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The Biology of the Red-Banded Leaf Roller, *Argyrotaenia Velutinana* (Wlkr.), In Missouri With Notes On Its Natural Control

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CONTENTS

Systematic Position 3
Review of Literature 4
Methods and Materials 5
Biology 6
Stages 6
Egg 6
Larva 7
Pupa 10
Adult 10
Natural Control Studies 12
Abstract 13
Literature Cited 14

THE BIOLOGY OF THE RED-BANDED LEAF ROLLER, *Argyrotaenia Velutinana* (Wlkr.), IN MISSOURI WITH NOTES ON ITS NATURAL CONTROL[1]

Earl R. Oatman[2] and Lee Jenkins[3]

The red-banded leaf roller, *Argyrotaenia velutinana* (Walker), is a native of North America and has been known for over 80 years. Only in recent years has it been considered a serious economic pest.

The species is most common east of the Mississippi River, ranging north from Texas to Minnesota and east from Kansas to Missouri, Tennessee, and North Carolina. It has also been reported from California and Manitoba, Canada.

The larvae have been recorded as feeding on a wide variety of plants, including fruit trees, small fruits, ornamentals, truck crops and weeds, with apple as the preferred host. The larvae feed on and just beneath the skin of the fruit, making prominent, shallow, irregular, feeding wounds which cork over if produced on immature apples or remain as fresh wounds on mature apples. The most common feeding area is on the underside of the leaves. The feeding habit is that of the regular leaf-tier type, causing a skeletonizing effect.

As in most apple-growing areas, the red-banded leaf roller became a serious pest to the growers of Missouri following the advent of DDT in 1946. This was apparently an indirect result of the use of DDT to control the codling moth. DDT did not control the leaf-roller larvae satisfactorily, but seriously reduced many of its natural parasites and predators. This upsetting of the biological checks which had previously suppressed the population allowed it to increase to a level of high economic importance. By 1951, the apple growers of Missouri considered the species their primary insect pest.

The following study was undertaken in 1951, with special emphasis on life history and natural control studies under Missouri conditions.

SYSTEMATIC POSITION

According to Freeman (1944), the species was described by Walker in 1863 as *Cacoecia velutinana.* At that time, Walker also described a second species, *Cacoecia triferana,* which has since been placed in synonomy with *velutinana.* Working independently, and at about the same time, Clements, in 1865, described two species of microlepidoptera, *Tortrix lutosana* and *Tortrix incertana.* These have, subsequently, been listed as synonyms of *velutinana.* The species was later placed in the genus *Lophoderus* by Fernald, in 1882, and, in 1902, Dyar

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placed it in the genus *Eulia.* Finally, in 1939, McDunnough placed *velutinana* in the genus *Argyrotaenia* where it now remains.

REVIEW OF LITERATURE

Some of the earliest accounts of the red-banded leaf roller were recorded by A. S. Packard, in 1890, who showed that the larvae were injurious to cranberries in Massachusetts, and by C. V. Riley who reported on its larval food habits in Missouri, in 1870. Fernald briefly mentioned the insect as feeding on apple foliage, in 1882, but it was not recorded as a pest of the fruit until 1918. By 1920, it was recognized as a potentially serious threat in apple-growing regions.

Chittenden (1920) first brought together all the available data on the red-banded leaf roller. His treatise included life-history observations and studies, distribution, history of the species, occurrence and type of injury, biological notes, food plants, natural enemies, and artificial control. Prior to 1920, the species was considered more of a pest on truck crops and ornamentals than on fruit. The following plants were listed as hosts: sweet corn, popcorn, beans, sweet potatoes, asparagus, celery, cabbage, parsley, strawberry, raspberry, blackberry, zinnia, syringa, hollyhock, snowball, and magnolia.

Frost (1920) noted that the red-banded leaf roller had suddenly become a serious pest on apples in Pennsylvania, and that it was commonly found feeding on apples at harvest.

Later, Frost (1921) mentioned the species was exceedingly abundant and injurious, causing most of the late feeding damage on apples. He first recorded the larvae were entirely green, differing in this respect from other leaf roller pests on apples.

