Biology and Control of The Seed-Corn Maggot On Spinach Foliage

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Bulletin No. B-506
March 1958

OKLAHOMA STATE UNIVERSITY
SCIENCE SERVING AGRICULTURE
1891
EXPERIMENT STATION

Contents

ACKNOWLEDGMENT

The authors wish to express appreciation for the excellent assistance given by the Department of Horticulture and particularly by Charles Galeotti, superintendent of the vegetable research station at Bixby.

Biology and Control of the Seed-Corn Maggot on Spinach Foliage

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The seed-corn maggot, **Hylemya cilicrura** (Rondani), usually a subterranean feeder, is an important foliage pest of spinach in Oklahoma. Such infestations cause contamination of foliage when crops are harvested during the early and intermediate periods of infestation. Seldom can harvest be delayed until progressive injury enables infested plants to be recognized and avoided.

In an attempt to develop effective control measures, the Oklahoma Agricultural Experiment Station conducted biological and insecticide tests from 1948 to 1957.[3] The investigation was conducted by the Department of Entomology in cooperation with the Departments of Horticulture and Biochemistry Research. Insectary studies were made at Stillwater and field work was conducted at Stillwater and the Vegetable Research Station at Bixby in eastern Oklahoma. Specific tests related to: oviposition habits, larval activity, seasonal development of the insect, relation of rainfall to foliage infestation, duration of immature stages, and insecticide tests. Observations on the type and extent of damage caused by the insect were recorded throughout the test period. This bulletin summarizes results of these tests and observations.

The larvae of **Hylemya cilicrura** feed on a wide range of substances including living plant tissues and decaying organic materials of both plant and animal origin (Reid, 1940). Larvae were collected from the buds of spinach on irrigated land in Texas in 1918 (Reid, 1936) and damage to spinach foliage in south Texas was also reported by Hawthorn (1932) and Smith (1933). Foliar infestations on spinach were reported from the Walla Walla district of Washington (Smith, 1933) and from Oklahoma and Arkansas (Walton and Ashdown, 1951). Smith (1933) referred to the seed-corn maggot larva attacking foliage as the spinach budworm. Guyer et al. (1957) in Michigan studied the different dipterous larvae associated with spinach and their control by granulated insecticides.

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3 Larval and adult specimens, determined by the authors as *H. cilicrura* (Rondani), were submitted for identification to C. W. Sabrosky of the Division of Insect Identification, B.E.P.Q. Larvae submitted included collections made during three years from field soil, field plants and potted plants which had been manually infested with eggs. Adult specimens submitted included flies caught in traps and those reared in the insectary in soil and on spinach plants; all larval and adult specimens submitted were determined to be *H. cilicrura* (Rondani).

Observations

Damage to Spinach Foliage

Observations indicated that damage to foliage by the seed-corn maggot was largely caused by feeding of the larvae in the terminal leaf clusters. Larvae that hatched on foliage outside the leaf cluster usually moved toward this area within a short time.

The favored feeding sites were between the small, tender leaves in the central portion of the cluster where the larvae fed by rasping and tearing the tissues. The developing leaves were entirely destroyed or stunted and malformed. Feeding was often followed within two or three days by an invasion of decay organisms which caused a black discoloration of the abraded leaves and those in contact with them. Occasionally second and third instar larvae were found within the petiole of the larger or outer leaves. The entrance holes were usually made near the basal end of the petioles and were on either the upper or lower surfaces. The tunnels, from 1 to 3 millimeters in diameter, were seldom more than 1 to 2 inches in length but in a few instances extended the length of the petiole.

Although plants were seldom killed by foliage infestations, as a rule they suffered moderate to serious reduction in weight and often were rendered unfit for use because of quality impairment and contamination. The number of seed-corn maggots found on an infested plant ranged from one to fourteen with an average of two to three. In many cases, larvae in all three instars were found in a single plant. A few puparia were found on the soil surface or on plant foliage, but nearly all mature larvae entered the soil to pupate.

