maximum 8		
Minimum 4			Minimum 4			Minimum 4		

Life cycle and emergence of adults of first generation.—Table VIII gives the complete life cycle of 10 parthenogenetic males, 9 normal males, and 22 females. By life cycle is meant the period of growth, or the period from the deposition of the egg to the emergence of the adult. It does not include the length of adult life, during which no growth occurs, nor the interval between emergence of adult and oviposition, these figures being given in a following paragraph.

TABLE VIII.—*Length of life cycle of the first generation of the dock false-worm, Wenatchee, Wash., 1915.*

Individual No.	Date of— Egg deposition.	Date of— Hatching.	Date of— Pupation.	Date of— Emergence.	Days in— Egg stage.	Days in— Larval stage.	Days in— Pupal stage.	Total life cycle in days.
Parthenogenetic males.								
1	Apr. 30	May 13	June 15	June 20	13	33	5	51
2	...do.....	...do.....	June 16	June 22	13	34	6	53
3	...do.....	...do.....	June 17	June 23	13	35	6	54
4	May 1	May 14	June 15	June 20	13	32	5	50
5	...do.....	...do.....	...do.....	...do.....	13	32	5	50
6	May 9	May 19	June 14	June 19	10	26	5	41
7	...do.....	...do.....	June 17	June 24	10	29	7	46
8	May 25	June 3	June 30	July 4	9	27	4	40
9	...do.....	...do.....	...do.....	...do.....	9	27	4	40
10	May 26	June 4	June 26	July 1	9	22	5	36
Total					112	297	52	461
Average number of days					11.2	29.7	5.2	46.1
Maximum life cycle, 54 days; minimum, 36 days.								
Normal males.								
1	Apr. 25	May 7	June 10	June 16	12	34	6	52
2	Apr. 27	May 9	June 19	June 24	12	41	5	58
3	...do.....	...do.....	June 21	June 27	12	43	6	61
4	Apr. 30	May 13	June 10	June 16	13	28	6	47
5	...do.....	...do.....	June 11	...do.....	13	29	5	47
6	...do.....	...do.....	June 13	June 17	13	31	4	48
7	...do.....	...do.....	June 16	June 22	13	34	6	53
8	May 8	May 16	...do.....	...do.....	8	31	6	45
9	...do.....	...do.....	June 17	June 23	8	32	6	46
Total					104	303	50	457
Average number of days					11.5	33.6	5.5	50.7
Maximum life cycle, 61 days; minimum, 45 days.								

TABLE VIII.—*Length of life cycle of the first generation of the dock false-worm, Wenatchee, Wash., 1915*—Continued.

Females.								
Individual No.	Date of—				Days in—			Total life cycle in days.
	Egg deposition.	Hatching.	Pupation.	Emergence.	Egg stage.	Larval stage.	Pupal stage.	
1	Apr. 25	May 7	June 8	June 15	12	32	7	51
2	...do.....	...do.....	...do.....	June 16	12	32	8	52
3	...do.....	...do.....	June 10	...do.....	12	34	6	52
4	...do.....	...do.....	...do.....	...do.....	12	34	6	52
5	...do.....	...do.....	June 13	June 18	12	37	5	54
6	...do.....	...do.....	June 22	June 28	12	46	6	64
7	Apr. 27	May 8	June 12	June 17	11	35	5	51
8	...do.....	...do.....	June 15	June 20	11	38	5	54
9	Apr. 28	May 9	...do.....	June 21	11	37	6	54
10	...do.....	...do.....	...do.....	...do.....	11	37	6	54
11	...do.....	...do.....	June 18	June 23	11	40	5	56
12	...do.....	...do.....	Jyne 20	June 26	11	42	6	59
13	...do.....	...do.....	June 24	June 29	11	46	5	62
14	Apr. 30	May 11	June 17	June 23	11	37	6	54
15	...do.....	...do.....	June 18	June 24	11	38	6	55
16	...do.....	...do.....	...do.....	...do.....	11	38	6	55
17	...do.....	...do.....	June 20	June 25	11	40	5	56
18	...do.....	...do.....	June 22	June 28	11	42	6	59
19	May 8	May 21	June 18	June 23	13	28	5	46
20	...do.....	May 23	...do.....	...do.....	15	26	5	46
21	...do.....	May 24	June 27	July 1	16	34	4	54
22	...do.....	May 25	July 1	July 6	17	37	5	59
Total					265	810	124	1199
Average number of days					12.0	36.8	5.6	54.5
Maximum life cycle, 64 days; minimum, 46 days.								
Normal average life cycle					10.7[1]	35.9	5.6	53.4

[1] Taken from Table V.

The parthenogenetic life cycle averages 46.1 days, the life cycle of normal males, 50.7 days, and the female life cycle, 54.5 days. The average life cycle of normal individuals of both sexes is 53.4 days.

Length of life of first-brood adults.—The warmer weather at the time the first-brood adults are flying appears to reduce the length of their lives, and the average of six adults was 5.3 days, with a minimum of 3 days and a maximum of 7 days.

