THE BIOLOGY AND CONTROL OF THE SEED-CORN MAGGOT [*Hylemya cilicrura* (Rondani)] ON SPINACH FOLIAGE

By

BENJAMIN H. KANTACK

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Kansas State College

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Thesis Approved:

R. R. Walton

Thesis Adviser

F. A. Fenton

Member of the Thesis Committee

D. E. Bryan

Member of the Thesis Committee

John E. Thomas

Member of the Thesis Committee

D. E. Howell

Head of the Department

Robert MacVicar

Dean of the Graduate School

PREFACE

In recent years the seed-corn maggot has presented a serious problem to the spinach industry in Oklahoma. Foliage infestations have caused serious losses to the growers and processors of this crop. Many growers have considered the use of insecticides as a possible control for this insect.

In the fall of 1952, Dr. R. R. Walton, associate professor of Entomology, in charge of vegetable research at the Oklahoma Agricultural Experiment St tion, suggested that I investigate the biology and possibilities of controlling this insect on spinach. This I have attempted to accomplish by biological investigations with particular emphasis on the source of foliage infestations nd the effect of various insecticidal treatments as possible control measures.

I wish to express my appreciation to my major adviser, Dr. R. R. Walton, for valuable advice and suggestions which aided me in planning and conducting this study. The author extends special acknowledgment to members of the examining committee consisting of Drs. D. E. Bryan, assistant professor of Entomology; D. E. Howell, professor and head of the Department of Entomology, Oklahoma A. & M. College; F. A. Fenton, professor and head emeritus of the Department of Entomology; and J. E. Thomas, associate professor of Botany and Plant Pathology, for their constructive criticisms of this manuscript. I am grateful to G. A. Bieberdorf, assistant professor of Entomology and Lt. G. A. Garrett, Entomologist, United States Air Force, for photog aphic illustrations; to Dr. R. G. Dahms, professor of

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Benjamin H. Kantack

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INTRODUCTION

Hylemya cilicrura (Rondani)[1], the seed-corn maggot[2], is a serious menace to the spinach industry in Oklahoma. The larvae are usually subterranean feeders on many vegetable crops; however, in recent years, foliage infestations on spinach have limited the production of this crop. Foliage infestations present a serious problem to the spinach canning industry as the presence of larvae and damaged leaves on the harvested foliage usually results in contamination of the canned product. In order to facilitate control studies, investigations have been conducted at the Oklahoma Agricultural Experiment Station in an attempt to determine how this foliage infestation occurs.

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[1]Order Diptera, family Anthomyiidae

[2]Muesebeck, C. F. W. 1950. Common names of insects approved by the American Association of Economic Entomologists. Jour. Econ. Ent. 43:117-138.

SURVEY OF THE LITERATURE

The seed-corn maggot is widely distributed throughout the temperate zones. The seed-corn maggot has been recorded from Canada to the Mexican border and from the Atlantic to the Pacific Coast, including all arable regions of the United States (Chittenden 1902, Hawley 1922). It also occurs in Alaska, Canada, Bermuda, South Americ , Europe, Asia, South Africa and Hawaii (Reid 1940), and Australia (Johnson 1952). Chittenden (1916) states that the seed-corn maggot is probably responsible for damage attributed to the cabbage maggot and onion maggot in the states south of New Jersey.

In American economic entomological literature, the seed-corn maggot has been discussed under various common and scientific names. Among the common names are the deceiving wheat fly, locust-egg anthomyian, anthomyian egg parasite, seed-corn maggot, corn anthomyia, bean fly, and fringed anthomyian (Hawley 1922). It also has been referred to as the spinach budworm (Smith 1933).

Hylemya cilicrura was described in the genus Chortophila by Rondani in 1865 (Reid 1940). Among the scientific names which have been applied to the seed-corn maggot, Reid (1940) listed the following: Phorbia fusciceps (Zett.); Anthomyia zeae Riley; Pegomyia fusciceps (Zett.); Chortophila fusciceps Zett.; Hylemyia deceptiva Fitch; Anthomyia augustifrons Meigen; Chortophila cilicrura Rond.; Phorbia cilicrura Rond.; and Anthomyia radicum var. calaloptent Riley.

The writer has followed the usage of Huckett (1924) with regard to the genus Hylemya instead of European authors who favor including this species in the genus Chortophila.

Host Plants and Adult Food

After emergence the adult flies seek moisture and are found in large numbers around flowering plants and accumulations of organic material, being particularly abundant in freshly cultivated fields rich in organic materials. Odors from several lcohols, including ethyl, isopropyl, and butyl, and from fermenting yeast mixed with honey, molasses, brown sugar and corn syrup are adult attractants (Peterson 1924). Dried silkworm pupae and cottonseed meal are also attractive to the flies (Hawkawa et al. 1933).

Adult feeding was observed by Reid (1940) on the following plants: chickweed, narcissus, huckleberry, strawberry, plum, peach, pear, chokecherry, apple, serviceberry, loblolly bay, cabbage, broccoli and collards. Sweetened water and egg white were also a source of food for the adult.

The larvae of the seed-corn maggot feed on a wide range of organic materials, including both living plants as well as decaying organic matter. Reid (1940) lists 45 species of living plants belonging to the following 18 families: Cannabinaceae, Caryophyllaceae, Chenopodiaceae, Compositae, Convolvulaceae, Cucurbitaceae, Cruciferae, Fagaceae, Gramineae, Iridaceae, Leguminosae, Liliaceae, Malvaceae, Polygonaceae, Pinaceae, Rosaceae, Solanaceae, Umbelliferae.

In addition, Reid (1940) reported larvae of this species fed on cottonseed meal, larch bark, locust eggs, animal tankage, fish meal and dead insects. The larvae have been reported feeding and causing extensive damage on Douglas fir and spruce seedlings in a nursery in Washington (Breakey et al. 1944). Hayes (1922) recorded serious damage by the seed-corn maggot to sorghums in Kansas. Howard (1900) reared this insect on human excrement.

The seed-corn maggot spreads Erwinia carotovora, the causual organism of potato blackleg. Leach (1940) found that these bacteria can survive in the insect during metamorphosis and are associated with all stages as the egg is surface-contaminated at oviposition.

Hylemya cilicrura larvae have caused extensive damage to many crops. Much of this damage has been seed and seedling failures as a result of subterranean feeding. In recent years it has become a serious pest of spinach as a foliage feeder.

According to Reid (1936), during 1918 specimens were collected from the hearts of spinach on irrigated land in Texas and F. H. Chittenden identified these insects as Hylemya cilicrura. Injury to spinach seedlings was described in December 1923, and February 1924, near Chadbourn, North Carolina (Reid 1936). The so-called spinach budworm was also reported as being in Texas by Hawthorn (1932). According to Hawthorn, it was found during cloudy and foggy weather. F. L. Thomas (1932) reported serious damage to spinach in the Winter Garden region of Texas and a similar account was published by Smith (1933) from the same area. Smith also stated growers had associated it with damp weather and that plants with spreading terminals were less subject to attack. Smith (1933) mentioned a report of similar damage from the Walla Walla district in Washington. Walton and Ashdown (1951) reported serious infestations in Oklahoma during the falls of 1949 and 1950 with lighter infestation on the spring crops.

Control

Control measures on various crops have included discretion in fertilizer use, shallow planting, early and late planting of crops, suberizing of potatoes, chemical treatments applied to soil and seed, poison bait and repellents.

Damage appeared more severe where heavy applications of barnyard manure were applied before planting (Smith 1933). In the South Atlantic States where this insect is a serious pest of potatoes, suberizing the cut potatoes before planting proved effective. Chemical treatments of sulphur, organic mercury compounds and mercuric chloride tended to increase damage (Reid et al. 1940). According to Reid (1936), the most severe infestations, especially in beans, occurred in soils with the greatest quantity of organic matter. Methods of prevention, such as using commercial fertilizers in place of organic materials, have been recommended. Chittenden (1902) recommended soaking sand in kerosene and placing around the young seedlings. Shallow planting of beans has also been recommended (Hawley 1922). Seed treatments as a control were ineffective on beans in New York. Chlordane and benzene hexachloride reduced maggot injury to some extent (Restich and Schwart 1948). Turner (1946) found no marked reduction in damage to beans seed-treated with Spergon at 3 per cent DDT. Aldrin, chlordane, dieldrin and lindane gave satisfactory results as seed-treatments on beans. DDT, parathion and toxaphene did not prove satisfactory (Howe et al. 1952). Howe and Schroeder (1951) obtained effective results combining fungicides with dieldrin and lindane as a seed treatment. Lindane combined with a suitable fungicide gave control on beans (Lange et al. 1951). Chlordane and BHC were effective on seed corn in Louisiana (Floyd and Smith 1949). Chloropicrin and DD (a mixture of dichloropropylene and dichloropropane) reduced injury to fir seedlings in a nursery (Breakey et al. 1944). Hawkawa et al. (1933) found that several mixtures consisting of pyrethrum and wood ash, tobacco powder and wood ash, naphthalene and wood ash tended to inhibit oviposition when spread over a field in large amounts. In a single repellent test conducted with tobacco compounds using nicotine resinate, tobacco oil and a 40 per cent nicotine sulph te on commercial white corn, some repelling effect was indicated (Hayes 1922).