Oviposition Sites in the Field

During certain periods, females laid eggs freely on spinach foliage in the field. Eggs were deposited on all parts of the foliage but usually over three-fourths were located on the small leaves in the terminal bud. On the larger leaves, eggs were generally deposited near the midrib or on the petiole and occasionally on the underside of the leaves. Typically, the eggs were firmly attached to the foliage by an adhesive substance secreted by the fly. The number of eggs found per plant varied from one to fifteen with the usual range being from three to seven. In almost all cases, where eggs were observed on the foliage they were also found on and in the soil beneath the plant, often being in contact with both the plant stems and the soil surface. However, abundant supplies of eggs were frequently found in the soil beneath plants which did not have eggs on their foliage.

Biological Tests

Relation of Plant Size to Oviposition Rate

Procedure

In 1955, a survey was made to determine whether or not plant size and stage of development affect the oviposition site selected by flies. Plants were selected and classified in three size groups having plant diameters of approximately 9 inches, 7 inches, and 4 inches, respectively. The 9-inch plants were vegetatively mature and had compact, well-developed terminal leaf clusters, while the 4-inch plants had open terminals. The 7-inch group had about an equal number of plants with compact and loosely formed buds.

Results

The effect of plant size and leaf cluster development on attractiveness for oviposition in the field is shown in Table 1. Flies selected medium-size to large plants in preference to small ones for oviposition. The stage of development of the terminal leaf cluster appeared to be more important than plant diameter as a factor in attractiveness. Mature plants were the most attractive, but medium-size plants with well-developed, compact leaf clusters were only slightly less attractive than the larger plants and much more attractive than plants with loose or poorly developed clusters. Eggs were not found on young plants which had not developed leaf clusters.

Relation of Egg Site and Larval Activity to Foliage Infestation

Procedure

Insectary and field tests were made in the autumn of 1952 and the spring and autumn of 1953 to determine how larvae reach the foliage,

Table 1.—Relation of spinach[1] plant size and development to rate of foliar oviposition, Bixby, April, 1955.

Approximate age of plant	Plant Diameter, In.	Type of Leaf Cluster	Number of Eggs on 100 Plants[2]
Five months[3]	9	Compact	37
Two months	7	Compact	31
Two months	7	Loosely formed	7
One month	4	Undeveloped	0

1 Bloomsdale Longstanding, a wrinkled leafed spinach variety.
3 "Carry-over" plants seeded in October.
2 Based on an examination of 100 plants of each type.

whether by hatching on the plant or hatching in the soil and crawling to the plant.

To obtain oviposition on foliage in the insectary, field-trapped flies were confined on potted plants with cylindrical, 16-mesh screen-wire cages. The cages were five inches in diameter and four inches tall. The tops of cages were covered with black cloth to darken the upper part of the cages and stimulate flies to remain near the plant and soil surface. A vial of sugar water with a cotton wick was placed in the cage to serve as food for the flies. Foliage-deposited eggs for manually infesting plants were collected from field plants on which flies had oviposited. These eggs were brushed from the foliage into containers and placed in the leaf cluster or on the leaf axis of caged plants.

Soil-deposited eggs were obtained by caging field-trapped flies on pots containing a mixture of soil and tankage. The eggs were collected from the soil mixture by stirring the soil with a dissecting needle and removing them with a camel hair brush. The eggs were placed in the soil of pots containing caged plants or were placed on plants as described above for foliage-deposited eggs.

In field tests, the numbers of eggs on foliage were recorded and the soil examined for the presence of eggs and larvae. In one field test, plants with foliage free of larvae were examined daily during the test period and all foliar eggs found were removed.

The possibility of larvae migrating from the soil to the plants and causing foliar infestation was studied in the insectary and in the field. Five tests were made in the autumn and spring using first, second, and third instar larvae that were hatched from eggs deposited in the soil by flies. Larvae from this source were also placed on the soil beneath plants or in the leaf cluster or on the older leaves of the plant. In all cases the foliage of plants was free of larvae at the beginning of the tests.

Results

Table 2 summarizes results of tests made to determine the relation of oviposition site to foliage infestation. Where eggs were manually placed on leaves or were deposited by flies on leaves, foliar infestations developed provided weather conditions were favorable. In 1952 (insectary test 1 and field test 1) under dry atmospheric conditions, all larvae that hatched on foliage wandered about on the plant without feeding and died within 24 hours. Similar conditions prevailed in October 1953 (insectary test 3) and again no infestations were established.

Table 2.—Relation of oviposition site to the larval infestation in spinach foliage.