Oviposition of first-brood adults.—Oviposition begins, in the case of first-brood females, sometimes within a few hours after emergence, and the maximum period observed was 5 days, with an average of 1.7 days. Eggs were secured from six mated females, the average number being 62.3, with a maximum of 92, and a minimum of 39; four single females deposited an average of 67.7 eggs, with a maximum of 90, and a minimum of 46. These females, being reared at the laboratory from eggs deposited there by females of the previous brood, may not have been quite as vigorous as those in nature, which may account for the smaller number of eggs.

SECOND GENERATION.

Incubation period of second-brood eggs.—The length of the second-brood egg stage is shorter than that of the first, owing to the warmer weather at this time, the fertile eggs having an average incubation period of 4.8 days, and the parthenogenetic eggs an average period of 4.3 days. The records for 238 fertile eggs and 202 parthenogenetic eggs are given in Table IX.

TABLE IX.—*Length of the incubation period of second-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date— Deposited.	Date— Hatched.	Incubation period.	Total days.	Number of eggs.	Date— Deposited.	Date— Hatched.	Incubation period.	Total days.
17	June 20	June 26	6	102	29	June 20	June 25	5	145
9	June 21	...do.....	5	45	1	...do.....	June 27	7	7
1	...do.....	June 27	6	6	53	June 21	June 26	5	265
9	June 22	...do.....	5	45	2	...do.....	June 27	6	12
27	...do.....	June 28	6	162	3	...do.....	June 28	7	21
18	...do.....	June 29	7	126	6	June 22	June 27	5	30
7	June 23	...do.....	6	42	14	...do.....	June 28	6	84
14	June 29	July 2	3	42	4	June 23	June 29	6	24
56	...do.....	July 3	4	224	7	June 29	July 2	3	21
3	June 30	...do.....	3	9	64	June 30	July 3	3	192
34	July 3	July 7	4	136	5	...do.....	July 4	4	20
34	...do.....	July 8	5	170	9	July 1	...do.....	3	27
1	...do.....	July 9	6	6	3	...do.....	July 5	4	12
5	July 4	...do.....	5	25	1	...do.....	July 6	5	5
1	...do.....	July 10	6	6	1	July 2	...do.....	4	4
2	...do.....	July 11	7	14					
238				1,160	202				869
Average incubation period				4.8	Average incubation period				4.3
Maximum				7	Maximum				7
Minimum				3	Minimum				3

Length of life of second-brood larvæ by instars.—Of 43 larvæ which were reared from fertile eggs only 17 reached the pupal stage. The greatest mortality, due to lack of moisture, occurred after the mature larvæ had formed their pupal cells. Forty-seven parthenogenetic larvæ were reared, 6 of them pupating. Table X gives a summary of the length of larval life of all larvæ reared.

TABLE X.—*Summary of larval life of second generation of the dock false-worm, by instars, Wenatchee, Wash., 1915.*

First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
Normal larvæ.																	
1	1	1	24	1	24	13	1	13	3	1	3	10	3	30	1	5	5
5	2	10	14	2	28	25	2	50	22	2	44	14	4	56	4	6	24
16	3	48	4	3	12	3	3	9	12	3	36	8	5	40	6	7	42
18	4	72	1	4	4	1	4	4	4	4	16	6	6	36	4	9	36
3	5	15				1	6	6	1	5	5	3	7	21	2	10	20
												1	8	8			
43		146	43		68	43		82	42		104	42		191	17		127
Av. 3.4			Av. 1.6			Av. 1.9			Av. 2.5			Av. 4.5			Av. 7.4		
Max. 5			Max. 4			Max. 6			Max. 5			Max. 8			Max. 10		
Min. 1			Min. 1			Min. 1			Min. 1			Min. 3			Min. 5		
Parthenogenetic larvæ.																	
17	3	51	16	1	16	7	1	7	4	1	4	1	2	2	4	7	28
22	4	88	27	2	54	34	2	68	21	2	42	9	3	27	1	8	8
8	5	40	4	3	12	6	3	18	18	3	54	20	4	80	1	13	13
									3	4	12	6	5	30			
												7	6	42			
												3	7	21			
47		179	47		82	47		93	46		112	46		202	6		49
Av. 3.8			Av. 1.7			Av. 2			Av. 2.4			Av. 4.4			Av. 8.1		
Max. 5			Max. 3			Max. 3			Max 4			Max. 7			Max. 13		
Min. 3			Min. 1			Min. 1			Min. 1			Min. 2			Min. 7		

Length of life of second-brood pupæ.—Pupal records were obtained from 12 normal pupæ, all males, with one exception, and from 3 parthenogenetic pupæ, and a summary of these records is given in Table XI.

TABLE XI.—*Summary of pupal stage of second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Normal individuals.			Parthenogenetic males.		
Number of individuals.	Days— Each.	Days— Total.	Number of individuals.	Days— Each.	Days— Total.
2	4	8	1	5	5
6	5	30	2	7	14
3	6	18			
1	8	8			
12		64	3		19
Average		5.3	Average		6.3
Maximum		8	Maximum		7
Minimum		4	Minimum		5

Life cycle and emergence of adults of second generation.—Table XII gives the complete life cycle, from egg deposition to emergence of adult, of 4 parthenogenetic males and 10 normal males of the second generation. The only female of this generation reared to maturity had an abnormal number of molts, and is included elsewhere in this paper.