Walton (1951) increased emergence of spinach seedlings using lindane and dieldrin as soil treatments. Lindane treated plots in this test showed an increase in plant stands of 102 per cent when applied at one pound per acre rate. Dieldrin applied at two-thirds pound per acre showed an increase of 32 per cent. Few accounts appear to be available involving control attempts on foliage infestations. Larval populations on foliage were reduced from 58 to 69 per cent using high pressure, high volume spray applications of chlordane, lindane and dieldrin. Lindane gave the highest reduction when applied at one pound per acre while dieldrin when applied at two-thirds pound per acre was almost as effective (Walton 1951).

H. cilicrura is subject to attack by natural enemies when in certain stages and when either above or below the soil surface. Chittenden (1902) mentioned records of H. cilicrura adults parasitized by a fungus disease Empus americana Thaxter. Miles (1950) reported parasitism by the nematode Heterotylenchus aberran Bouien. Among insect enemies Reid (1940) recorded Xylocrabro stirpicola Packard, Aphaereta muscae Ashmead nd several species of spiders attacking H. cilicrura. The follo ing irds ere also listed: English spar ow, Passer domesticus (Linnaeus); p lm warbler, Dendroica palmarum (Gmelin);

crested mynah, _Aethiopar cristatellus_ (Linnaeus); black swift, _Nephoecetes niger_ (Kennerly); and old-squaw duck, _Clangula hyemalis_ (Linnaeus).

METHODS AND MATERIALS

Trapping records were taken during the fall growing season from September 23 to November 22, 1952, and from September 12 to November 22, 1953 at Stillwater, and at Bixby from September 17 to November 17, 1953. For these records, a 12"x12"x4", 16-mesh screen wire trap was used. The top of the trap was fitted with a 4-inch plywood square on which a 2-inch screen funnel was inverted. The funnel was grooved to fit either a quart jar or a screen cylinder. Tankage (a mixture of dried animal residues) was used for bait in all traps.

The positive phototropism of the flies was used in removing them from the traps. The quart jars or screen cylinders were covered with a dark cloth and a cloth sleeve was fitted over the open end of the jar or cylinder. The mouth of a glass vial which was exposed to light was inserted in the cloth sleeve. With this arrangement, the flies crawled from the darkened container into the vial where they could be conveniently handled and examined.

Cages were constructed from 16-mesh screen wire, each cage measuring five inches in diameter and four inches in height. A black cloth was placed on top of the cages, since by darkening the upper portion of the cage, the flies tend to stay nearer the soil and plants. A vial of sugar water with a cotton wick was used for feeding caged specimens.

To obtain a supply of eggs deposited in the soil during the fall of 1952 and again in 1953, two cages of flies were maintained on pots of soil containing tankage but no plants. As flies in these cages died, fresh field-trapped adults were introduced in order to maintain a density of 25 flies per cage. Eggs were collected from these caged pots by stirring the soil with a dissecting needle and then picking up the eggs individually with a damp camel hair brush.

Eight-inch pots were seeded to spinach using the commercial variety Bloomsdale Longstanding. Cages were placed over these pots which previously had been thinned to three plants per pot. Six cages were maintained from September 22 to November 21 and six from October 15 to November 20, 1952. Fresh field-trapped adults were introduced in each cage regularly and 20 flies were kept in each cage. Daily examinations were made to collect eggs deposited on foliage and to determine if larvae migrated up into the terminal buds.

Field surveys were taken on foliage oviposition during the fall of 1952, the spring and fall of 1953, and the spring of 1954. Subterranean feeding of the larvae was observed in the field during April and November 1953, and on potted plants in 1952. Foliage feeding was observed in the field during the spring of 1953 and again in the fall of 1953 on both field and potted plants.

Rearing Methods

Eggs from both soil and spinach foliage were used in rearing studies in the laboratory. Specimens were observed from the eggs to the adult stage by rearings made in the soil and in spinach buds.

Small Stender dishes containing a soil and tankage mixture at a 3:1 ratio and a small piece of sliced potato were used for soil rearings. The soil was maintained at a medium moist condition.

Incubation records were taken at a temperature of about 70° F. to 72° F. The per cent hatched and the length of the incubation period were recorded. Eggs were placed on top of the soil for rearings made in the soil. For specimens reared on foliage, the eggs were placed in the terminal buds. These eggs were also hatched, but no incubation period was determined since these eggs were field-gathered. However, most of the eggs hatched within one to two days after gathering.

The lengths of the larval stages were recorded for larvae from eggs collected in the soil and for larvae reared from eggs collected from spinach foliage reared in the soil and on a foliage medium. The per cent survival along with the length of larval stage were recorded. Studies were made at mean temperatures of about 70° F. and 62° F. throughout the larval period.

All larvae were removed from the rearing medium immediately following pupation and placed in jelly glasses containing a fine silty-loam soil. The pupae were buried in the soil to a depth of about one inch and the soil was kept at a medium moist condition. Records on emergence were taken, and durations of the stages were recorded at mean temperatures of approximately 70° F. and 82° F. Comparisons were made between specimens from soil-collected eggs and from foliage-collected eggs on different food media in regard to the duration of various stages in the life cycle.

Mounts of fresh eggs collected from the soil and foliage were studied for structural differences. Mounts of newly-h tched larvae from both egg sources were made and compared as were second and third instar larvae reared in soil and on the foliage. Comparisons were made by microscopic studies of the posterior spiracles and bucco-pharyngeal apparatus. Larval mounts were made on standard glass slides with Hoyer's mounting medium.

Control Methods

Low pressure, low volume control tests were initiated at Muskogee, Oklahoma on spinach planted in Janu ry 1953. One spray application of each insecticide was applied using a Bean sprayer with hollow cone nozzles (1.5 gallons per hour), delivering a volume of five gallons per acre at 120 pounds pressure. Nozzles were adjusted about eight inches above the plants. Plant examinations were made on each of four plots four days after applying the treatment.

The insecticides used and rates of applications were as follows:

Insecticide	Lbs. Per Acre Applied
Lindane-20% emulsion concentrate	0.4
Parathion-25% emulsion concentrate	0.375
Tetraethyl pyrophosphate-25% liquid concentrate	0.375

In high pressure, high volume tests t Bixby during March 1953 on spinach carried over from fall drilled plantings, one applic tion for each of methyl parathion and lindane was made at pressures of 200 and 300 pounds respectively. These insecticides were applied using a Bean orchard sprayer with hollow cone nozzles (60 gallons per hour) spaced 30 inches apart and at about 18 inches above the plant buds. A volume of 50 gallons per acre with 0.4 pound toxicant was applied. A random plant sample of infested plants was examined one week later from each plot.

Control tests were continued in the fall of 1953 at Bixby. This planting was made on September 12 in three row plots with all rows 18 inches apart. These plots were 200 feet in length. As a result of excessive drouth, this spinach was irrigated at weekly intervals during the first four weeks.

In low volume, low pressure applications, a Bean Spartan garden sprayer mounted on bicycle wheels was used. Hollow cone nozzles (1.5 gallons per hour) spraying a volume of about five gallons per acre at 60 to 80 pounds pressure were used in all applications.

The first application was made when foliage eggs were first observed and application was repeated three times at weekly intervals by which time all foliage eggs had hatched. A second series of plots received three treatments at two-week intervals.

Random plants were harvested and examined one week to ten days after the second, third and fourth applications on the one-week series. Examinations were made after the first and third applications on the two-week series.

The insecticides used and the rates of applications are given below:

Insecticide	Lbs. Per Acre	Application Interval
Chlordane-42.0% emulsion concentrate	1.0	1 week
Aldrin-23.1% emulsion concentrate	0.25	1 week
Dieldrin-18.5% emulsion concentrate	0.25	1 & 2 weeks
Dieldrin-18.5% emulsion concentrate	0.50	2 weeks
Lindane-20.0% emulsion concentrate	0.25	1 & 2 weeks
Lindane-20.0% emulsion concentrate	0.50	2 weeks
Parathion-25.0% emulsion concentrate	0.25	1 week
Heptachlor-25.0% emulsion concentrate	0.25	1 week
Endrin-18.5% emulsion concentrate	0.25	1 week
Chlorthion-25% water wettable powder	0.25	1 week

With the exception of chlorthion which was a water wettable powder, all materials were applied as emulsions. Chlorthion is an organic thiophosphate having the formula, O, O, dimethyl, O, 3, chloro-4-nitro phenyl thiophosphate.

In a third block, certain materials were applied at 500 pounds pressure with a Bean orchard sprayer using hollow cone nozzles (60 gallons per hour) supplying 125 gallons of spray per acre. One application for each of endrin, lindane, parathion, and chlorthion was made. The number of damaged plants and number of live maggots found were recorded four days after treatment.