Test No.	Test Period	Larval Infestation in Soil	Eggs in Test: Original Source	Eggs in Test: Where Placed	Eggs in Test: No. per Plant	Plants in Test: Number	Plants in Test: Percent with Foliar Infestation
			Insectary Tests				
1	Nov. 1952	Absent	soil	foliage	6	14	0
		Present	soil	soil	2 to 6	15	0
2	October 1953	Absent	soil	foliage	10	15	0
3	Nov. 1953	Absent	soil	foliage	5	5	20
		Absent	foliage	foliage	5	5	20
			Field Tests				
1	Nov. 1952	Absent	soil	foliage	5	15	0
2	April 1953	Present	flies	soil and foliage	4 to 5	40	35
3	Nov. 1953	Present	flies	soil and foliage	3 to 8	100	53
		Absent	flies	foliage	4 to 10	11	60
		Present	flies	soil and foliage	0	120	1

The failure to establish a foliage infestation manually in 1952 was not considered significant, however, since no foliar infestations became established in the field during this period (field test 1). In the other tests in 1953, however, where eggs were placed on foliage, larval infestations of the foliage developed on 20 to 60 percent of the plants (insectary test 3, and field tests 2 and 3). Conversely where eggs were not present on foliage, or were removed daily (field test 3), only one plant out of 120 developed a foliar infestation. It is believed that in the latter case the foliar infestation was produced by a foliage-deposited egg that was overlooked during the daily examinations. The presence or absence of larvae in the soil beneath plants did not appear to affect the development of foliar infestations. In field tests 2 and 3, larvae were present in the soil and foliage infestations developed. In insectary test 3 and in one treatment of field test 3, larvae were not in the soil but foliar infestations developed, nevertheless. Under normal field conditions there was no indication that larvae left the soil and crawled upon the aerial portion of the plants.

Table 3 summarizes tests on the relation of larval activity to the development of foliar infestations. Results indicate that larval migra-

Table 3.—Relation of larval activity to the development of infestation of spinach foliage.

Test No.	Test Period	No. of Plants	Larvae in Test: No. per Plant	Instars	Where Placed	Migration	Foliage Feeding
1	Oct. 1952	24	4	3rd	on soil	entered soil	None
2	Oct. 1952[1]	36	Many	all	in soil[2]	in soil	None
3	Nov. 1952	12	3	2nd	on soil	entered soil	Slight
4	Nov. 1952[1]	12	Several	all	in soil[2]	in soil	None
5	Nov. 1952	14	5	1st	on plants	entered soil	None
6	Nov. 1952	5	10	3rd	on plants	entered soil	None
7	Mar. 1953	4	4	3rd	on plants	entered soil	None
8	Oct.-Nov. 1953[1]	120	Many	1st 2nd 3rd	in soil[2]	in soil	On one plant
9	Nov. 1953	6	8	1st	on plants	on plants and soil	None

[1] Field Tests.
[2] Larvae present in the soil under field plants as a result of oviposition by flies.

tion from the soil to the plant is not an important cause of infestation. They also indicate that larvae taken from soil and placed on plants are not likely to become established and feed normally on foliage.

In all tests, including a total of 217 plants and over 650 larvae, normal foliar infestation was established on only one plant.

Seasonal Development

Procedure

Seasonal development was studied by recording dates of adult activity, oviposition, larval activity and pupation.

Records of adult activity were obtained from bait traps operated in 1952 and 1953. Traps were operated at Stillwater in the autumn of 1952, at Bixby in the spring of 1953, and at both locations in the autumn of 1953.

Flies were caught in a trap consisting, in part, of a rectangular cage, 12 x 12 x 4 inches in size. It was made of light metal framework covered with 16-mesh screen-wire and supported by 4-inch, metal legs. The bottom of the cage was open and the top was fitted with a plywood frame to hold an inverted screen-wire funnel. A screen-wire cylinder, open at the lower end, was placed over the funnel and attached in a groove running around the plywood frame, thus retaining the flies when they crawled through the funnel. A small dish of commercial tankage (a mixture of dried animal residues) was placed under the trap to serve as bait.

Traps were examined at one or two day intervals and records on oviposition, larval infestation, and pupation were based on examination of 25 to 100 plants, selected at random, at one- to two-week intervals.

Results

Flies were usually active from February to early June and from early September to early December. Few flies were observed or collected during December, January, June, July, or August. Although few were seen during the winter months, on winter days when the temperature exceeded 50° F., limited numbers of flies became active and oviposited in soil. Flies were seldom seen from mid-June to September.