In 1925, Frost published a bulletin on the biology and control of the red-banded leaf roller in Pennsylvania, stressing the life history and parasites of the insect. He found it overwintered in the pupal stage, with the adults emerging early in the spring. Three complete generations were reared. The first-generation eggs were laid on the limbs and larger branches; the second and third on the foliage of the apple. The first- and second-brood larvae fed principally on the foliage, but many of the third brood moved to the fruit to feed. Frost reared 13 species of hymenopterous parasites and one species of Diptera from the larval and pupal stages.

Walden (1926) reported that apples injured by the surface feeding of the red-banded leaf roller were most apparent at harvest. He noted that the larvae, when present, continued to feed on apples in storage before pupating.

Hough (1927) published a bulletin on the biology and control of the red-banded leaf roller in Virginia, giving the results of seasonal and life history observations, habits of the insect, general appearance, food plants, and parasites. He found that there was a partial fourth generation in 1925. Sixty-three food plants were listed, with apples as the preferred host. Hough found parasitism was important in keeping down outbreaks. He recorded nine species of parasites.

Hall (1930) reported that the red-banded leaf roller had a full first and second generation and a partial third generation in Ontario, Canada. He noted the insect overwintered in the pupal stage; eggs hatched from May 24 to mid-September; there were five larval instars; and that it was ordinarily suppressed by climatic conditions, parasites and orchard sanitation, but, under favorable conditions, it became an economically important pest.

Hall (1933) presented a study of the biology and life history of the apple leaf rollers of Ontario in which the red-banded leaf roller was listed. A key to the identification of mature leaf-roller larvae was also included.

Townsend (1943) reported there were two annual broods of the red-banded leaf roller in Connecticut. He suggested that the decline of the insect after several years of abundance was due to natural factors, primarily parasites.

Glass and Chapman (1949) stated that the first-brood larvae of the red-banded leaf roller injured 40 to 50 percent of the fruit in unsprayed orchards with commercial damage in sprayed apple orchards in New York in 1948. Where the second-brood larvae were abundant, 50 to 75 percent of the fruit dropped prematurely, and many apples left on the trees were unfit for storage or sale. Spring-brood moth flight occurred before bloom and most of the eggs were laid by time of full blossom. First-brood moths were most active laying egg packets during mid-July. Parasites, predators, and diseases were not important in checking the population.

Taschenberg (1949) noted that the red-banded leaf roller was more common in New York vineyards in 1948 than before. He reported that all parts of the grape cluster were attacked. Damage was by surface feeding on the berry, pedicels, and peduncle, as well as by webbing left on the cluster.

Rings (1949) noted that the red-banded leaf roller larvae were feeding on plums and peaches in Ohio, in 1948. The first-brood larvae were more serious on Stanley plums than those of the second brood. The second-brood larvae, however, caused more damage to peaches than the first. He suggested there was a possibility that this species might become increasingly important on peaches and other stone fruits.

METHODS AND MATERIALS

Life history studies of the red-banded leaf roller were conducted primarily in a screened insectary measuring 6 x 7 x 10 feet.

First-generation larvae and pupae were collected from infested apple orchards near Columbia, Missouri, in 1951, and placed in a 2-cubic-foot screen-wire cage for emergence and oviposition. Mated females laid their egg packets on fresh sprigs of apple leaves. The newly emerged larvae were transferred to individual apple leaves kept fresh in small vials of water. These were placed inside separate jelly glasses. Forty-five to fifty first-instar larvae were used for the study of each generation. When the larvae reached the third instar, the jelly glasses were covered with cheesecloth and fastened with rims from the top of ice-cream cartons. This prevented the escape of the larvae and protected them

from destruction by natural enemies. Upon pupation, the cheesecloth covers were replaced by circular screen-wire covers which fitted snugly inside the rim of the jelly glass. Records were kept on the number of days in the pupal stage, and the sex of the emerging moths. Newly emerged males and females were paired and placed in separate cheesecloth-covered battery jars. The adults were provided with drops of sugar-water solution, and observed daily for oviposition, mating, feeding, and longevity. A minimum of 20 pairs of adults were observed for records of each generation throughout the season. The egg packets were observed daily for hatching, and the method of emergence of the larvae was noted.