When foliage eggs were first observed on February 27, 1954, additional tests were initiated at Bixby on the carry-over crop. This planting was made in October in three row plots, 18 inches apart and 600 feet in length. A total of six weekly applications of endrin, lindane and parathion were applied on each of two replicates. Applications were made at 350 to 400 pounds pressure, using a Bean orchard sprayer with hollow cone nozzles (60 gallons per hour), adjusted eight inches above the plants. Insecticides were applied at 0.5 pound per acre in approximately 100 gallons of water. A random sample of 125 plants from each of two replicates was taken seven days after the final application.

Additional control tests were conducted on spinach planted in January with an additional variety (Giant Noble) being introduced. These plantings were made in four row plots, 600 feet in length, and spaced 16 inches apart. The first applications were made when foliage eggs were first observed and continued weekly until three applications were made. All applications were applied as mentioned in the preceding paragraph, except in this test approximately 150 gallons of water per acre were applied. Endrin, lindane and parathion treatments were applied on the Bloomsdale Longstanding variety. Additional parathion treatments were tested on the Giant Noble variety. Random samples of 100 plants from each of four replicates were taken two weeks after last treatment.

EXPERIMENTAL STUDIES

Biological Results

(1) Adult Activity

Field observations and trapping records indicate that H. cilicrura adults are most abundant in Oklahoma from September to early November, and from late February to late May (Table 1). Adults may be found throughout the year but are few in number during the coldest part of the winter and during the summer months. During periods of greatest activity, adults are particularly abundant in freshly cultivated fields rich in organic matter and near flowering plants.

H. cilicrura closely resembles other members of the family Anthomyiidae and to the casual observer resembles a small house fly (Figure 1). The body measures 3 to 5 mm in length. The thorax may vary in color from a yellowish gray to black. The abdomen appears slender, each segment being marked off by a narrow black band.

The degree of activity depends on weather conditions. Observations on caged specimens showed limited activity of adult flies at temperatures below 50° F. and above 85° F. Some activity was observed, however, at temperatures near freezing. Adult activity was largely inhibited during periods of windy and rainy weather, and no activity was observed at night as the adult appeared to rest on the soil and the sides of the cage. These observations agree with studies made by Reid in 1940.

During periods of high temperatures, adult activity in the field was greater during the cooler portions of the day with flies usually

Table 1. Number of *Hylemya cilicrura* (Rond.) adults trapped in 1952 and 1953

Date	1952 Stillwater	1953 Stillwater	1953 Bixby
Sept.			
12	--	6	--
13	--	6	--
14	--	7	--
15	--	5	--
16	--	20	--
17	--	23	22
18	--	3	18
19	--	14	30
20	--	11	25
21	--	12	4
22	--	14	37
23	6	16	28
24	3	20	16
25	6	45	43
26	--	--	4
27	1	26	4
28	9	30	4
29	9	8	0
30	14	3	0
Oct.			
1	4	16	0
2	10	13	29
3	10	9	3
4	10	12	15
5	7	8	9
6	--	8	4
7	7	5	6
8	11	3	22
9	40	8	26
10	30	6	4
11	25	5	25
12	25	5	25
13	10	11	25
14	21	10	46
15	10	15	130
16	12	15	8
17	7	9	29
18	8	17	43
19	6	20	22
20	4	30	8

(Continued)

Date	1952 Stillwater	1953 Stillwater	1953 Bixby
Oct.			
21	21	31	5
22	25	9	4
23	35	9	5
24	15	10	10
25	12	0	5
26	14	0	6
27	13	0	4
28	15	0	0
29	12	5	0
30	13	4	0
31	30	3	0
Nov.			
1	25	4	14
2	45	3	6
3	5	4	5
4	45	3	3
5	10	3	3
6	20	0	0
7	12	0	0
8	15	0	0
9	10	1	0
10	5	0	0
11	15	2	0
12	25	1	0
13	15	0	0
14	14	0	0
15	11	0	0
16	15	0	0
17	0	0	0
18	0	0	--
19	0	0	--
20	0	0	--
21	0	0	--
22	0	0	--

-- No record

being most active in the early morning and late afternoon hours. When periods of high temperatures prevail, adults usually seek cool, moist places to rest, but when temperatures were favorable, they were observed hovering over fields and spinach plants.

(2) Oviposition in Cages

Eggs of H. cilicrura field-trapped adults were deposited freely in and on the soil surface in cages where a small amount of tankage was incorporated in the first inch of soil. Oviposition was inhibited by extremely dry or extremely wet soil conditions. A medium-moist soil was preferred. Eggs were deposited singly or in groups, as many as 20 eggs were found in one group. Eggs of the seed-corn maggot were of normal anthomyiid shape, white in color, elongate-ovoid with the posterior end blunted (Figure 2). The eggs measured about .35 mm in width and about 1 mm in length. The outer chorion was reticulated.

Foliage oviposition was observed once on caged spinach plants during the period of September to November 1952. In this instance, two eggs were deposited on the plant near the mid-rib of a large leaf. Oviposition in the soil around caged plants was observed frequently throughout the entire study. Apparently environmental conditions conducive to foliage oviposition did not exist in this test. It should be noted, however, that very few foliage eggs were observed in the field during this same period (Table 2).

No attempt was made to determine the average number of eggs per field-trapped female in these cage tests. Reid (1940) found one field-trapped female to oviposit 49 eggs in one day.

(3) Oviposition in the Field

Adult females in the field seek moist soils rich in organic

Figure 1. Adults of the seed-corn maggot, *Hylemya cilicrura*.

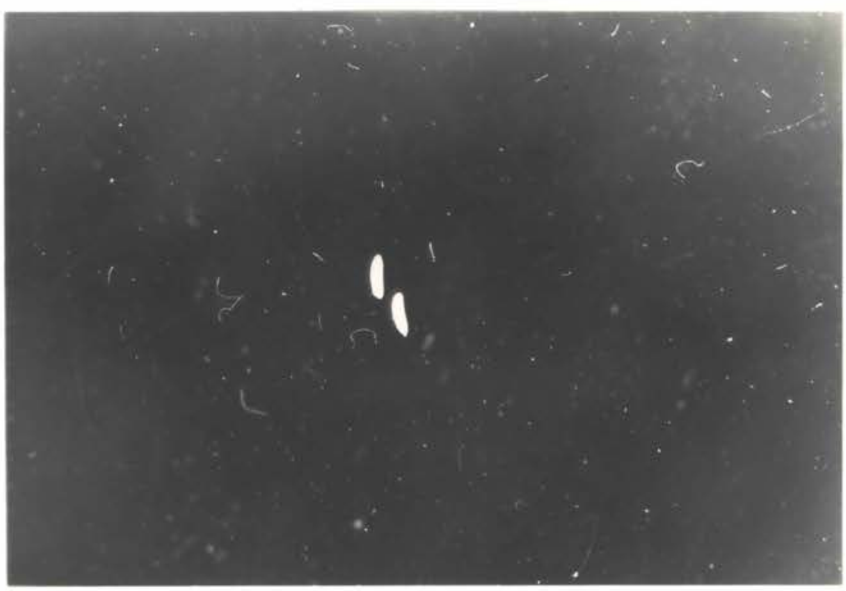

Figure 2. *Hylemya cilicrura* eggs collected from the soil.

Table 2. Foliage oviposition and infestation by _H. cilicrura_ on four spinach crops at Bixby, 1952, 1953 and 1954.

Date Examined	Number of Plants Examined	Per Cent of Plants		
		With Eggs	With Larvae	Damaged by Larvae
Fall 1952				
Oct. 31	1,000	0.7	0.0	0.0
Nov. 7	1,500	0.3	0.0	0.0
Spring 1953 (Carry-over crop)				
Apr. 10	100	47.0	14.0	26.0
Apr. 17	100	5.0	15.0	40.0
Fall 1953				
Oct. 20	500	0.0	0.0	0.0
Oct. 27	350	0.5	0.0	0.0
Nov. 3	250	36.0	0.0	0.0
Nov. 10	50	18.0	8.0	8.0
Nov. 17	100	0.0	36.6	36.6
Nov. 28	150	0.0	18.0	35.0
Spring 1954 (Carry-over crop)				
Feb. 27	100	4.0	0.0	0.0
Mar. 4	200	0.0	0.0	0.0
Mar. 11	100	54.0	0.0	0.0
Mar. 18	100	5.0	2.0	2.0
Mar. 25	100	22.0	10.0	10.0
Apr. 1	100	16.0	14.0	14.0
Apr. 8	250	-----*	15.0	25.0
Spring 1954				
Apr. 1	100	10.0	0.0	0.0
Apr. 8	100	11.0	1.0	1.0
Apr. 15	100	5.0	29.0	29.0
Apr. 29	400	2.0	-----*	15.0
Spring 1954**				
Apr. 1	50	10.0	0.0	0.0
Apr. 8	50	35.0	0.0	0.0
Apr. 15	100	2.0	11.0	11.0
Apr. 29	400	1.0	-----*	21.0

*No record

**Giant Noble, a flat-leaved variety, introduced for comparison with Bloomsdale Longstanding.

matter to oviposit. The f vorite oviposition sites appear to be on or near sources of larval food, especially where sprouting seeds and decaying vegetation are abundant. Freshly cultivated fields appear most suitable. This increased attraction may result from the increased amount of organic matter exposed on the soil surface. Eggs were found on and in the soil and in small cracks beneath plants and in the spaces between plants. In many instances where eggs were observed beneath the plants, eggs were also found on the foliage.