Trapping records are summarized in Tables 4 and 5. In the two years when traps were operated in the autumn, the earliest catches varied from September 12 to 17. Unrecorded observations made over several years indicate fly activity begins earlier than these dates if rains occur in late August or early September. The latest trap records, November 6 to 16, are not typical of most years but are characteristic of excessively dry seasons. In autumns with normal rainfall and temperature, flies may continue activity well into December, and even on warm days in January and February small numbers of active flies may be seen. Peak populations in the autumn are generally reached during October. As in the case of the autumn trapping records, those obtained in the spring (Table 5) are not highly representative of average spring activity. Usually activity begins a week or so earlier and reaches its peak in April with a decline in number of flies as warm days occur in May. Fly

Table 4.—Trapping records of flies in autumn.

	Significant Trapping Dates				Distribution by Months, Percent		
Location	Year	Earliest	Peak	Latest	September	October	November
Stillwater	1952	Sept. 13	Oct. 9	Nov. 16	16	58	26
	1953	Sept. 12	Oct. 21	Nov. 12	30	66	4
Bixby	1953	Sept. 17	Oct. 15	Nov. 6	45	51	4
Mean		Sept. 14	Oct. 15	Nov. 11	30.3	58.3	11.7

Table 5.—Trapping records of flies in spring of 1953, Bixby.

Significant Trapping Records		Distribution by Months	
Record	Date	Month	Percent
Earliest	February 18	February	4
Peak	May 6	March	12
Latest	June 1	April	26
		May	57
		June	1

activity in the autumn, after early November, and in the spring during May and June, did not appear to produce infestation of spinach foliage.

There was considerable difference among the three years in the seasonal development of **H. cilicrura** on the early spring crop (Table 6).[1] Initial oviposition ranged from February 27 to April 10 and the last eggs were laid from March 29 to April 29 in the three years. Larvae were active in foliage from mid-March to the latter part of April. Thus, oviposition extended over periods of 19 to 40 days and larvae were estimated to be present in foliage for shorter periods of 20 to 30 days.

In the regular spring crop, which was planted in February or March, infestation usually occurred from 2 to 4 weeks later than on the early spring crop and extended into late April or early May.

Records on oviposition and larval infestation during the autumn were obtained during the years 1949 to 1956, inclusive (Table 6). Initial foliar oviposition records ranged from September 28 to October 31, with the average date occurring shortly after mid-October. The latest dates on which eggs were found ranged from November 7 to November 30 with the average late record occurring in mid-November. The earliest dates that larvae were observed varied from October 13 to November 10 with the average being in the last one-third of October. Larvae were observed in plants as late as the last half of December.

The estimated earliest dates of pupation in the spring ranged from April 1 to 30. In the autumn, pupation began during the first half of November.

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[1] Called the carry-over crop due to the fact that it is planted in the fall, survives the winter as rootstocks, and then develops a second foliage crop when favorable temperatures occur in February, March, and April.

Table 6.—Seasonal development of field infestations on spinach foliage, Bixby, 1949—1956.

Year	Egg Records			Larval Records		Estimated Earliest Date of Pupation
	Earliest	Peak	Latest	Earliest	Peak	
			Early Spring or "Carry-Over" Crop			
1951	--	--	--	Mar. 11	--	--
1953	Apr. 10	Apr. 10	Apr. 29	Apr. 10	Apr. 17	Apr. 17
1954	Feb. 27	Mar. 11	Apr. 8	Mar. 18	Apr. 8	Apr. 1-5
1955	Mar. 3	Mar. 19	Mar. 29	Mar. 15	Mar. 29	Apr. 1-5
			Spring Crop			
1954	Apr. 1	Apr. 8	Apr. 29	Apr. 8	Apr. 15	Apr. 25-30
1955	Mar. 20	Apr. 3	Apr. 21	Apr. 3	Apr. 21	Apr. 15-20
1956	No foliar eggs found			No larval infestation found		
			Autumn Crop			
1949	--	--	--	Oct. 24	--	--
1950	--	--	--	Oct. 18	--	--
1951	--	--	--	Oct. 15	--	--
1952	Oct. 31	Oct. 31	Nov. 7	No larval infestation found		
1953	Oct. 27	Nov. 3	Nov. 10	Nov. 10	Nov. 17	Nov. 10-15
1954	Oct. 17	Nov. 5	Nov. 12	Oct. 24	Nov. 12	Nov. 10-15
1955	Sept. 28	Oct. 13	Nov. 28	Oct. 13	Nov. 3	Nov. 1- 5
1956	Oct. 18	Nov. 16	Nov. 30	Oct. 25	Nov. 16	Nov. 16