Overwintering pupae of the third and fourth generations, in rolled leaves, were placed in 10 x 20 inch screen-wire cylinders, covered at the ends with cheesecloth. These were left in the outdoor insectary to provide emergence records of the spring generation of moths. The life-history studies were continued through the spring of 1952.

Individual eggs and newly emerged larvae were measured with an ocular micrometer. Measurements of the last-instar larvae, pupae, and the wing spread of male and female moths were also recorded.

Throughout the life-history studies, data on predators, parasites, and disease organisms were accumulated.

Apple orchards in central and southwestern Missouri were visited during the 1951 growing season, and during the spring of 1952, for field observations on the seasonal activities of the red-banded leaf roller.

Larvae and pupae, including overwintering pupae, were collected during visits to outlying infested orchards, and held in ice-cream rearing cartons in the insectary for parasite emergence.

The material suspected of being diseased was sent to Dr. E. A. Steinhaus, Department of Insect Pathology, University of California at Berkeley, for identification.

The parasites were determined by the following specialists: B. D. Burks, K. V. Krombein, C. F. W. Muesebeck, and L. M. Walkley, of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

BIOLOGY

There are three complete generations and a partial fourth of the red-banded leaf roller in Missouri. It overwinters in the pupal stage.

Stages

Egg.—The egg is a pale, yellowish-green, granulate, oval disc, averaging 0.68 by 0.85 mm. The egg packet consists of closely appressed, overlapping, individual eggs covered with a gelatinous envelope (Figs. 2 and 4). As the embryos develop, the packet becomes gray-green, and the outlines of the larvae become distinct just before hatching. The packets are difficult to see on a smooth, dark-green background. After hatching they have a silvery appearance.

The first-generation eggs were laid on the trunk, main branches, and smaller branches (Fig. 2) of the apple tree, and were observed from within a few inches of the ground to a height of 7 feet. A few egg packets were found during the late silver-tip stage. Some of the eggs were hatching just prior to full bloom. The egg packets usually were large. One packet found on a tree trunk contained 178 eggs. The eggs of the first, second, and third-generation adults were laid on the upper surfaces of the leaves (Fig. 4). The incubation periods are shown in Table 1.

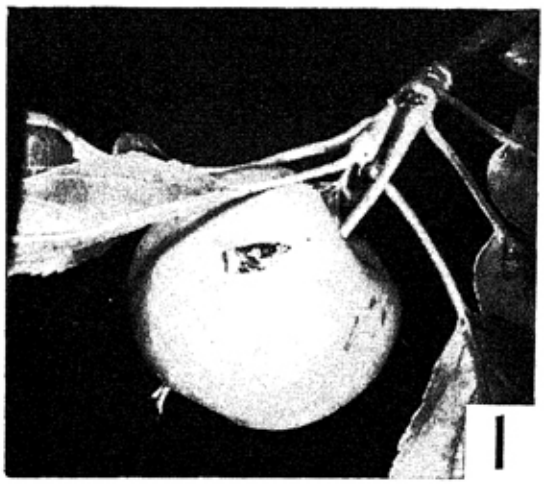
TABLE 1-INCUBATION PERIOD OF THE EGG PACKETS OF THE RED-BANDED LEAF ROLLER.

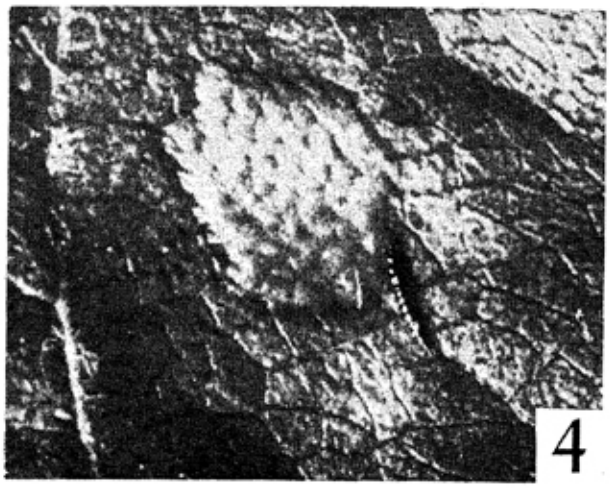
Generation	Number Observed	Number Days		
		Minimum	Maximum	Average
First	80	8	25	16.0
Second	65	5	9	6.7
Third	60	5	8	6.5
Fourth	58	9	15	11.8