H. cilicrura females oviposit freely on spinach foliage during certain periods of adult activity (Figure 3). Apparently some environmental factor or factors, possibly moisture and temperature conditions, stimulate the female to oviposit on the plant. In selecting spinach plants on which to deposit their eggs, the females usually choose average to large size plants with well-developed buds. In most instances, plants six weeks of age or older were selected, but in a few cases eggs were found on very small plants. The soil organic matter content appears to influence oviposition on the foliage as more eggs were found in areas where decaying organic materials were incorporated in the soil. The attracting influence of organic matter usually results in heavier oviposition on certain sections within a field. This increased foliar oviposition may be a result of a concentration of the fly population in these areas by the attraction of the organic matter. Infested plants are also favorite sites for egg deposition. Apparently the odors emitting from decaying plant tissue also attract the ovipositing female.

The eggs were found in all parts of the foliage, but over 75 per cent were located on the small leaves directly in the terminal buds.

Some eggs were collected from the outer leaves, usually near the midrib of larger leaves. Eggs were also collected from the petioles and in a few instances were found attached to the underside of large leaves. This confirms a report by Brooks (1951) who found some eggs in small clumps on the stems and leaf petioles. The eggs are attached on oviposition with an adhesive material secreted by the female and are usually firmly attached to the spinach leaves. For extent of foliage oviposition, see Table 2.

During field surveys, eggs were noted near the base of spinach plants. In many instances, eggs were deposited directly in contact with the plant and the soil, usually between the stems and surrounding soil. It should be noted that foliage eggs were usually also present on plants where eggs were found at the base.

(4) Larval Activity

The larvae were yellow to white in color and cylindrical in shape. There were 12 segments including the head, all of which were legless. The larvae varied in size from about 1 mm for newly-hatched larvae to about 7 mm for mature larvae (Figure 4). Young larvae were active upon emergence from the egg and moved about in search of food. Usually they grouped together; however, isolated maggots were found. After hatching, the larvae usually moved downward regardless of whether they were in the soil or on the plants. The larvae were omnivorous and as they migrated downward, they fed on any organic materials which were available. In many instances, the germinating seeds and seedlings were killed by the subterranean feeding. In studies of flies caged over spinach seedlings during 1952, subterranean feeding in the soil was observed on four plants in three different pots. No feeding was

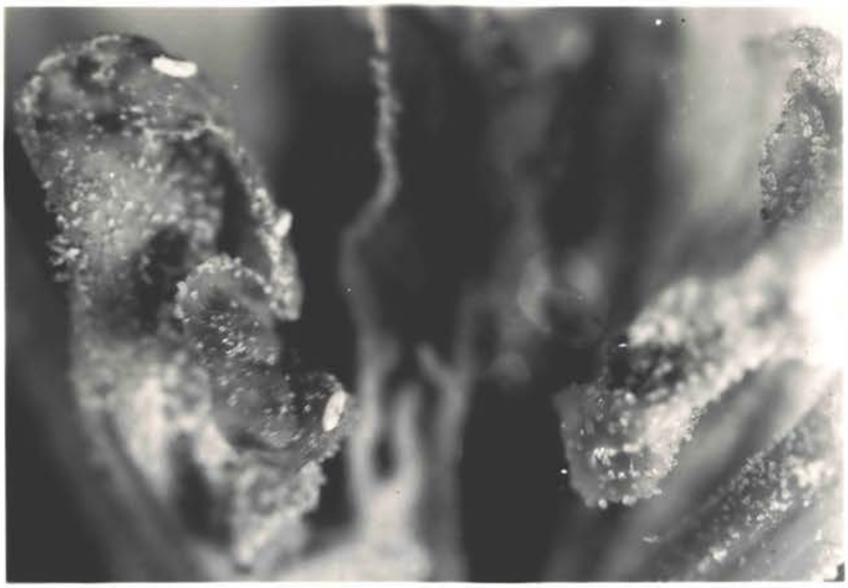

Figure 3. Bloomsdale Longstanding spinach plant showing eggs of Hylemya cilicrura on the bud leaves.

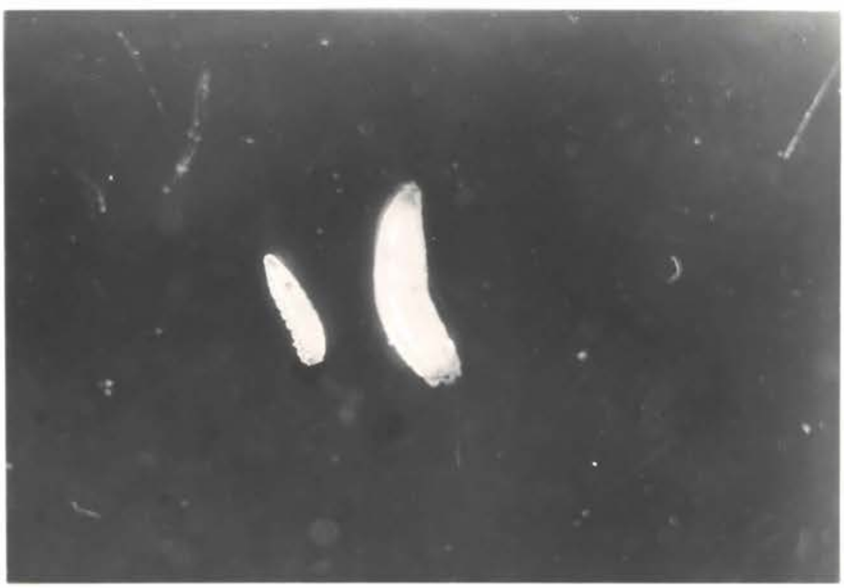

Figure 4. Hylemya cilicrura larvae, seven and thirteen days old.

observed on 21 plants in the other seven pots, although all stages of larvae were found in the soil.

Subterranean feeding of larvae was also observed on spinach seedlings in the field during April 1953. In one examination, 12 maggots were observed feeding on roots of two plants. These larvae were near the soil surface and were estimated to be in the late second instar. Examination of 100 plants in the field during November 1953 showed subterranean feeding on one plant. Three third instar maggots were found feeding on the main root just below the soil surface. This plant also had one maggot feeding in the bud. Many larvae were in the soil around each of the 100 plants, but feeding was essentially limited to the tankage which had been mixed in the soil around these plants. Larvae grown in a mixture of soil, tankage and a small piece of decaying potato fed on the tankage as well as on the potato. Larvae were not observed to feed on the potato until they were four to five days old, and apparently their earlier subsistence depended on the tankage or other organic materials in the soil.

H. cilicrura larvae have been reported as attacking only plant tissue on which there are living micro-organisms. Huff (1928) reared maggots from egg to adult on pea and bean seedlings free from bacteria. Apparently under normal field conditions, micro-organisms aid this insect's development by preparing suitable substrata for feeding as decay usually accompanies damage on spinach as well as other seedlings.

Field observations showed that plants with tight terminal bud growth were more subject to attack. Smith (1933) found that plants with loose open bud growth were less subject to attack. The larvae fed by rasping the tissues, and the smaller tender leaves in the bud were the favorite feeding sites. Developing leaves were destroyed and the damage with the accompanying decay gave a brown to black appearance to infested spinach buds (Figures 5, 6, 7, 8). In cage studies where larvae were grown from egg to adult in the bud, this black discoloration started three days after the eggs had hatched. As the larval period neared completion, the damage became more pronounced and usually by the time the larva left the plant to pupate, some stems had been entered. Larvae of various sizes were found in infested spinach buds and in many cases all three instars were found on the same plant. In some instances large maggots were removed from inside the stems, especially after the bud had been completely destroyed. Usually the spinach plant survives foliage infestations, but occasionally a weak plant succumbs during heavy attacks. Malformed plant growth usually follows bud infestations and many terminal buds were damaged or completely destroyed.

Pupal development was generally completed in the soil, but in a few instances, puparia have been found on the soil surface and on and in infested plants. In the latter cases, puparia were found in the terminal buds and inside the petioles. When first formed, the puparium appeared red to brown in color and became darker as the pupal period progressed. The length of the puparium averaged approximately 5 mm (Figure 9).