Relation of Rainfall to Foliage Infestation

Procedure

Rainfall records were kept throughout the test period to determine whether or not a relationship exists between rainfall and foliage infestation. Maximum levels of infestation were correlated with the amount of rainfall received during the developmental periods of foliar infestation. These periods were March and April in the spring and September and October in the autumn. Egg and larval counts were made on 25 to 100 plants, selected at random, at intervals of one to two weeks. The records included 18 crop seasons (two per year) from 1948 through 1956.

Results

Levels of infestation appeared to be influenced by amounts of rainfall occurring during the developmental periods of foliar infestation (Table 7). The four highest levels of larval infestation, ranging from 22 to 40 percent, occurred in the autumns of 1949 and 1951 and in the spring and autumn of 1953. Foliar infestations were either absent or

Table 7.—Relation of foliage infestation to rainfall, Bixby, 1948—1956.

Year	Maximum Percent Plants Infested with: Larvae	Maximum Percent Plants Infested with: Eggs	Inches Rainfall March and April[1]	Maximum Percent Plants Infested with: Larvae	Maximum Percent Plants Infested with: Eggs	Inches Rainfall September and October[2]
1948	--[3]	--	8.2	0	--	0.6
1949	0	--	3.3	22	--	6.1
1950	0	--	2.1	17	--	3.0
1951	4	--	4.1	29	--	11.5
1952	--[4]	--	6.0	0	1	0.5
1953	40	47	12.5	37	36	9.8
1954	15	54	4.9	3	7	4.1
1955	3	17	3.8	4	12	5.5
1956	0	0	3.1	5	16	2.7

1 Normal rainfall (at Tulsa WB, nearest normal record) 7.2 in.
2 Normal rainfall (at Tulsa WB, nearest normal record) 7.3 in.
3 "Heavy" infestation reported by Station Superintendent at Bixby.
4 "Light" infestation reported by Station Superintendent at Bixby.

not reported in the autumn of 1948, the spring of 1949 and 1950, the autumn of 1952, and the spring of 1956. In the other nine seasons infestations varied from 1 to 17 percent.

In the four seasons with highest infestations, rainfall for the developmental periods ranged from 6.1 to 12.5 inches for an average of 10 inches. Normal average rainfall was 7.2 inches for the March-April period and 7.3 inches for the September-October period. During the five seasons when foliar infestations did not appear, rainfall varied from 0.5 to 3.3 inches with an average of 1.3 inches. In seven seasons when rainfall averaged 4.0 inches, 7.3 percent of the plants were infested. Quantitative records were not obtained in the spring of 1948 and 1952. In 1948, when rainfall was 8.2 inches, a "heavy" infestation was reported; in 1952, when precipitation was 6.0 inches, infestation was described as "light."

The correlation of foliar infestation with rainfall appeared to be caused by moisture effects on both the eggs and larvae of the seedcorn maggot. Oviposition in soil, in cages, and in the field occurred freely when the soil and soil surface were moderately moist but was inhibited by excessively wet or dry soil. Flies oviposited freely on field plants when the soil was moist and the air humid but laid few eggs on foliage under dry conditions. There were indications that an abrupt advent of dry weather conditions reduced the potential foliar infestation. On March 11, 1954, 54 percent of the carry-over plants contained eggs. During the following week dry winds greatly reduced soil moisture leading to the production of blowing dust. On March 18, the egg infestation was reduced to 5 percent and only 2 percent of the plants were infested with larvae. By the end of the following week, no significant change occurred in the larval infestation, demonstrating that the 54 percent egg infestation on March 11 was largely eliminated. Observations made in other seasons also indicated dry winds and blowing dust reduced egg and young larval infestations on foliage.

Duration of Immature Stages

Procedure

Duration of immature stages of the insect were determined by rearings made in the soil and on the foliage. Daily observations were made and dates of hatching, pupation, and adult emergence were recorded.