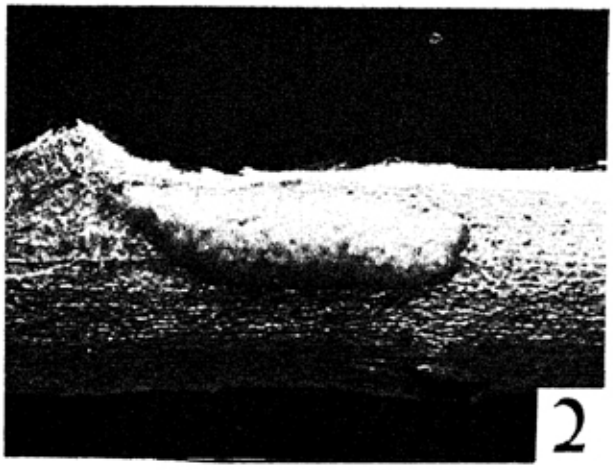
Larva.—The newly emerged, yellowish-green larvae average 1.5 mm. in length. The mature, grass-green larvae (Figs. 5, 6, and 10) average 18 mm. in length when full grown. The larvae spin silk which is used for rolling a leaf (Fig. 7), fastening leaves together, fastening a leaf to an apple (Fig. 8), or fastening several immature apples together. Some of the damage was caused by larval feeding on the leaves (Fig. 7). Economic damage occurred when the larvae fed on the immature and mature apples, and on apples in storage (Figs. 8 through 12). There were five larval molts and instars. The newly emerged larvae generally fed on the lower surfaces of the leaves, protecting themselves by eating into and webbing over their feeding areas.

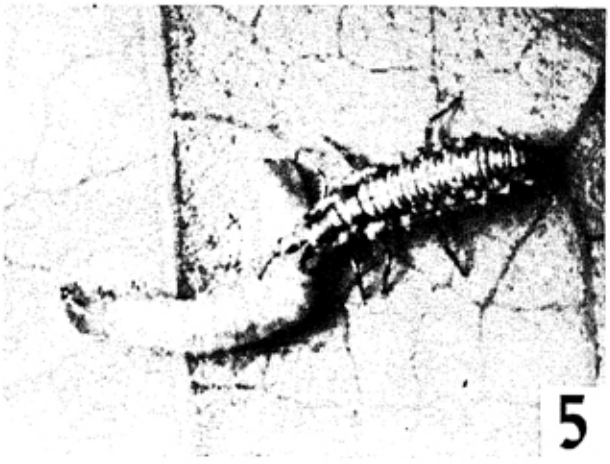
When disturbed by spraying, larvae dropped and hung suspended on silken threads from their places of concealment. Some that dropped to the ground cover beneath the trees formed a place of concealment on various types of vegetation. The larvae fed on several plants commonly found beneath the apple trees. Some of these were: smartweed, burdock, ironweed, bullnettle, goldenrod, pokeweed, morning glory, poison oak, horseweed, blackberry, coral berry, elm, post oak, and sassafras sprouts. They fed on sourdock and red clover near the insectary. The species was also reared from peach, cherry, mock orange, and red raspberry, during the study.

The larvae of the first generation fed principally on the succulent apple foliage, moving to the water sprouts, as the older leaves hardened (Fig. 7). Some damage was done to the immature apples by this generation (Fig. 8). The second and most of the third-generation larvae also fed primarily on the leaves, especially the outer new growth and the inner water sprouts. The third-generation larvae with the extended larval stage (pupae overwintered) generally fed on mature apples during and prior to harvest. The larvae of the fourth generation caused most of the damage to the fruit. They left the hardened leaves to feed on