TABLE XII.—*Length of life cycle of the second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Individual No.	Date of— Egg deposition.	Date of— Hatching.	Date of— Pupation.	Date of— Emergence.	Days in— Egg stage.	Days in— Larval stage.	Days in— Pupal stage.	Total life cycle in days.
Pathenogenetic males.								
1	June 21	June 26	July 15	July 22	5	19	7	31
2	...do....	...do....	July 16	July 23	5	20	7	32
3	June 30	July 3	....	Aug. 1	3	....	....	32
4	...do.....	July 4	July 27	...do.....	4	23	5	32
Total					17	62	19	127
Average number of days					4.2	20.6	6.3	31.7
Maximum life cycle, 32 days; minimum, 31 days.								
Normal males.								
1	June 20	June 26	July 16	July 22	6	20	6	32
2	...do.....	...do.....	July 18	July 23	6	22	5	33
3	...do.....	...do.....	July 19	...do.....	6	23	4	33
4	June 22	June 28	July 14	July 20	6	16	6	28
5	...do.....	...do.....	...do.....	July 22	6	16	8	30
6	...do.....	June 29	July 16	...do.....	7	17	6	30
7	...do.....	...do.....	July 17	...do.....	7	18	5	30
8	...do.....	June 28	July 19	July 23	6	21	4	31
9	...do....	June 29	July 26	July 31	7	27	5	39
10	June 30	July 3	Aug. 1	Aug. 6	3	29	5	37
Total					60	209	54	323
Average number of days					6	20.9	5.4	32.3
Maximum life cycle, 39 days; minimum, 28 days.								

Since the complete rearings of this generation were few in number, the average life cycle of normal individuals has been compiled from the figures in Tables IX, X, and XI, and is given in Table XIII.

TABLE XIII.—*Average life cycle of normal individuals of the second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Number of days in— Egg stage.	Number of days in— Larval stage.	Number of days in— Pupal stage.	Total life cycle in days.
4.8	21.3	5.3	31.4

Length of life of second-brood adults.—No records were made of the length of life of second-brood adults.

Oviposition of second-brood adults.—Observations were made on a single pair of second-brood adults. The female deposited 34 eggs the first day after she emerged and 40 eggs the second day, making 74 eggs in all.

THIRD GENERATION.

Incubation period of third-brood eggs.—Seventy-four fertile eggs of this brood hatched in 4 to 6 days after being deposited, with an average incubation period of 4.7 days. No parthenogenetic eggs were secured.

Length of life of third-brood larvæ by instars.—Twenty-nine larvæ were reared from fertile eggs, 9 of them pupating, the remainder either dying or burrowing into the earth at maturity and being lost. No parthenogenetic larvæ were reared. Table XIV gives a summary of the length of larval life by instars of all larvæ reared.

TABLE XIV.—*Summary of larval life of third generation of the dock false-worm, by instars, Wenatchee, Wash., 1915.*

Normal larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	3	1	3	3	1	3	1	1	1	2	2	4	7	4	28
6	2	12	17	2	34	16	2	32	8	2	16	3	3	9	2	5	10
19	3	57	5	3	15	5	3	15	6	3	18	7	4	28	9	......	38
3	4	12	25	......	52	24	......	50	2	4	8	3	5	15	Av........ 4.2		
29	......	82	Av........ 2.1			Av........ 2.1			1	6	6	15	......	56	Max....... 5		
Av........... 2.8			Max....... 3			Max....... 3			18	......	49	Av........ 3.7			Min....... 4		
Max.......... 4			Min....... 1			Min....... 1			Av........ 2.7			Max........ 5					
Min.......... 1									Max....... 6			Min........ 2					
									Min....... 1								

Length of life of third-brood pupæ.—Pupal records were obtained from 9 pupæ of fertile eggs, 4 males and 5 females, and these are given in Table XV.

TABLE XV.—*Summary of pupal stage of third generation of the dock false-worm, Wenatchee, Wash., 1915.*

Number of individuals.	Days.	
	Each.	Total
4	4	16
4	5	20
1	6	6
9	....	42
Average number of days.................. 4.7		
Maximum.............. 6		
Minimum.............. 4		

Life cycle and emergence of adults of third generation.—Since all but one of the third-brood larvæ reared to the adult stage came from eggs collected in the field, it is not possible to give a complete life cycle of this generation. Table XVI gives a partial life cycle (omitting the egg stage) of 5 males and 5 females.

TABLE XVI.—*Length of partial life cycle of the third generation of the dock false-worm, Wenatchee, Wash., 1915.*

Individual No.	Date of— Hatching.	Date of— Pupation.	Date of— Emergence.	Days in— Larval stage.	Days in— Pupal stage.	Total life cycle in days.
Males.						
1	July 25	Aug. 12	Aug. 17	18	5	23
2	July 28	Aug. 13	Aug. 18	16	5	21
3	Aug. 1	....	Aug. 22	....	....	21
4	Aug. 17	Sept. 3	Sept. 8	17	5	22
5	...do.....	...do.....	Sept. 9	17	6	23
Total				68	21	110
Average number of days				17	5.2	22
Maximum life cycle, 23 days; minimum, 21 days.						
Females.						
1	July 25	Aug. 12	Aug. 17	18	5	23
2	...do.....	Aug. 13	...do.....	19	4	23
3	July 28	Aug. 14	Aug. 18	17	4	21
4	...do.....	Aug. 15	Aug. 19	18	4	22
5	Aug. 11	Aug. 26	Aug. 30	15	4	19
Total				87	21	108
Average number of days				17.4	4.2	21.6
Maximum life cycle, 23 days; minimum, 19 days.						