(5) Source of Infestation

(a) Oviposition on spinach foliage

During these investigations, it was noted that serious infestations followed periods of heavy foliage oviposition. This is shown by comparisons of the foliage oviposition records with the infestation

Figure 5. Plant infested with Hylemya cilicrura larvae compared with a non-infested plant. Note the injury in the terminal bud.

Figure 6. Plant showing injury by larvae of Hylemya cilicrura.

Figure 7. Non-infested plant showing no injury to the terminal bud.

Figure 8. Infested plant showing severe damage to the terminal bud and leaf petioles.

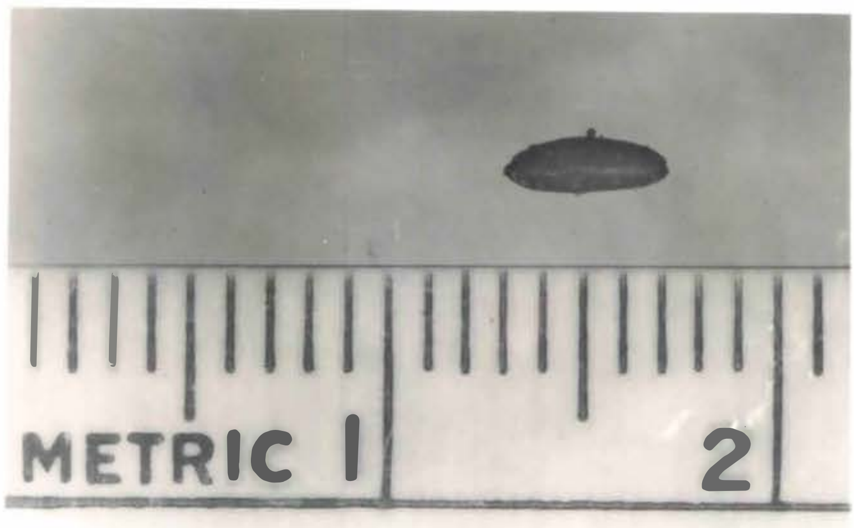

Figure 9. Puparium of Hylemya cilicrura

records for the fall of 1952 and the spring and fall of 1953 (Table 2). It should be noted that 20 to 60 per cent of the plants with foliage eggs later became infested or damaged (Table 3). In the fall of 1952, a total of 2500 plants were examined. Weekly examinations were made during the period from September 15 to December 1. It may be noted that a very small per cent of plants had eggs on the foliage, the maximum being only 0.7 per cent on October 31 (Table 2). No larvae were found on the foliage during the entire growing season. Apparently environmental conditions were not conducive to foliage oviposition or larval infestation of spinach foliage.

Following periods of heavy foliage oviposition during late February, March, and early April of 1953, a serious foliage infestation developed at Muskogee and at Bixby. No records are presented on the extent of foliage oviposition at Muskogee since many of the eggs had hatched before the field surveys were initiated. However, many plants were observed with foliage eggs and a total of 21 per cent of the plants were infested in March.

Eggs were found on 47 per cent of the plants at Bixby when the first examination was made on April 10, 1953, and at that time, 26 per cent of the plants were infested or damaged. When the second examination was completed on April 17, 40 per cent of the plants were damaged. This was a 14 per cent increase in plant damage during this seven-day period.

Oviposition records were taken weekly at Bixby from September to December during 1953 (Table 2). The total number of plants with eggs could not be recorded because many eggs hatched between the weekly examinations. At the peak of foliage oviposition on November 3,

Table 3. The effect of foliage oviposition on the development of larval infestations in spinach buds during 1953.

Date	Location and Type of Test	Source of Eggs	Location of Eggs	Date Examined	Number Plants Examined	Per Cent Plants Infested
April 10	Bixby-Field*	Foliage	Foliage	April 17	40	35
Nov. 3	Stillwater-Lab**	Soil	Foliage	Daily	5	20
Nov. 3	Stillwater-Lab**	Foliage	Foliage	Daily	5	20
Nov. 3	Bixby-Field	Foliage	Foliage	Nov. 22	56	51
Nov. 3	Bixby-Field	Foliage	Foliage	Nov. 30	44	54
Nov. 3	Bixby-Field***	Foliage	Foliage	Nov. 30	11	60
Nov. 1	Stillwater-Field	Soil	Soil	Daily	120	0.8

*Plants staked in field
**Plants seeded in pots in insectary
***Plants caged in field

36 per cent of the plants contained foliage eggs. Eggs were first noted on October 27, but only two eggs were found on this date. Examination of 100 plants one week later indicated an 8 per cent larval infestation while 18 per cent of the plants had eggs on the foliage. On November 17, no foliage eggs were observed and 36.6 per cent of the plants were infested on that date. Although a natural lag occurred, this pronounced increase of the infestation during this seven-day period suggests that some of the small larvae were overlooked on November 10. When the final examination was made on November 28, 18 per cent of the plants were infested and 35 per cent were infested or damaged. The absence of maggots from a portion of the damaged plants appeared to be caused by pupation since no larval mortality was observed.

Records were taken on foliage oviposition from February 14 to April 29, 1954 on carry-over and spring planted spinach (Table 2). Foliage eggs were first observed on the carry-over plants on February 27 when 4.0 per cent of the plants contained eggs. No foliage eggs were found when plants were again examined on March 4, but on March 11 eggs were found on 54.0 per cent of the plants. Plant examinations one week later showed a 2.0 infestation with first instar larvae. At this time the soil was extremely dry and many of the plant buds were full of dust particles as a result of blowing dust. These unfavorable conditions appear to have reduced the developing infestation. Foliage oviposition continued during the next three weeks on the carry-over crop and weekly surveys showed from 5 to 22 per cent with eggs and 2 to 15 per cent of the plants infested. When the final sample of 250 plants was taken on April 8, 25 per cent of the plants were damaged.

Oviposition on the spring planted varieties was first observed on April 1 when eggs were found on 10 per cent of the plants (Table 2). Examination of 100 plants from the Bloomsdale Longstanding planting showed 11 per cent with foliage eggs and 1.0 damaged. A 50 plant sample taken from the Giant Noble plots showed 35 per cent of the plants with eggs, but no larvae were observed. This was the highest level of oviposition recorded on the spring crop. On April 15 Bloomsdale Longstanding plants showed a 5 per cent egg infestation and a 29 per cent larval infestation, as compared with a 2 per cent and 11 per cent infestations, respectively, for Giant Noble plants.

When the final sample of 400 plants was harvested, 15 per cent of the Bloomsdale Longstanding plants were found damaged as compared with a 21 per cent on the Giant Noble. This increase of foliage oviposition and infestation on the Giant Noble planting was not significant.

The number of eggs deposited on foliage ranged from one to fifteen with the average being about five. As many as 14 maggots have been removed from an infested plant; however, the usual range was one to six with an average of two to three maggots per infested plant. All larval stages were found on infested plants, and in several cases, all instars were found on a single plant.

Additional laboratory and field studies were conducted to determine the effect of foliage oviposition on larval infestations on spinach foliage during 1952 and 1953 (Table 3). During November 1952, a total of 84 _H. cilicrura_ eggs collected from the soil from caged specimens in the laboratory were placed in the buds of 14 non-infested potted plants. Later observation revealed that nearly all the eggs had hatched but no infestation developed. These results parallel observations made in the field during this period and which are discussed in an earlier section.

In field studies during April 1953, non-infested plants bearing eggs on the foliage were staked in the field (Table 3). Examination of this group one week later revealed a 35 per cent bud infestation with first instar larvae.

During October 1953, a total of 150 eggs deposited in the soil by caged adults were collected. Ten eggs were placed in each of 15 non-infested spinach buds. Observations showed that the eggs had hatched but no infestation developed. Again no infestation was observed in the field during this period.

In laboratory studies in November 1953, another 25 eggs were collected from the soil. Five eggs were placed in each of five buds on potted spinach plants. Later observations revealed a bud infestation on one of these plants. During this same period, another 25 eggs were collected from the foliage in the field. These eggs were placed in five buds on potted spinach plants, each bud receiving five eggs. Infestation developed on one of these plants. On the basis of these results in the laboratory, no differences appeared to exist between the two egg sources as one infestation was produced from the soil-collected eggs and one from the foliage-collected eggs. Note that during the period these bud infestations were produced in the laboratory, foliage oviposition was occurring and bud infestations were developing in the field (Table 3). Thus, conditions appeared to be favorable for the development of larval infestations on foliage.

During November 1953, a second group of non-infested plants bearing eggs were staked in the field and examination of these plants 19 days later revealed a 51 per cent foliage infestation (Table 3). Later examinations of the plants showed 54 per cent of them were damaged or infested.

Eleven non-infested plants bearing four to ten eggs per terminal bud were caged in the field at Bixby on November 1, 1953 (Table 3). All the soil in a 10-inch area around these plants was removed to a depth of one foot below the soil surface, and wet sand taken one foot below the soil surface was placed around each plant. This was done to eliminate any larval migration from the soil to the plant foliage. Examination of these plants on November 30 revealed a 60 per cent infestation.