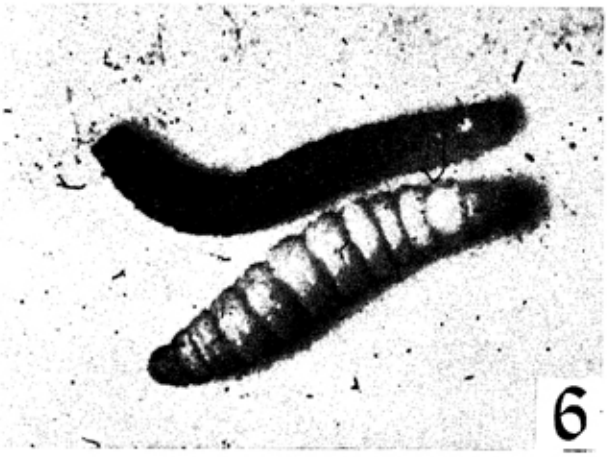
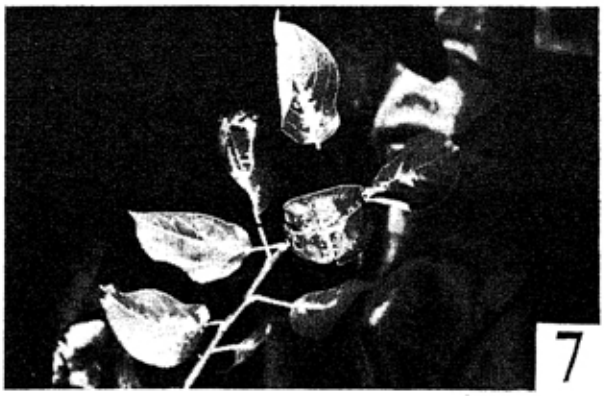
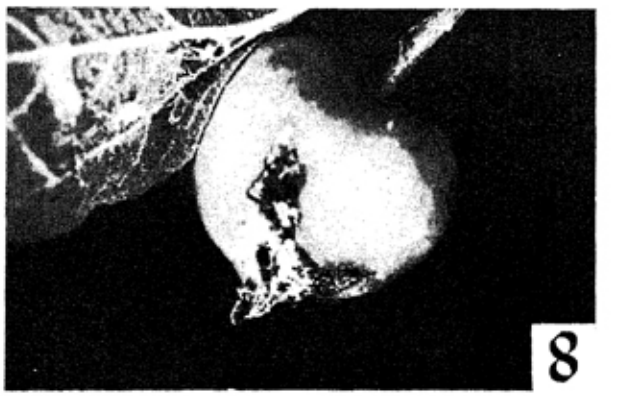
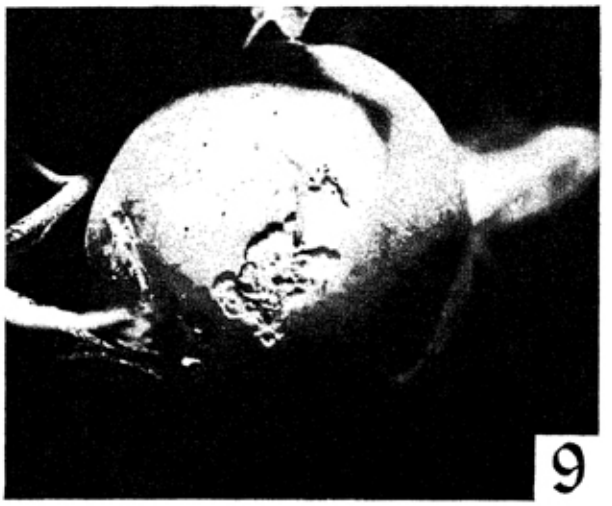