As Table XVI is very incomplete, the length of the complete average life cycle has been compiled from separate results obtained for the various stages and is given in Table XVII.

TABLE XVII.—*Average length of complete life cycle of the third generation of the dock false-worm, as compiled from the various stages, Wenatchee, Wash., 1915.*

Number of days in— Egg stage.	Number of days in— Larval stage.	Number of days in— Pupal stage.	Total life cycle in days.
4.7	17.6	4.7	27.0

Length of life of third-brood adults.—One male kept with the larval food plant lived 7 days, and two females each lived 5 days.

Oviposition of third-brood adults.—Third-brood females deposited eggs up to 4 days after emerging, the average being 1.9 days, figuring from date of emergence to date of deposition of each egg.

One mated female deposited a total of 133 eggs, and another escaped after depositing 95 eggs. Two single females were observed one of which deposited 83 eggs and the other 104.

FOURTH GENERATION.

Incubation period of fourth-brood eggs.—The length of the fourth-brood egg stage averages a little shorter than that of the second brood, the weather in August being warmer than in June. Records of 174 fertile eggs showed an average incubation period of 3.8 days, and records of 62 parthenogenetic eggs deposited during the same period showed an average of 4.4 days. Table XVIII gives the records for the 174 fertile eggs, and for 157 parthenogenetic eggs, 95 of them being deposited from August 31 to September 4, when the weather was cooler. This makes the total average higher than that of the fertile eggs, as no records of these were secured during this cooler period.

TABLE XVIII.—*Length of the incubation period of fourth-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date— Deposited.	Date— Hatched.	Incubation period.	Total days.	Number of eggs.	Date— Deposited.	Date— Hatched.	Incubation period.	Total days.
1	Aug. 18	Aug. 21	3	3	14	Aug. 20	Aug. 24	4	56
26	...do.....	Aug. 22	4	104	12	...do.....	Aug. 25	5	60
19	...do.....	Aug. 23	5	95	10	Aug. 21	...do.....	4	40
41	Aug. 19	Aug. 22	3	123	11	...do.....	Aug. 26	5	55
28	...do.....	Aug. 23	4	112	8	Aug. 22	...do.....	4	32
6	...do.....	Aug. 24	5	30	6	...do.....	Aug. 27	5	30
1	...do.....	Aug. 25	6	6	1	Aug. 23	...do.....	4	4
25	Aug. 20	Aug. 24	4	100	1	Aug. 31	Sept. 6	6	6
1	...do.....	Aug. 25	5	5	18	...do.....	Sept. 7	7	126
1	...do.....	Aug. 26	6	6	2	...do.....	Sept. 8	8	16
11	Aug. 21	Aug. 24	3	33	2	...do.....	Sept. 9	9	18
11	...do.....	Aug. 25	4	44	10	Sept. 1	Sept. 7	6	60
3	...do.....	Aug. 26	5	15	19	...do.....	Sept. 8	7	133
					1	...do.....	Sept. 9	8	8
					14	Sept. 2	Sept. 8	6	84
					1	Sept. 3	...do.....	5	5
					20	...do.....	Sept. 9	6	120
					3	...do.....	Sept. 10	7	21
					4	Sept. 4	Sept. 11	7	28
174				676	157				902
Average incubation period				3.8	Average incubation period				5.7
Maximum				6	Maximum				9
Minimum				3	Minimum				4

Length of life of fourth-brood larvæ by instars.—As the fourth-brood larvæ do not pupate the same season, but pass the winter in the larval stage, only the period from hatching to the forming of the pupal or hibernating cell by these larvæ is given in the summary in Table XIX.

TABLE XIX.—*Summary of larval life of fourth generation of the dock false-worm, from hatching to forming of pupal cell, Wenatchee, Wash., 1915.*

First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	21	2	42	1	1	1	3	2	6	2	6	12	9	1	9
7	2	14	3	3	9	9	2	18	1	2.5	2.5	2	7	14	2	2	4
13	3	39	2	3.5	7	8	3	24	6	3	18	4	9	36	2	4	8
4	4	16	4	4	16	5	4	20	4	4	16	1	10.5	10.5			
4	5	20	1	4.5	4.5	1	6	6	4	5	20	2	11	22	13	......	21
4	6	24	1	10	10	1	7	7	1	6	6	1	12	12	Av........		1.6
3	8	24							1	8	8	1	13	13	Max......		4
			32	......	88.5	25	......	76	1	10	10	1	14	14	Min......		1
36	......	138	Av..........		2.7	Av..........		3				1	17	17			
Av........		3.8	Max..........		10	Max..........		7	21	......	86.5						
Max......		8	Min..........		2	Min..........		1	Av..........		4.1	15	......	150.5			
Min......		1							Max........		10	Av..........		10			
									Min........		2	Max..........		17			
												Min..........		6			

The foregoing table includes individuals from both fertile and parthenogenetic eggs, since there was but little difference between them.