In rearings made in soil, eggs and larvae were placed in an open Stender dish containing a mixture of 10 percent tankage and 90 percent soil with a small piece of potato added.

Foliage rearings were made by placing eggs or larvae on the buds of plants in pots or in the field. When the mature larvae left the plant to enter the soil, preparatory to pupation, they were placed in fine, silty loam soil in open jelly jars where the length of the pupal period was determined.

Results

Data concerning the duration of immature stages of **H. cilicrura** are summarized in Table 8.

The average incubation period for eggs collected from the soil was 1.58 days compared to 1.20 days for foliar eggs. The latter eggs were gathered from field plants and the time of oviposition was more difficult to estimate than was the case for soil-collected eggs where fresh soil in pots made daily examination possible. Because of this fact, the difference in the incubation period of the eggs from the two sources was not considered significant.

The length of the larval period of specimens hatched from the two types of eggs was determined by rearing them on two kinds of media and at two mean temperatures of 62° and 70° F. The type of medium had a marked effect on the rate of larval development. Specimens reared at 62° F. in a soil-tankage mixture containing pieces of potato completed development in 14.4 days as compared to 24.5 to

Table 8.—Duration of immature stages in the insectary, Stillwater, 1952, 1953.

Original Source	Rearing Medium	Number of Specimens	Range in Days	Mean Days	Percent 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[1]	18	14-17	15.6	72	70°F.
Foliage	Soil[1]	16	13-21	15.2	87	70°F.
Soil	Soil[1]	22	9-19	14.4	68	62°F.
Soil	Foliage	6	24-25	24.5	33	62°F.
Foliage	Foliage	4	__-25	25.0	25	62°F.
			Prepupa and 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.

[1] Containing approximatly 10% tankage and small pieces of potato.

25.0 days for those fed on spinach foliage at the same temperature. That spinach foliage is a poor diet and habitat for this species was further indicated since only 25 to 33 percent of the larvae pupuated as compared to 68 to 87 percent of those reared in the soil.

A difference of 8° in the mean rearing temperatures did not greatly affect larval development. Larvae reared in soil at 70° F. completed development in 15.6 days compared to 14.4 days required by larvae from the same source at 62° F.

The source of eggs had no significant effect on larval development. In the first comparison, at a mean temperature of 70° F., larvae hatched from eggs collected in the soil reached the prepupal stage in 15.6 days compared to 15.2 days necessary for those hatched from foliar eggs.

The duration of the prepupal-pupal period was not affected by either the source of eggs or the type of media on which the specimens had lived and fed as larvae. Of the three factors tested, only temperature had an influence on the length of the resting period. A total of 43 specimens kept at a mean temperature of 70° F., required 16.5 days to emerge as compared to 11.8 days for 39 specimens kept at 62° F.

Insecticide Tests

Procedure

During the last four years of the study, 15 insecticides were compared for effectiveness in controlling foliage infestations. The majority of the materials tested were applied as emulsion or solution sprays in schedules of one to six applications. Tests were made with concentrate sprays, dilute sprays, and with dust and granular formulations.

Results

Table 9 summarizes results of a typical concentrate spray test conducted in the autumn of 1953 and a high volume spray test made in the spring of 1954. Applications in the concentrate test were made October 27, November 3, November 10, and November 17. On these dates the percent of plants containing foliar eggs was 0.5, 36.0, 18.0, and 0.0, respectively. Thus the treatment schedule coincided with oviposition. Examinations made a week after each application indicated that treatment effectiveness was largely limited to the first two applications. The early applications were made when the plants were small and while the terminal leaf clusters were loose enough to permit insecticides to contact larvae among the overlapping leaves. The results of the final examination, made ten days after the fourth application, showed no significant differences among insecticides.

In the high volume spray test (Table 9) the treatment schedule was correlated with the oviposition period. Here again only moderate effectiveness was demonstrated. It is surprising that no better results were obtaind with sprays containing doubled amounts of toxicant (0.5 lb./acre) and applied at high pressure than with the concentrate sprays (Table 9). In this test, however, leaf clusters of the plants were well formed before treatment (and oviposition) began.

The results of six tests including chlorinated hydrocarbon and organic phosphate toxicants varied considerably, but in no case exceeded

Table 9.—Effect of concentrate and high-volume sprays on spinach foliage infestations, Fall, 1953, Spring, 1954.