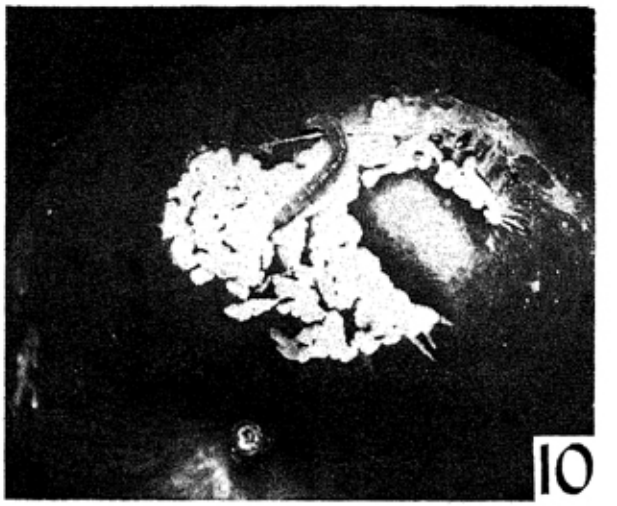
PLATE I

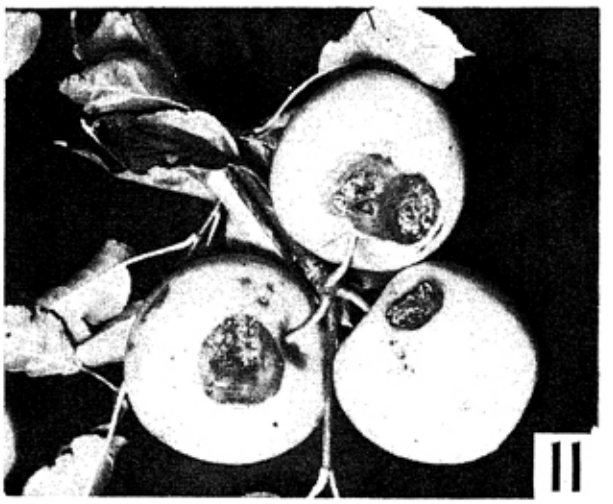
Red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.): Fig. 1. Female on apple; Fig. 2. First-generation egg packet on apple twig; Fig. 3. Pupa in pupation site on apple leaf; Fig. 4. Predaceous thrips feeding on egg packet on apple leaf; Fig. 5. Aphid-lion larva feeding on mature larva; Fig. 6. Mature normal larva (top) and virus infected (bottom).











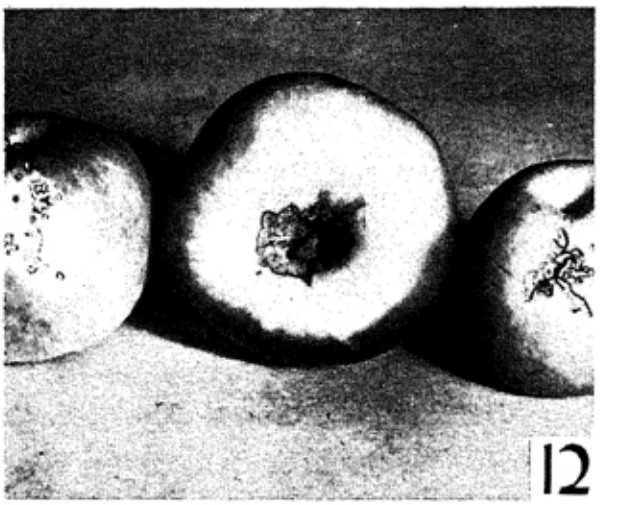


PLATE II

Red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.): Fig. 7. Larval feeding injury to apple leaves; Fig. 8. First-generation larval injury to leaf and immature apple; Fig. 9. Larva feeding on mature apple; Fig. 10. Mature larva feeding on apple in storage; Fig. 11. Larval injury to apple cluster; Fig. 12. Injured apples at harvest.

the maturing apples (Fig. 9). Larvae overlooked in the grading and packing operations continued to feed on the stored fruit until they pupated (Fig. 10). Many of the fourth-generation larvae withstood temperatures as low as 5 to 13° F. for several days and lived 53 days without feeding. They pupated normally. The length of the larval stage is shown in Table 2.

TABLE 2-LENGTH OF THE LARVAL STAGE OF THE RED-BANDED LEAF ROLLER.

Generation	Number Observed	Number Days		
		Minimum	Maximum	Average
First	35	21	34	27.6
Second	39	20	33	23.9
Third	10	19	28	22.4
Third[a]	16	66	82	71.1
Fourth[a]	15	65	88	77.5

[a]Overwintered in pupal stage.