Life cycle of fourth generation.—Table XX gives a partial life cycle of 13 individuals of the fourth generation, including the period from oviposition to the forming of the pupal cell by the full-grown larvæ. This averages 32.6 days for parthenogenetic individuals and 32.7 days for normal individuals. In order to arrive at the complete length of the life cycle of individuals of this generation, we must add to this approximately 200 days, which is the average time spent by the larvæ in the pupal cell, and also 10.5 days, which is the average length of the spring brood (fourth generation) pupal period as shown in Table II. This makes an average total of about 243 days, the complete life cycle of the fourth generation.

TABLE XX.—*Length of partial life cycle of the fourth generation of the dock false-worm, Wenatchee, Wash., 1915.*

Parthenogenetic individuals.						
Individual No.	Date of—			Days in—		Average partial life cycle in days.
	Egg deposition.	Hatching.	Forming pupal cell.	Egg stage.	Larval stage.	
1	Aug. 20	Aug. 24	Sept. 15	4	22	26
2	...do....	...do....	Sept. 16	4	23	27
3	Sept. 1	Sept. 7	Oct. 3	6	26	32
4	...do....	...do....	Oct. 6	6	29	35
5	Sept. 2	Sept. 9	Oct. 10	7	31	38
6	Sept. 3	Sept. 11	Oct. 11	8	30	38
Total..........................				35	161	196
Average number of days..........				5.8	26.8	32.6
Maximum life cycle, 38 days; minimum, 26 days.						

TABLE XX.—*Length of partial life cycle of the fourth generation of the dock false-worm, Wenatchee, Wash., 1915*—Continued.

Normal individuals.						
Individual No.	Date of—			Days in—		Average partial life cycle in days.
	Egg deposition.	Hatching.	Forming pupal cell.	Egg stage.	Larval stage.	
1	Aug. 19	Aug. 23	Sept. 18	4	26	30
2	Aug. 20	Aug. 24	...do....	4	25	29
3	...do....	...do....	Sept. 19	4	26	30
4	...do....	Aug. 26	...do....	6	24	30
5	Aug. 21	...do....	Sept. 22	5	27	32
6	...do....	...do....	Oct. 4	5	39	44
7	...do....	Aug. 27	Sept. 24	6	28	34
Total				34	195	229
Average number of days				4.8	27.8	32.7
Maximum life cycle, 44 days; minimum, 29 days.						

SUMMARY OF LIFE-HISTORY STUDIES.

Table XXI gives a summary of the length of each stage of each generation of the dock false-worm, as worked out at Wenatchee, Wash., in 1915. The column marked "Total life cycle in days" gives the time elapsing between egg deposition and emergence of adult, and the last column gives the time elapsing between the egg deposition of one generation and that of the next. It will be seen that the total of this column (four generations) is 365.6 days, or approximately one year.

TABLE XXI.—*Summary by stages of the length of each generation of normal individuals of the dock false-worm, Wenatchee, Wash., 1915.*

Generation.	Average number of days—				Total life cycle in days.	Average number of days from egg deposition to egg deposition.
	In egg stage.	In larval stage.	In pupal stage.	From emergence to oviposition.		
First	10.7	35.6	5.6	1.7	51.9	53.6
Second	4.8	21.3	5.3	1.5	31.4	32.9
Third	4.7	17.6	4.7	1.9	27.0	28.9
Fourth	3.8	233.0	10.5	2.9	247.3	250.2
Total						365.6

The seasonal history of the dock false-worm is shown in the diagram in figure 6. In order to avoid crowding, only three points in the life history are shown for each generation, namely, the hatching of the eggs, pupation, and the emergence of the adults. Oviposition would come a day or two later than the adult emergence.

ABNORMAL NUMBER OF LARVAL MOLTS.

We have seen that normally the dock false-worm molts five times, and that consequently there are six instars in the larval stage. It seems certain that occasionally, however, there are seven larval instars. When this was first suspected several larvæ were being reared on a single plant, and while the molted skin was always removed from the leaf when the record of molting was made, there was some doubt as to whether any of the larvæ actually did pass an extra molt. Subsequently, however, the majority of larvæ were reared singly, that is, only one to a plant, and several apparently