Insecticide	Plants Damaged (percent)	Plant Damage Reduction (percent)	Number Living Larvae Per 100 Plants	Larval Reduction (percent)
	Concentrate Sprays, Fall, 1953[1]			
Heptachlor	15	57	2.0	70
Chlordane	16	55	2.7	60
Aldrin	17	51	2.7	60
Dieldrin	15	57	3.0	55
Lindane	19	46	3.0	55
Endrin	19	46	3.3	50
Parathion	24	23	3.5	50
Untreated	35	--	6.7	--
	High-volume Sprays, Spring, 1954[2]			
Endrin	14	36	6.4	66
Lindane	16	34	9.6	48
Parathion	21	16	16.0	14
Untreated	25	--	18.4	--

[1] Results based on 50 plants selected at random from each of three replicates. Insecticides applied four times at weekly intervals at 0.25 lb. actual toxicant per acre except chlordane which was applied at 1.0 lb. per acre.

[2] Results based on 125 plants selected at random from each of two replicates. Insecticides applied six times at weekly intervals at 0.5 lb. actual toxicant per acre in 100-150 gallons of water at 350-400 psi.

the effectiveness shown in the tests previously described. Tests were made on autumn, early spring, and spring crops with plant sizes ranging from young plants with beginning leaf clusters to mature plants ready for harvest. They included comparison of flat leaf types of spinach with the crinkled or curled types. Neither season nor plant type caused significant differences in control tests. The stage of plant development influenced treatment effectiveness. Control effectiveness was progressively lower as the terminal leaf clusters became larger and closer fitting. In view of such results, and also in consideration of the proven toxicity of several of the insecticides to **H. cilicrura,** it was apparent that the difficulty was due largely to the fact that the toxicants did not penetrate the overlapping leaves to contact the larvae.

In two tests made in November 1956, phosdrin, a short-lived phosphate insecticide, was tested against a larval population ranging from first to third instars on Bloomsdate Longstanding plants slightly over two months of age. Only infested plants were included in the test. Single applications of spray and dust formulations were made. In the first test (Table 10), in which the toxicant was applied at 0.3 lb. per acre, the level of control was comparable to the most effective results obtained with materials, previously mentioned.

Table 10.—Effect of a single application of phosdrin spray and dust on foliage infestations, Bixby, November 2-9, 1956.

Treatment	Number on 50 Infested Plants: Living Larvae	Dead Larvae	Eggs	Percent Larval Reduction Over Check
Phosdrin 0.12% spray[1]	5	6	13	72
Phosdrin 1.0% dust[2]	6	7	21	67
Untreated Check	18	1	30	--

[1] Applied at 0.3 lb. actual toxicant and 30-35 gallons of spray per acre at a pressure of 40 psi.
[2] Applied at 30 lbs. of dust containing 0.3 lb. actual toxicant per acre.

In the second test (Table 11), in which the amount of toxicant was increased to 0.5 lb. per acre, control effectiveness approached or reached the commercially satisfactory level, ranging from 89 to 100 percent control. The insecticidal action of phosdrin proved to be

Table 11.—Effect of a single application of phosdrin spray and dust on foliage infestations, Bixby, November 14-21, 1956.

Treatment	Number on 25 Infested Plants: Living Larvae	Dead Larvae	Eggs	Percent Larval Reduction Over Check
Plants harvested and examined November 16.				
Phosdrin 0.12% spray[1]	2	15	11	89
Phosdrin 1.0% dust[2]	1	12	6	95
Untreated Check	28	4	18	--
Plants harvested and examined November 21.				
Phosdrin 0.12% spray[1]	0	10	6	100
Phosdrin 1.0% dust[2]	2	13	5	90
Untreated Check	19	1	4	--

[1] Applied at 0.5 lb. actual toxicant and 65-70 gallons per acre at a pressure of 40 psi.
[2] Applied at 50 lbs. of dust containing 0.5 lb. actual toxicant per acre.

quite rapid, producing kills within two days after treatment. Sprays and dusts were approximately equal in effectiveness, but the former burned plants considerably at the higher rate of application.