Pupa.—The pupa (Fig. 3) is light greenish-brown at first changing to a mahogany-brown before the adult emerges. The pupae were found primarily in tightly rolled leaves which had been tied with silk. However, in the fall, they were also found under a light webbing of silk on a fallen apple upon which the larvae had been feeding. The rolled leaf with the carpet of spun silk served as protection and to anchor the pupal case when the adult was struggling to emerge. The anterior end of the empty pupal case often protrudes from the rolled leaf. The peak of pupation for the third-generation overwintering pupae was around the middle of October. The fourth-generation pupae of the red-banded leaf roller constituted the majority of the overwintering pupae. They were found in the rolled leaves on the ground under the apple trees among other leaves and debris of the previous year's growth. The fourth generation began pupating during the first days of November and continued into the first half of December, with the peak occurring during the latter half of November and the first days of December. There was no apparent correlation between temperature and time of pupation. The length of the pupal stage is shown in Table 3.

Adult.—The wing expanse of the red-banded leaf roller measures from 11.0 to 15.5 mm. The male is usually smaller than the female. A reddish-brown band extends obliquely across the fore wing, giving the insect its common name. The

TABLE 3-LENGTH OF THE PUPAL STAGE OF THE RED-BANDED LEAF ROLLER.

Generation	Number Observed	Number Days		
		Minimum	Maximum	Average
First	30	9	16	12.7
Second	27	6	10	8.4
Third[a]	8	7	9	8.0
Fourth[b]	--	--	--	----

[a]Part of third generation overwintered in pupal stage.
[b]Overwintering pupae.

color of the female (Fig. 1) is more intense and the pattern more regular in outline than the male, which is mottled. The female abdomen is truncate posteriorly, whereas that of the male is slender with a tuft of comparatively long hairs at the posterior which give it a pointed appearance.

Spring moth emergence began during the early silver-tip stage of apple tree development. The peak of emergence occurred within 2 weeks, with most of the moths emerging within 4 weeks. Emergence was closely related to the temperature. The first moths were found resting on the leaves and other debris on the ground adjacent to overwintering pupation sites in rolled leaves from which they had just emerged. Others were seen resting on the tree trunks and main branches next to fresh egg packets.

Moth flight activity was most common from mid-afternoon until early evening, during which time the adults flew among the apple trees in a fluttering, erratic, fashion. The males were more active than the females. They were attracted to and fed upon sugar water.

Mating usually took place between mid-afternoon and the early evening hours. The moths assumed a horizontal position during copulation, with the posterior ends of their abdomens together and the wing tips of one or the other of the two sexes held slightly over those of the other. One pair was observed in copulation for 1½ hours. Mating occurred usually within 24 hours after emergence and the female generally oviposited within the next 24 hours. This normal sequence was interrupted, and often delayed several days, by adverse weather conditions.

Egg-laying activity was closely related to the temperature. Meteorological disturbances, such as severe electrical storms, also interrupted egg-laying activities. Females were frequently observed laying eggs during the afternoon and early evening hours. The ovipositing female used a pumping circular motion, touching her abdomen several times to the surface where the egg was to be laid. The egg was then deposited and drawn to the center of the egg mass, producing an overlapping effect (Figs. 2 and 4). The female then moved slightly forward or to one side before laying the next egg. The process was repeated until the egg packet was formed. Females in the insectary readily deposited egg packets on a glass surface. The average number of egg packets, eggs per packet, and eggs per female for each generation are shown in Table 4.

TABLE 4-EGG DEPOSITION PER FEMALE RED-BANDED LEAF ROLLER.

Generation	Number of Females	Average Number		
		Egg Packets	Eggs/Packet	Eggs
Spring	25	5.2	42.4	208.5
First	25	5.8	50.2	242.1
Second	20	5.2	42.9	208.7
Third	25	7.5	28.4	204.1

The length of adult life varied between generations. Table 5 shows that the spring adults had the longest, and the first generation the shortest, life span. The male life span was generally less than that of the female.

TABLE 5-LENGTH OF THE ADULT STAGE OF THE RED-BANDED LEAF-ROLLER.