Daily examinations of a third group of non-infested plants not bearing eggs but growing in infested soil revealed foliage feeding in one bud. This plant also showed evidence of subterranean feeding. These plants were observed daily from November 1 to December 1, 1953 and all foliage eggs found were removed. These records show that larvae hatched in the soil do not cause major foliage infestations but such infestations result from foliage oviposition.

Oviposition on the foliage appeared to be limited to certain periods of the growing season. In 1952, oviposition on and in the soil occurred frequently during September and October but no foliage eggs were observed until October 31 and these were few in number. During 1953, eggs were found on and in the soil from early September until December 1; however, eggs were not found on the foliage until October 27. In the spring of 1954, foliage eggs were first observed on February 27 and observed frequently until the spring crop was harvested.

Records for the last few years indicate that temperature, humidity and rainfall may influence H. cilicrura females in selecting the oviposition site, and these factors probably influence any subsequent infestation. A severe dr uth was recorded in Oklahoma during the last six months of 1952. October 1952 was the driest October recorded in Oklahoma history. The rainfall recorded in inches during the fall of 1952 at Bixby, Oklahoma w s as follows: September 0.47, October 0.00, and November 2.40. In contrast to these moisture conditions of 1952, above average rainfall was recorded in all spinach-growing areas during March, April, October and November of 1953. Rainfall recorded at Bixby for these months was as follows: March 4.50, April 8.00, September 2.40, October 7.38 and November 2.88. During February, March, and April of 1954, the rainfall recorded at Bixby was 0.68, 0.93, and 3.93 respectively which was below normal for this period. It appears the low rainfall and low humidity conditions existing during the fall of 1952 inhibited foliage oviposition by H. cilicrura adults and suppressed any infestation which might have occurred. L rvae normally develop in a medium-moist soil or tissues within the plant terminals. Apparently the moist conditions during early April and early November in 1953 were favorable for the establishment of foliage infestations. Although heavy foliage oviposition occurred during early March of 1954, only low levels of infestations were reached; however, heavier infestations were observed from late March until the crop was harvested in late April. The maximum infestations recorded in 1954 were somewhat lower than those for the same period in 1953 (Table 2). Unfavorable weather conditions may account for the lower foliage infest tions. Analyses of weather conditions show that the mean temperatures recorded for the fall of 1952, spring and fall of 1953, and spring of 1954 were not significantly different.

Smith (1933) associated foliage infestations with damp and foggy weather in the Winter Garden region of Texas. Smith also stated since foliage infestations appear during damp weather that mildew organisms might possibly aid the insect in attacking plants. No mildew or blue mold was observed on infested plants during these studies in 1953. Plants infested in the laboratory also appeared to be free of disease with no evidence of mold or mildew.

In a study conducted from November 1 to December 1, 1953 on the effect of organic matter on foliage oviposition, 100 non-infested plants were staked in the field. A tablespoon of tankage was mixed in the soil around the base of each of these plants. Another 20 plants were staked in this field but these plants received no tankage. Daily examinations of these 100 plants with tankage revealed 26 instances of foliage oviposition. One instance of foliage oviposition was observed on the 20 plants growing in soil with no tankage. Other field observations during 1953 showed that foliage oviposition was heavier on plants growing where heavy applications of organic fertilizers had been applied. Heavier foliage infestations were also observed when plants were growing in soils rich in organic matter. Smith (1933) and Reid (1936) observed that when all other factors were equal, foliage infestations were higher when plants were growing in soils rich in organic materials.

The attracting influence of organic matter on H. cilicrura females appears to largely account for the heavier oviposition and subsequent infestations found on certain areas within the same field.

(b) Migration of larvae from foliage to soil

During November of 1952, a total of 70 newly-h tched larvae from soil eggs was placed in 14 terminal buds on potted spinach plants. Five larvae were placed in each bud. No infestation developed and no maggots were found during later examination of the soil taken from these pots. Apparently all these larvae died before becoming established on the plant or in the soil.

Another 10 larvae eight days old, reared from soil-collected eggs in soil, tankage, and potato, were placed in five buds, each bud receiving two larvae. No evidence of feeding was observed and all of these larvae immediately entered the soil. In this case, four puparia were recovered during examination of the soil bout two weeks later.

During March of 1953, another 17 larvae estimated to be 10 days old were collected from spinach foliage in the field and placed in buds of four healthy potted plants. No feeding was observed and these larvae crawled immediately from the plant into the soil.

No larvae or puparia were recovered during later screening of the soil in these pots. Apparently the movement to a new feeding medium disturbed the larvae and they were not able to complete development.

In November 1953, 48 newly-h tched larvae from soil-collected eggs were placed in six buds and one bud showed slight evidence of feeding. Examinations of the soil and plants indicated that none of these larvae survived.

It has been observed in the field that in many cases plants showed damage but no larvae could be found. It was concluded that in most cases the larv e involved had left the plant to pupate.

It has been found that pupation begins about 20 days after the eggs were first observed on the plants, and as a result, many damaged plants without larvae were found. A few puparia have been observed on the soil surface. In the laboratory during November 1953, the larvae were found to leave the plant and enter the soil about two days before pupation.

(c) Migration of larvae from soil to foliage

Larval migration studies were continued in the insectary during October and November of 1952. On October 21, larvae, seven days old and reared from soil-collected eggs, were placed on the soil in pots, each of which contained three well-developed spinach plants. Three to four larvae were placed in each of eight pots. No migration from the soil to the foliage was observed during a period of approximately one week. The larvae were not observed to come to the soil surface nor was there evidence of them feeding on the foliage. There is a question as to how long the larvae survived, however, since no living specimens were found when the soil was screened at the end of seven days.

In another test during the same season, observations were made on 12 pots similar to those described above. As a result of oviposition on and in the soil by adults caged on the pots, large numbers of larvae in all stages were present in the soil in each pot. Daily observations revealed no larval movement occurred during a period of 36 to 60 days.

On November 22, 1952, 40 larvae, five days of age, reared on soil and tankage from eggs collected in the soil, were placed on the soil in four pots. Each pot containing three well-developed spinach plants received ten larvae. Examination of the plants 24 hours later showed three larvae feeding in the same bud. During daily examinations, larval movement from plant to plant was observed in this one pot and all three plants in this pot showed evidence of larval feeding during this three-day period. Examinations made during the next few days did not reveal the larvae to be on the plants and it was assumed that they entered the soil.

During the fall of 1953, 100 non-infested plants were staked in the field. A tablespoon of tankage was incorporated in the soil around each plant. As a result of heavy oviposition in the soil and tankage, a large population of developing larvae were present around each of these 100 plants. These plants were examined daily from November 1 until December 1, and all foliage eggs found on these plants were removed. On November 30, one second instar maggot was observed feeding in a terminal bud and three third instar maggots were found feeding on the underground stems of this plant. No other foliage feeding was observed during this period.

In the same field, a second group of 20 plants were staked, but in this case no tankage was added to the soil. Ten freshly-laid eggs were collected from the soil in the field and placed in the soil around each of these 20 plants. Daily observations were made from November 1 to December 1 and all foliage eggs found on these plants were removed. No foliage infestation was observed on these plants and examination of the soil around them on December 1 revealed only three third instar larvae around two plants. This low soil population was in contrast to the heavy infestation in the soil-tankage mixture mentioned above.

This evidence indicates that some larval migration may take place in the field; however, it appears to be limited and foliage oviposition apparently accounted for the heavy foliage infestation observed during these studies.

(6) Duration of Immature Stages

(a) Egg

The hatching periods for H. cilicrura eggs are given in Table 4. Records are shown for eggs collected from the soil and for eggs collected from the foliage. The incubation period for soil eggs ranged from one to three days with a mean of 1.66 and 1.53 days at mean temperatures of 70° and 72° F. The range in days for foliage-collected eggs was one to two days with a mean of 1.2 days at 70° F. (Table 4). It should be stated in this case that these foliage eggs were field gathered and the exact time of oviposition and the temperatures they were subjected to in the field are unknown. Apparently this accounts for the slight difference in the incubation period recorded for the foliage eggs. In these studies, 90 per cent or more of all eggs hatched.

(b) Larva

The length of the larval period for larvae hatched from soil-collected eggs in November 1952 and reared in soil, tankage and potato, were found to average 15.6 days at a mean temperature of 70° F. with a 72 per cent survival. In comparison, foliage eggs were collected in November and reared under the same conditions. The average length of this stage for this group was 15.2 days with 87 per cent surviving to the pupal stage (Table 4).

In November 1953, rearings were made from soil-collected eggs

Table 4. Duration of immature stages of H. *cilicrura* during 1952 and 1953.