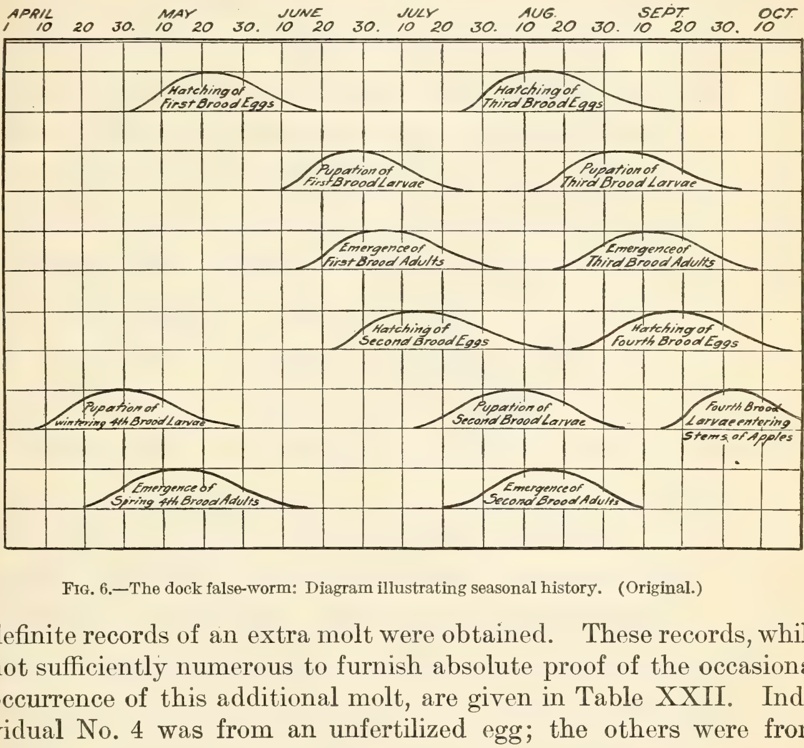

FIG. 6.—The dock false-worm: Diagram illustrating seasonal history. (Original.)

definite records of an extra molt were obtained. These records, while not sufficiently numerous to furnish absolute proof of the occasional occurrence of this additional molt, are given in Table XXII. Individual No. 4 was from an unfertilized egg; the others were from fertile eggs.

TABLE XXII.—*Records of larvæ of the dock false-worm having seven instars, Wenatchee, Wash., 1915.*

Individual No.	Generation.	Date of—									Sex.
		Hatching.	First molt.	Second molt.	Third molt.	Fourth molt.	Fifth molt.	Sixth molt.	Pupation.	Emergence.	
1	1st.	June 29	July 1	July 8	July 11	July 15	July 19	July 26	Aug. 1	....	♀
2	1st.	July 3	July 5	...do....	...do....	July 14	...do....	July 22	July 29	Aug. 3	♀
3	1st.	...do....	July 7	July 9	...do....	July 13	July 17	July 21	....	....	..
4	1st.	July 4	...do....	...do....	...do....	July 14	...do....	July 19	....	....	..
5	3d.	July 28	July 31	Aug. 2	Aug. 4	Aug. 10	Aug. 12	Aug. 17	....	....	..
6	3d.	Aug. 4	Aug. 7	Aug. 10	Aug. 11	Aug. 15	Aug. 19	Aug. 23	....	....	..
7	3d.	...do....	...do....	...do....	Aug. 13	...do....	...do....	Aug. 21	....	....	..
8	4th	Aug. 26	Aug. 27	Aug. 29	Sept. 1	Sept. 4	Sept. 9	Sept. 21	....	....	..
9	4th	...do....	Aug. 30	Sept. 9	Sept. 16	Sept. 19	Sept. 21	Oct. 3	....	....	..
10	4th	Aug. 27	Aug. 29	Aug. 31	Sept. 4	Sept. 10	Sept. 16	Sept. 22	....	....	..

RELATION OF TEMPERATURE TO DEVELOPMENT.

Temperature has a very decided influence on the development of insects. Within certain limits increased temperature will hasten development, other factors being equal. The dock false-worm seemed peculiarly susceptible to changes in temperature, and it has already been noted that all stages of its development were shorter in the summer than in the spring. For example, the incubation period of the first-brood eggs (April–May) averaged 10.7 days, while that of the second-brood eggs (June–July) averaged only 4.8 days. Some observations were made on the length of the pupal stage, which, while not taking into consideration the possible effect of differences in humidity and other factors, show very definitely the effect of changes in temperature. The temperature records were obtained from a Richard thermograph placed in the rearing shelter. A sudden rise or fall of temperature hastened or retarded adult emergence. Before April 16 the temperature had only occasionally got above 70° F. From April 16 to 19, inclusive, the daily maximum was above 80° F., and the daily minimum about 50°, whereas it had been about 40° previously. The sawfly pupæ responded to this rise in temperature, and on two days, April 18 and 19, 20 adults emerged from pupæ that had pupated during a period of eight days, or from April 5 to 12, inclusive.

Table XXIII compares the length of the pupal period with the average temperature. This temperature was obtained as follows: The average daily temperature was computed by the sufficiently accurate method of averaging the daily maximum and minimum. Then the average temperature for each individual was obtained by adding the daily averages for the pupal period (including the day of pupation and the day of emergence) of that individual, and dividing by the number of days. The average temperature for a pupal period of any given number of days was then obtained by simply adding the average temperatures of all individuals having a pupal period of that number of days and dividing by the number of individuals. In all, the average temperatures for 137 pupæ of the spring brood and first brood were computed, pupæ from unfertilized eggs not being considered.