A considerable number of dead larvae were found in the terminals of plants treated with phosdrin as contrasted with very few dead forms recovered in earlier tests where other materials were used. These facts indicate that phosdrin affected larva within the leaf cluster as well as on the exposed foliar surfaces. Nearly all larvae on such exposed surfaces were within the first instar and, therefore, were difficult to find following death, due to desiccation or dispersal by wind or water.

During the autumn of 1957, three insecticides in granular formulations were compared with phosdrin dust. These included parathion, malathion and heptachlor applied at rates of 0.5 pound to 1.5 pounds of toxicant per acre. Treatment was applied November 14 and infestation counts were made one week later.

The results of the 1957 tests are given in Table 12. Granular formulation of each of the insecticides was equal to or greater in effectiveness than the phosdrin dust. Parathion and malathion at the higher rates of application (1.0 and 1.5 lbs. per acre, respectively) gave com-

Table 12.—Effect of single applications of granular or dust formulations on foliage infestations, Bixby, November 14-21, 1957.

Insecticide Formulation[1]	Pounds of Toxicant Per Acre	Number[2] Living Maggots Per 100 Plants	Percent Larval Reduction Over Check	PPM Residue[3] on Plants Harvested at: 1 Hour	7 Days
Parathion 5% granules	1.00	0.0	100.0	0.00	0.00
" " "	0.50	0.7	95.1	---	---
Malathion 10% granules	1.50	0.0	100.0	---	---
" " "	0.75	1.3	90.2	---	---
Heptachlor 2½% granules	1.50	1.0	93.0	0.83	0.25
" " "	0.75	1.7	88.2	---	---
Phosdrin 1% dust	0.50	1.3	90.2	---	---
Untreated Check	---	14.4	----	0.00	0.00

1 Treatments applied November 14. Granular formulations applied in a 12-inch band, centered over the row, by means of a sieve-type hand applicator. Dust applied with a rotary hand duster.

2 Based on an examination of 50 plants collected at random November 21 from each of four replicates.

3 Samples harvested at Bixby, transported during a two-hour period to Stillwater, and placed in frozen storage until analyzed.

plete control. At the lower rates of 0.5 to 0.75 lb. of toxicant per acre the percent reduction of the population ranged from 88 to 95.

The results of tests in 1956 and 1957 are quite encouraging. The degree of control was within levels of satisfactory commercial control. The short life of phosdrin, residually or systematically, makes it particularly suitable for use on vegetable crops within a few days of harvest. The residue data on parathion and heptachlor granules indicate that excessive residues would not result from treatment made one week before harvest.

Summary

The seed-corn maggot, **Hylemya cilicrura** (Rondani), usually a subterranean feeder on several crops, is an important foliage pest of spinach in Oklahoma. The chief damage from foliar infestation results from contamination of the foliage, thereby prohibiting or postponing harvest of the crop. Oviposition on foliage, particularly the terminal leaf cluster, accounts for foliar infestations. Larvae were never observed migrating from the soil to the foliage, and no foliar infestations were established when larvae were taken from the soil and placed on foliage. The favored feeding sites for larvae were between the tender developing leaves within the leaf cluster, but occasionally larvae tunneled within the petiole of larger leaves. Adults preferred medium to large plants with compact terminal leaf clusters.

The heaviest foliar infestations occurred in seasons of above normal rainfall, and infestations were absent or low in seasons of extreme drought. Reduced infestations under dry conditions appeared to be due to reduced oviposition rates, deterioration of eggs, and increased mortality of young larvae. Foliar infestations occurred from mid-October to mid-December and from mid-February to early June.

Oviposition on foliage extended over a period of 20 to 30 days. The average incubation period of eggs was from 1.20 to 1.58 days. Larvae reared on spinach foliage completed development in an average of 25 days compared to only 14 to 16 days for those in soil containing tankage and potato. The average prepupal-pupal period ranged from 12 to 14 days.

Non-systemic, contact insecticide sprays controlled foliage infestations when plants were small and the leaf cluster was relatively open, but became progressively less effective as the cluster became tighter, affording shelter for larvae. Phosdrin, a short-lived phosphate insecticide, which appeared to act systemically, killed larvae of all

instars within the leaf cluster and gave control ranging from 89 to 100 percent.

Treatments of granular formulations of parathion, malathion or heptachlor gave results equal to or greater than that of phosdrin dust. Limited data indicated that excessive residues of parathion or heptachlor on plants would not result from a single application of a granular formulation made one week before harvest.

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