Source	Rearing Medium	Number of Specimens	Range in Days	Mean Days	Per Cent Survival	Mean Temperature
EGGS						
Soil	Soil	20	1-3	1.66	90	70° F.
Soil	Soil	30	1-2	1.53	90	72° F.
Foliage	Soil	45	1-2	1.20	93	70° F.
LARVAE						
Soil	Soil	18	14-17	15.6	72	70° F.
Foliage	Soil	16	13-21	15.2	87	70° F.
Soil	Soil	22	9-19	14.4	68	62° F.
Foliage	Soil	24	---20	20.0	10	62° F.
Soil	Foliage	6	24-25	24.5	33	62° F.
Foliage	Foliage	4	---25	25.0	25	62° F.
PREPUPA & PUPA						
Soil	Soil	13	16-17	16.7	100	70° F.
Foliage	Soil	12	14-17	15.4	100	70° F.
Foliage	Soil	2	9-10	9.5	100	82° F.
Soil	Soil	15	16-18	17.0	93	70° F.
Foliage	Foliage	3	15-18	17.0	100	70° F.
Soil	Foliage	2	11-13	12.0	100	82° F.
Foliage	Foliage	1	---12	12.0	100	82° F.
Foliage	Foliage	4	11-12	11.7	100	82° F.
Foliage	Foliage	30	11-12	12.0	86	82° F.

using soil, tankage and pot to as the rearing medium. The average larval period for this group was 14.4 days at 62° F. In this case, 68 per cent survived to the pupal stage. Another group of larvae from foliage-collected eggs was studied under the same conditions during this period. The average days required to complete development was 20.0 and only 10 per cent survived to the pupal stage. In this rearing, the medium became heavily infested with mold which may have increased larval mortality (Table 4).

Larvae from soil-collected eggs feeding in the buds required an average of 24.5 days to complete development at 62° F. The larvae from foliage-collected eggs required 25 days to reach the pupal stage under the same conditions (Table 4). Note that larvae reared in the soil media developed faster than larvae reared in the spinach buds when rearings were made at the sa e temperature. The larvae required 8 to 10 days longer to complete development in the spinach buds. The duration of the larval period for H. cilicrura depends on the temperature as well as the feeding medium. Within the optimum temperature range, the length of this period decreases as temperature increases.

The er cent survival for larvae feeding on the foliage was lower as it may be noted that only two plants were infested in the laboratory.

(c) Prepupa and pupa

Specimens kept at a mean temperature of 70° F. required from 14 to 18 days to complete the pupal period while those at 82° F. completed development in 9 to 13 days. The per cent survival ranged from 86 to 100 in this study.

The duration of the pupal stage did not appear to be affected by differences in egg source or food supply. Temperature appears to determine the length of this stage. Within the optimum temperature range, the pupal period becomes shorter as the temperature increases.

(7) Structural Comparisons of Foliage and Soil Specimens

To consider the possibility that two or more population of flies were involved, adult flies collected from field traps, adult flies reared from eggs in the soil and adult flies reared from foliage eggs in the soil were submitted to the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine, Washington, D. C. in 1952. These specimens were determined by C. W. Sabrosky as being Hylemya cilicrura (Rond.), the seed-corn maggot.

Additional specimens were submitted during 1953 from the following sources: adults collected from field traps, adults reared in the soil from eggs collected from the soil, adults reared in the soil from eggs collected from the spinach foliage, adults reared in spinach buds from eggs deposited on the foliage, and adults reared in spinach buds from eggs collected from the soil. All these specimens were identified as Hylemya cilicrura.

Fresh slide mounts of H. cilicrura eggs collected from the soil were compared with mounts made from fresh foliage eggs. No morphological differences were observed.

Slide mounts of various larval stages were made in the laboratory. Examinations were made of the posterior spiracles, buccopharyngeal apparatus and general body structure. Mounts prepared from larvae 1, 7 and 13 days old hatched from eggs collected on the foliage were compared with mounts of larvae of the same age which were hatched from eggs collected from the soil. Slide mounts made from larvae feeding in the soil were also compared with mounts from larvae collected from the foliage. No structural differences were noted.

Pupal cases were taken from rearings made using both foliage and soil eggs on different feeding media. No structural differences were noted upon comparison of these specimens.

Insecticide Tests

Tests to control the seed-corn maggot on spinach foliage were conducted in the spring and fall of 1953. Ten insecticides were tested in spray formulations. In two of the tests, applic tions were made with low volume, low pressure sprayers and in the other two tests, a high volume, high pressure spray was used.

(1) Low Pressure, Low Volume Application

On March 28, 1953, single applications of concentrate spr ys of lindane, parathion or tetraethyl pyrophosphate were made to the established foliage infestation at Muskogee, Oklahoma. At the time of treatment, the pl nts in this test were of medium size and characterized by loose, open bud growth. The larvae infesting these plants were estimated to be in the second instar. Four days after treatment a random sample of 40 infested plants was taken from the four replications. The reduction of foliage larvae when compared with the untreated check was as follows: lindane 70 per cent; parathion 70 per cent; and TEPP 60 per cent.

Additional control tests were continued at Bixby, Oklahoma during the fall of 1953. In this test four applications of concentrate sprays with eight insecticides were made to the foliage (T ble 5).

The first application was applied on October 27 when the first foliage eggs were found. Note that only 0.5 per cent of the plants contained eggs at this time (Table 2). On November 3 when the second spray was applied, 36 per cent of the plants contained foliage eggs. Thus, timing of the spray applications coincided closely with foliage oviposition.

Table 5. The effect of four weekly applications of concentrate sprays on spinach foliage infestations of the seed-corn maggot in the fall of 1953.

Treatment*	Number Plants Damaged	Per Cent Reduction Plant Damage**	Number Larvae	Per Cent Larval Reduction
Heptachlor	23	57	6	70
Chlordane	24	55	8	60
Aldrin	26	51	8	60
Dieldrin	23	57	9	55
Lindane	29	46	9	55
Endrin	29	46	10	50
Parathion	36	23	10	50
Chlorthion	33	38	29	-45
Untreated	53		20	

*All insecticides applied at 0.25 lb. per acre except chlordane w ch was applied at 1.0 lb. per acre.
**Based on 50 plants from each of three replic tes.

Seven days after the second spray application, a 50 plant random sample was examined. At this time parathion, chlordane, and endrin had caused 80 to 100 per cent reduction in foliage larvae when compared with the untreated check. Other treatments of aldrin, heptachlor and chlorthion caused a larval reduction of about 70 per cent. Lindane and dieldrin caused only 50 and 20 per cent reduction at this time. It should be mentioned that the first application of lindane was of questionable value because of deterioration of the material in the container which was not discovered until later. All larv e found during this examination were estimated to be in the first instar.

Another sample of 60 plants from all replicates in each treatment was taken seven days after the third application. The per cent larval reduction revealed at this time was as follows: aldrin 66; chlorthion and lindane 60; dieldrin, heptachlor, endrin, parathion 50; and chlordane 32. All larval stages were found on this examination.

Ten days after the fourth application, the final examination was made and the per cent reduction in foliage larvae and plant damage is shown in Table 5. All larvae observed in this examination were estimated as third instar.

With the exception of chlorthion, the differences between insecticides were not significant. The preliminary plant examination taken after the second spray application shows the highest larval reduction. The second plant sample shows roughly the same reduction for all treatments except chlorthion and chlordane. These variations were probably due in part to the failure to find a high per cent of the small larvae in the first and second examination. Apparently the degree of control achieved in this test was a result of the first two spray applications. During the first two applications, the plants were smaller and the terminal buds were more exposed to the spray. The larvae were also small and had not become as well established in the plant buds as was the case during later application.

A third series of plots were treated with lindane and dieldrin under the same conditions as mentioned previously. However, in this test, applications using 0.25 and 0.50 pound per acre toxicant were applied at 14-day intervals. Examinations of 50 plants were made after the first and third applications in the plots treated at the 0.25 pound per acre rate. No reduction in foliage larvae was found when compared with the check. When the final sample was taken, a 70 per cent reduction was found in the plots treated with dieldrin at 0.50 pound per acre. Lindane showed no reduction. Again it should be emphasized that the first application of lindane was of doubtful value because it had deteriorated.

(2) High Pressure, High Volume Application

On March 31, 1953, single applications of a high pressure, high volume spray of lindane and methyl parathion were applied to the spinach foliage at Bixby, Oklahoma. The plants used in this test were very large and characterized by tight terminal buds. All larval stages were well established in the buds at the time of treatment.

Examination of 40 infested plants taken at random from each plot was made seven days after treatment. No significant reduction in the population was noted when these plants were compared with the check. As a result of the advanced stage and size of the infested plants, many larvae probably were not reached with the insecticide.

In another test, single applications of lindane, endrin, chlorthion and parathion were applied to an established foliage infestation on November 26, 1953. Examination of a 250-plant sample taken at random from all three replications four days after the treatment showed no significant reduction of foliage larvae in any of the treatments. When this treatment was applied, the larvae were approaching maturity and the maggots were deep in the terminal buds.