TABLE XXIII.—*Length of pupal period of the dock false-worm compared with the average temperature, Wenatchee, Wash., 1915.*

Pupal period in days	14	13	12	11	10	9	8	7	6	5	4
Average temperature in ° F	55.31	55.88	57.65	58.12	58.29	58.62	59.66	61.65	66.60	67.94	70.60
Increase	....	0.57	1.77	0.47	0.17	0.33	1.04	1.99	4.95	1.34	2.66

While no rule can be formulated from the foregoing table, it will be noted that the amount of increase in temperature required to reduce the pupal period one day was greater as the pupal period grew shorter. It required an increase of 3.31° to reduce the pupal period from 14 days to nine days, a reduction of five days, while in order to reduce it from nine days to four days, a further reduction of five days, an increase in temperature of 11.98° was necessary, or over three times as much. The reason for this is evident. It must be remembered that during the pupal stage important changes are taking place. The relatively simple larva is being transformed into the highly complex adult insect. These changes require a certain minimum amount of time, in this case apparently three or four days. On the other hand, there is, at least theoretically, no limit to the maximum amount of time during which the insect may remain in the pupal condition. Hence, as we approach the minimum a greater increase in temperature is necessary in order to produce a given reduction in the length of the pupal period.

NATURAL ENEMIES.

HYMENOPTEROUS PARASITES.

ICHNEUMONIDS.

The overwintering material of the dock false-worm, collected in March, 1915, proved to be rather heavily parasitized. Accordingly a careful record was kept of the parasites, and some knowledge of their life histories was obtained. The parasites emerging were all ichneumonids, and belong to seven distinct species. Mr. R. A. Cushman has examined these and finds them to be *Epiurus pterophorae* Ashm., *Spilocryptus* sp., *Aenoplex* sp., *Bathymetis* sp., *Bathythrix* sp., and two species of Cratocryptus. As only three species were recognized at the time of rearing, and the data obtained were rather meager, they are not presented here. It is certain, moreover, that some of these species are secondary parasites. It is hoped that the opportunity will be presented for further investigations in order to work out this problem.

The adults of all these ichneumonid parasites emerge through a hole bored opposite the pupal cell and not through the entrance hole of the false-worm. They are all more active than the adult sawfly. They are all similar in appearance, and not unlike the adult sawflies, being slender and black, with reddish legs. The antennæ are longer, however, the abdomen more slender, and the ovipositor of the female is conspicuous. The adults of Spilocryptus are further distingushed by a reddish band across the anterior half or two-thirds of the abdomen.

None of these parasites was reared from false-worms that had bored into apples, which indicates that the parasites oviposit in the worms, by means of their stout ovipositors, after the worms have bored into the stems and formed their pupal cells. The parasites would have little opportunity of ovipositing in worms in the apples, even if they could reach them, since the apples are usually picked and hauled away not long after they become infested.

From the infested stems collected in 1915, a total of 261 insects was reared, comprising 92 ichneumonid parasites and 169 sawflies. Thus there was a parasitism of 35.2 per cent.

CHALCIDIDS.

In July and August, 1915, parasitized eggs of the dock false-worm were taken near Wenatchee, Wash. These were black in contrast to the light color of normal eggs. In due time a single small chalcidid emerged from each through a small hole near one end. Specimens submitted to Mr. J. C. Crawford were determined by him to be *Trichogramma minutum* Riley, a minute chalcidid which parasitizes eggs of various Lepidoptera and Hymenoptera, and often practically annihilates its host, at least temporarily. Eggs of the sawfly were collected at intervals from July 26 until September 8, and the amount of parasitism determined. Eggs had been collected several times previous to July 26, but none had been observed to be parasitized. Table XXIV shows the percentage of parasitism.

TABLE XXIV.—*Percentage of parasitism of the eggs of the dock false-worm by Trichogramma minutum, Wenatchee, Wash., 1915.*

Date of observation.	Total number of eggs.	Number parasitized.	Percentage parasitized.
July 26	33	13	39.3
Aug. 2	15	3	20.0
Aug. 16	11	0	0.0
Aug. 23	28	2	7.1
Aug. 30	158	13	8.2
Sept. 8	23	1	4.3
Total	268	32	11.9

BRACONIDS.

Kleine (1908) mentions a parasite of the dock false-worm in Germany, which proved to be *Rhysipolis* sp., a braconid.

PREDACIOUS ENEMIES.

Since the dock false-worm is a soft-bodied larva, living unprotected on the leaves of its food plants, it would be reasonable to suppose that predacious enemies in the form of other insects or birds would prey upon it. Only one such case has been noted, however.

On August 12 a chrysopid (lacewing) larva was discovered in the act of devouring one of the false-worms on a plant at the laboratory. The worm was small, having passed its first molt the day before. On August 26 another chrysopid larva was found eating a worm that had hatched August 24. It is probable that ladybird larvæ sometimes also feed upon immature false-worms.

REMEDIAL MEASURES.