Generation	Number Observed	Number Days					
		Minimum		Maximum		Average	
		♂	♀	♂	♀	♂	♀
Spring	25	4	4	22	20	12.4	13.4
First	22	2	2	10	12	5.3	7.6
Second	20	3	3	14	24	7.6	9.8
Third	30	2	8	18	23	11.4	13.8

NATURAL CONTROL STUDIES

Predators observed feeding on the red-banded leaf roller were: birds and aphid-lions on larvae in orchards; thrips and aphid-lions on egg packets in the insectary; and the aphid-lion on all stages in the insectary during life history studies. The thrips and aphid-lions are shown feeding in Figures 4 and 5.

A low incidence of larvae affected with the granulosis virus, *Bergoldia clistorhabdion* Wasser and Steinhaus, was observed in the orchards. However, the virus occurred frequently in the insectary, affecting 27 percent of the third-brood larvae in 1951. Diseased larvae changed from green to a bleached straw color accompanied by a soft, puslike, bloated appearance (Fig. 6). There was 100 percent mortality of the infected larvae.

In the summer and fall of 1952, this virus reduced the entire population of red-banded leaf rollers to such low numbers that it was difficult to find living larvae in orchards. This condition prevailed in Missouri and Kansas orchards in 1953, but by 1954 a few orchards again displayed slight damage by these insects. The population built up progressively in succeeding years and by 1956-57 was again a problem of major proportions in the Missouri-Kansas area. By 1959, at least some populations of red-banded leaf rollers in southern Missouri exhibited a marked resistance to TDE, an insecticide usually considered as almost specific against this pest.

Hymenopterous parasites were the most important natural control factor. They were reared from the larval and pupal stages. Forty percent of the first-generation larvae collected in central Missouri in 1951, and 18 percent of the overwintering pupae collected in southwestern Missouri in 1952, were parasitized.

The species of parasites were as follows:

ORDER HYMENOPTERA

Family Bethylidae

Goniozus platynotae Ashm.

Family Braconidae

Apanteles tischeriae Vier.

Apanteles sp.

Clinocentrus tarsalis Ashm.

Microgaster epagoges Gah.

Microgaster pantographae Mues.
Oncophanes atriceps (Ashm.)

Family Chalcididae

Brachymeria ovata (Say)
Brachymeria sp.

Family Ichneumonidae

Atrometus praediscae (Ashm.)
Chorinaeus sp.
Glypta vulgaris Cress.
Glypta sp.
Horogenes obliteratus (Cress.)
Horogenes sp.
Haplaspis mandibularis (Prov.)[4]
Itoplectis conquisitor (Say)
Isdromas sp.
Otacustes sp.
Pimpla aequalis Prov.
Sp. of Hemitelini

Family Pteromalidae

Dibrachys cavus (Walk.)

Goniozus platynotae Ashm. was the most abundant parasite. The largest number of species was in the family Ichneumonidae.

ABSTRACT

There are three full generations and a partial fourth generation of the red-banded leaf roller in Missouri. Spring-generation moths emerged from overwintering pupae early in the silver tip stage of apple tree development. There was a close correlation between emergence and temperature. The first egg packets were laid in late silver tip stage, and hatched a few days before full bloom. Egg packets of the first generation were laid on the trunk, branches and twigs, and those of the second, third, and fourth generations were deposited on the upper surfaces of the leaves. First-generation larvae fed on the succulent leaves, but also injured immature fruit. Second-generation larvae damaged less fruit, feeding primarily on succulent, outer, terminal leaves and inner water sprouts. Third- and fourth-generation larvae left the hardening leaves to feed on maturing apples, causing most of the fruit injury. Fourth-generation larvae also fed on apples in storage when overlooked in packing and grading operations. Third- and fourth-generation larvae survived several days and nights of below freezing temperatures, and several weeks without food, yet pupated normally. Overwintering third-generation larvae pupated in October; the fourth in November and early December. There was apparently no correlation between pupation and temperature. The aphid-lion was the principal predator, feeding primarily on the larval

[4]Probably hyperparasite.

and egg stages. Minor predators included birds and thrips, feeding on the larval and egg stages respectively. Parasites were the most effective natural control factor. Twenty-two hymenopterous species were reared from the larval and pupal stages. The larvae were infected by a granulosis virus, especially prevalent under insectary conditions, resulting in 100 percent mortality of the infected larvae.

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