When foliage eggs were first observed during February 1954, applications of high volume, high pressure sprays of endrin, lindane and parathion were made on the carry-over crop at Bixby. When the final sample was taken one week after the last applications, endrin showed a 66 per cent larval reduction as compared with 48 and 14 per cent for lindane and parathion respectively (Table 6).

Table 6. The effect of weekly applications of high volume, high pressure sprays* on spinach foliage infestations of the seedcorn maggot in the spring of 1954.

Treatment	Number Plants Damaged	Per Cent Reduction Plant Damage	Number Larvae	Per Cent Larval Reduction
---Test No. 1. Carry-over crop of Bloomsdale Longstanding, six applications, February 27-April 1**				
Endrin	35	36	16	66
Lindane	41	34	24	48
Parathion	53	16	40	14
Untreated	63	---	46	---
---Test No. 2. Spring crop, three applications, April 1-15***				
Bloomsdale Longstanding:				
Endrin	43	32		
Parathion	45	29		
Lindane	60	4		
Untreated	63	---		
Giant Noble (flat-leaved variety):				
Parathion	72	15		
Untreated	84	---		

*Insecticides applied at 0.5 lb. toxicant per acre in 100-150 gallons of water and at 350-400 psi.
**Based on 125 plants from duplicate plots.
***Based on 100 plants from each of four plots.

Similar tests on the spring spinach were initiated when foliage eggs were first observed. A random sample was taken two weeks after treatment. A total of three applications of endrin, parathion and lindane made to the Bloomsdale plants showed 32, 29, and 4 per cent reduction in plant damage respectively. No larval counts were made. A similar parathion treatment was applied to a flat-leaved variety, Giant Noble. This variety was included in the test to determine if its growth characteristics, which differed in certain respects from the Bloomsdale Longstanding variety, influenced the effectiveness of insecticidal treatment. The latter variety is characterized with thick, highly convoluted or wrinkled leaves and relatively tight terminal bud clusters. The Giant Noble plants possess thin, flat leaves and appeared to have a slightly looser arrangement of developing leaves in the bud. These growth characteristics did not appear to increase the effectiveness of the treatments, since the reduction in plant damage on Giant Noble was 15 per cent, being actually lower than the 29 per cent reduction obtained in Bloomsdale plots with the same chemical.

During 1954, an additional test was conducted on plants infested with larvae. Hand applications were made using diazinon, Systox, lindane at 0.1 per cent; parathion at 0.05 per cent; and a lindane-pyrethrins mixture at 0.1 and 0.05 per cent respectively. These insecticides were applied in a solution using an isoparaffin oil (Soltrol 180) as the liquid carrier (Goodhue 1953). A single application of each insecticide was applied to 10 infested plants in each of three replicates. The plants were harvested four days later and the number of larvae recorded. The per cent larval reduction for these treatments when compared with the check was as follows: diazinon 40, lindane 23, parathion 11, Systox 5, and lindane-pyrethrins gave no reduction.

Practical levels of control were not achieved by any of the insecticides when applied as either concentrate, low pressure sprays or as high volume, high pressure applications. In the majority of the tests, weekly applications were timed to coincide with foliage oviposition. Several of the toxicants used, including lindane, aldrin, dieldrin and chlordane were shown to be toxic to larvae of this species when used as seed and soil treatments (Howe et al. 1952, Howe and Schroeder 1951, Floyd and Smith 1949, Lange et al. 1951 and Walton 1951). In the absence of an established cause of failure, several factors are suggested as possibly affecting the results. Inadequate insecticide coverage of the terminal bud interior, where most of the larvae were situated, appears to be the most likely explanation. Growth and development within the bud, with resulting new and untreated tissues, may have permitted larvae to feed without toxic hazards. Insecticide residues may have not persisted at mortal levels through the one-week interval between applications. Another possible factor would be an interaction between the plant tissues and the insecticide resulting in detoxification. Investigations should be continued to determine the effect of these and other factors on control.

SUMMARY AND CONCLUSIONS

In recent years foliage infestations by the larvae of the seed-corn maggot, *Hylemya cilicrura* (Rondani), have caused severe losses to the spinach industry in Oklahoma. Adults were found throughout the year but the peak of activity occurred from late February until late May and from early September until December. Only limited activity was noted at temperatures below 50° and above 85° F. and few flies were active during windy and rainy periods. Adults frequented freshly cultivated fields and flowering plants. Caged adults oviposited freely on and in the soil and oviposition on the plant under caged conditions occurred once in 1952. Eggs were deposited singly or in groups with as many as 20 eggs found in one group. Medium moist areas were preferred for egg deposition. Under field conditions, oviposition on and in the soil occurred frequently. Favorite sites for egg deposition appeared to be on or near sources of larval food, especially where sprouting seeds, seedlings and decaying organic materials were abundant. Eggs were also found in small cracks and open areas in the field. During certain periods, *H. cilicrura* females oviposited freely on spinach foliage. Average to large size plants were selected and eggs were deposited on all portions of the plant. However, over three-fourths of the eggs were found on the small leaves in the terminal buds. As many as 15 eggs have been found on a spinach plant with the average ranging from four to five eggs per plant. Oviposition and foliage infestations were heavier where plants were growing in soils rich in organic materials. The hatching period for eggs deposited in the soil or on foliage ranged from one to three days at temperatures of about 70° F. In these studies, 90 per cent or more of all eggs hatched.

Young larvae were active immediately after emergence from the egg and moved about in search of food. Subterranean and foliage feeding by larvae was observed in the field and laboratory as well as larval feeding on decaying organic materials. The number of maggots per plant ranged from one to fourteen with the average being from two to three. All larval instars were found infesting spinach foliage and in several instances, all instars were collected from a single plant. Plants with tight terminal bud growth were more subject to attack. The larvae fed by rasping the plant tissues and developing leaves were malformed or destroyed. Larvae were also observed to tunnel in leaf petioles. Decay organisms commonly attack such injured plant tissues. From 20 to 60 per cent of plants with foliage eggs later became infested with larvae as compared with an infestation of one per cent on plants that had no foliage eggs. Foliage infestations were produced in the laboratory using eggs collected from the soil as well as eggs collected from the foliage. At a temperature of 62° F., larvae reared in a medium of soil, tankage and potato pieces, matured in 14.4 days as contrasted with 24.5 days for larvae reared on spinach foliage.

An examination of several thousand plants during the course of the investigation showed that pupation nearly always occurred in the soil with only a very few puparia being found in plants. The pupal period for specimens was the same length regardless of source of egg or feeding medium. At a mean temperature of 82° F., the pupal period was 11.9 days compared with 15.7 days for specimens kept at a mean temperature of 70° F.

Heavy foliage infestations developed in the spring and fall of 1953 when precipitation was near normal or above. In the fall of 1952 when precipitation was greatly below normal, no foliage infestation developed. In the spring of 1954 with below normal rainfall, low to moderate infestations developed.

Larval infestation of spinach foliage generally resulted from oviposition on the bud and leaves. Larval migration from the soil to the foliage was observed in a very few cases, but this did not appear to be an important factor in producing foliage infestation. No structural or biological differences were observed when comparing the egg, larva, pupa and adult forms collected or reared from foliage eggs with specimens collected or reared from soil eggs.

Practical control levels were not obtained by any of the insecticide treatments. A total of 13 toxicants, including heptachlor, chlordane, aldrin, dieldrin, lindane, endrin, parathion, methyl parathion, tetraethyl pyrophosphate, chlorthion, diazinon, Systox and a lindane-pyrethrins mixture was tested as foliage sprays in six field tests made during three seasons. The first seven insecticides listed produced up to a range of 50 to 70 per cent larval reduction when timed with foliage oviposition. Treatments made after the larvae were well established in mature plants were generally ineffective. The last six insecticides listed above were less effective than the first group. High volume, high pressure sprays were no more effective than concentrate sprays of the same insecticides applied at low pressures.

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VITA

Benjamin H. Kantack
Candidate for the degree of
Master of Science

Thesis: THE BIOLOGY AND CONTROL OF THE SEED-CORN MAGGOT [*Hylemya cilicrura* (Rondani)] ON SPINACH FOLIAGE

Major: Entomology

Biographical and Other Items:

Born: September 26, 1927 at Greenleaf, Kansas

Undergraduate study: Kansas State College, 1946-51

Graduate study: O. A. M. C., 1952-54

Experiences: Farming, 1937-46; Employed by Mor-Pak Preserving Corp., Stockton, California as Weighmaster; Summers of 1947, 1952, Goodyear Tire & Rubber Company, Topeka, Kansas; Summer 1948, 1949, Libby, McNeil & Libby, Pineapple Division, Supervisor, Maunaloa, Molokai, T.H.; Oklahoma Agricultural Experiment Station, Research Assistant, 1952-54.

Member of Phi Sigma Society, The Central States Entomological Society, The Entomological Society of America, and Associate Member of The Society of Sigma Xi.

Date of Final Examination: May, 1954.

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AUTHOR: Benjamin H. Kantack

THESIS ADVISER: Dr. R. R. Walton

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TYPIST: Frances I. Kantack