Remedial measures may become necessary for the control of the dock false-worm where its food plants are abundant. Thorough and frequent cultivation will keep the plants from growing in orchards where clean cultivation is practiced. The bindweed (*Polygonum convolvulus*), sometimes called black bindweed, is ordinarily classed as a noxious weed, and the other plants are often troublesome and should be kept out of an orchard, even when the false-worm is not present. However, this is not always possible in orchards kept in sod, or where a perennial cover crop, such as alfalfa, is grown. With this in mind, in the fall of 1915 the writer performed a number of experiments in banding trees and in cleaning out the growth of weeds about them, to determine the best method of preventing the full-grown worms from climbing up and getting at the fruit. This work was done in the orchard from which the overwintering larvæ were collected in the spring. It is situated in the Entiat Valley, 20 miles north of Wenatchee, Wash. A portion of the orchard was selected where there was an average infestation of worms on the bindweed. The latter was growing up into the trees in many places, clinging to the trunks and lower limbs. The orchard consisted of Esopus (Spitzenburg) trees, alternating with Jonathans. Only the latter were used, since the year before it was noted that the Jonathans were injured more than the others. Sixteen trees were used, divided into four plats of four trees each. In Plats A, B, and C, the bindweed and alfalfa were cut off near the ground under the trees, and some of the lowest branches were clipped off, leaving no way for the larva to get into the tree except by way of the trunk. A band of a commercial sticky substance, one-eighth inch thick and 3 inches wide, was then applied to the trunks of the trees in Plat A, just below the point where the main limbs branched out. In Plat B, an 8-inch strip of cotton batting was placed about the trunk of each tree and tied on with cord about the middle. The upper half of the cotton band was then rolled down over the cord. Plat C received no treatment aside from clearing out the weeds and clipping a few branches. Plat D was used as a check and was left untouched. This work was done on August 26, as many of the larvæ were found to be approaching maturity. The fruit was picked October 5, and during the interval other work prevented the writer from visiting this orchard. The owner found it necessary to prop some of the more heavily loaded limbs, and these props were not banded. Some of the lower limbs, too, became so heavy that they were practically lying on the ground. This prevented the bands from forming an absolute protection against the worms, but there was sufficient protection to make a decided difference. The results of the apple counts made on October 5 are given in Table XXV.

TABLE XXV.—*Number and percentage of apples injured by the dock false-worm in the experimental plats, Entiat, Wash., 1915.*

Condition of fruit.	Plat A (commercial sticky substance).					Plat B (cotton).				
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.
Injured	7	19	7	4	37	0	2	11	4	17
Sound	298	510	628	700	2,136	170	332	466	620	1,588
Total	305	529	635	704	2,173	170	334	477	624	1,605
Per cent injured	2.30	3.59	1.10	0.57	1.70	0.00	0.60	2.30	0.64	1.06

Condition of fruit.	Plat C (weeds cleared).					Plat D (check).				
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.
Injured	5	23	14	4	46	25	22	38	22	107
Sound	185	535	272	133	1,125	351	531	556	483	1,921
Total	190	558	286	137	1,171	376	553	594	505	2,028
Per cent injured	2.63	4.12	4.90	2.92	3.93	6.65	3.98	6.40	4.36	5.27

This period was almost rainless, and the bands of cotton and commercial sticky substance were in perfect condition on October 5. No difference in effectiveness can be ascribed to the two materials used for bands, the average infestation for the two plats being 1.43 per cent. This is an infestation of only a little over one-fourth that of the check plat. The slightly greater infestation in Plat A (1.70 per cent, as against 1.06 per cent in Plat B) was due to the fact that five props were used in this plat, while only one was used in Plat B, giving the worms more opportunity of reaching the fruit in the former. It was noticed in picking the fruit in these plats that most of the injured apples were on the lower limbs and the limbs that were propped. Practically none were found in the tops of the trees.

The results in Plat C show that merely clearing away the weeds and clipping off the lower branches is of some value, the infestation being about three-fourths that of the check plat. This method may be recommended where banding materials are not at hand.

In general, it may be stated that efficient protection will be secured from the dock false-worm by banding the trees with cotton batting or other repellent materials safe to the trees, provided the lower limbs are kept well up from the ground and any props used are also banded. The bands should be applied about August 15, and not later than September 1, and under ordinary conditions will remain effective until the fruit is picked. A satisfactory sticky substance may be made by heating 5 pounds of resin until it is melted and then adding 3 pints of castor oil, stirring thoroughly. In using any sticky substance it may be applied directly to the trunks of the larger trees, but if there should be any occasion to use it on trees not more than three or four years old (trees of this age sometimes bear a few apples), a band of paper should first be tightly wrapped about the trunk and the material applied to this, otherwise it may roughen the bark of the tree. Needless to say, this paper band should be removed after the fruit is picked. A band of this substance one-sixteenth inch thick and 3 inches wide is sufficient and will cost about 3 cents a linear foot. The cotton bands are cheaper, costing from 1 to 2 cents a linear foot for bands 6 or 8 inches wide. It takes only a few minutes to apply either material to a tree.

SUMMARY.

The dock false-worm is the larva of a sawfly (*Ametastegia glabrata* Fallén) found all over Europe and in Canada and the northern part of the United States, from the Atlantic to the Pacific.

The larva is a green, wormlike creature, which feeds on dock and related plants; frequently, however, where conditions are favorable, it finds its way at maturity into apple trees, where it bores into the apples to hibernate, making them unsalable.

The dock false-worm has four generations annually, each generation occupying roughly a month, except the fourth, the larvæ of which hibernate and complete their development the following spring. Only the larvæ of this last generation are known to bore into apples.

A number of parasites have been reared, both from the egg and from the full-grown larva, and while these are valuable in partially controlling the false-worm, probably they will never control it absolutely.

Apples may be protected from this insect by keeping the orchard free of dock and other food plants, or, where this is not possible, by banding the trees with cotton or some sticky substance safe to the trees in the latter part of August and leaving the bands on until after the fruit is harvested.

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