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A Decade with the Alfalfa Weevil in Tennessee

University of Tennessee Agricultural Experiment Station

Stelmon E. Bennett

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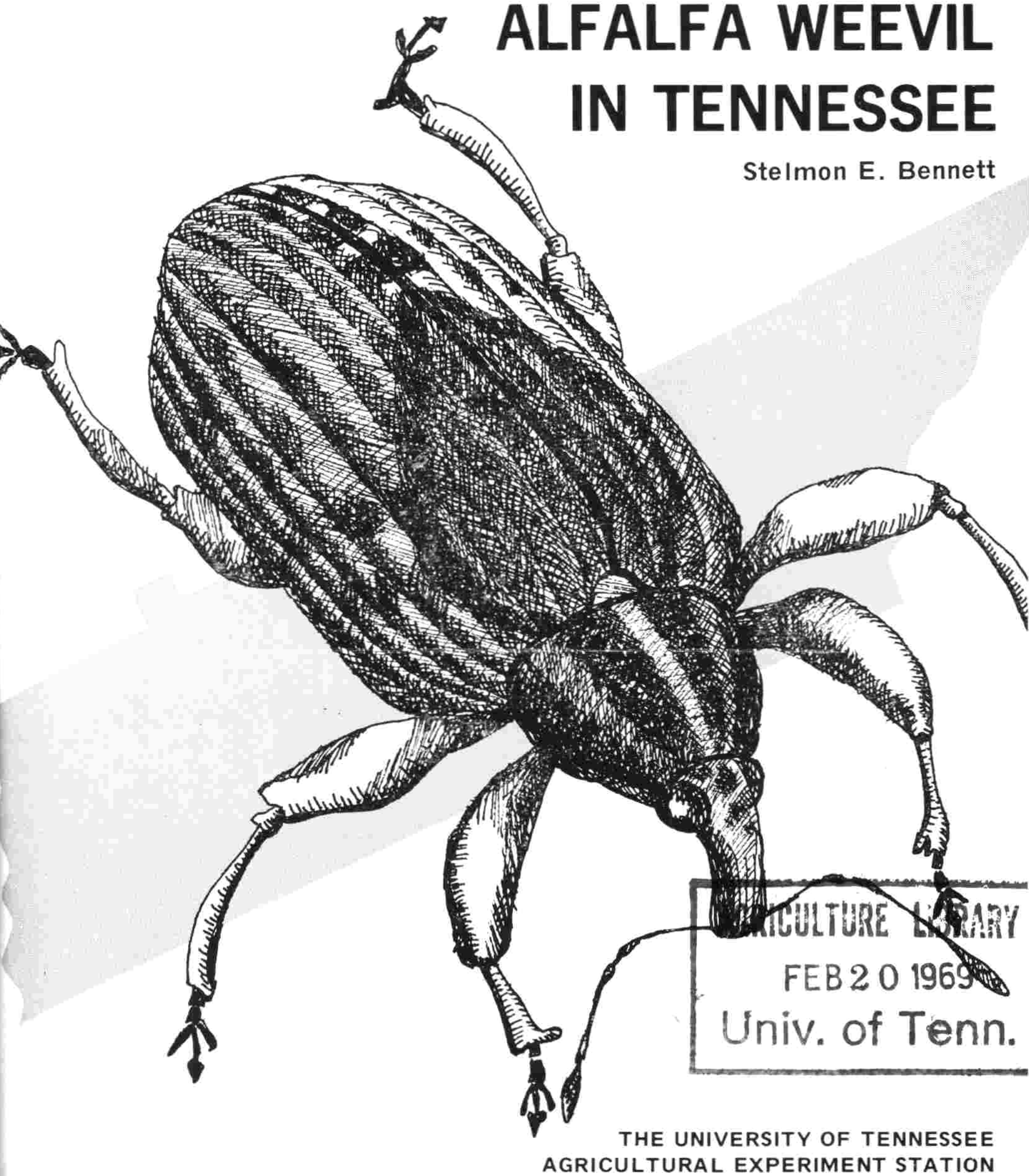

THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION
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CONTENTS

CONCLUSIONS AND FUTURE RESEARCH TRENDS

1. The alfalfa weevil infests the entire state and economic losses are tremendous.

2. The weevil has one generation in Tennessee except for possibly Johnson County.

3. Control can be accomplished with recommended insecticides but demands more careful timing than was necessary with heptachlor.

4. If Furadan or Supracide are labeled, a possible one-application chemical control would be available which should promote a definite increase in acreage of alfalfa seeded.

5. The weevils were much later in 1968, populations were lower, and control was much easier to obtain with recommended insecticides.

6. Cultural control practices are being investigated such as plant breeding for resistant varieties and alfalfa managed as an annual (cooperative with Purdue and Kentucky).

7. Parasites of all stages of the weevil are being released annually in hopes of establishment and consequent reduction in overall population.

8. Radiation and chemosterilant investigations underway are being continued.

ACKNOWLEDGMENTS

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A DECADE WITH THE ALFALFA WEEVIL IN TENNESSEE

by

Stelmon E. Bennett*

INTRODUCTION

The alfalfa weevil *(Hypera postica* (Gyllenhal)), a native of Europe, was first found in Utah in 1904. Since 1904 it has spread over the alfalfa-producing area of the West. In 1952 an infestation was found in Maryland, Delaware, New Jersey, Pennsylvania, and the weevils have spread since that time over all of the East as well as into the alfalfa-producing areas of the Midwest. The weevil was first found in Tennessee in 1959. However, because of the size and distribution of the infested area, it was most likely present in 1958.

The weevil is the most important pest of alfalfa in the State of Tennessee and has been responsible for reducing the acreage from an all time high of 250,000 acres to about 50,000 in 1968. Excellent control was obtained with heptachlor in the early 1960's, especially with a fall application of heptachlor-impregnated fertilizer. This practice not only controlled the weevil but also increased yields through increased growth and more cuttings due to proper fertilization.

In 1964 heptachlor was withdrawn from use on alfalfa because of residues in the milk. Although good control was still being obtained in Tennessee with heptachlor, weevil resistance to heptachlor had shown up in Maryland, Virginia, and North Carolina.

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* Head of the Agricultural Biology Department.

From 1964 through 1967 a great deal of research effort has been expended to find another satisfactory control method, mostly with disappointing results. However, in 1966 an experimental systemic carbamate insecticide, Niagara 10242, looked promising and also a phosphorus compound, GS 13005. The insecticides, named Furadan and Supracide respectively, gave good control with a single application in 1967 and 1968. If a label is granted for the use of either Furadan or Supracide in 1968, an upward trend in alfalfa acreage should begin.

DISTRIBUTION AND HOST PLANTS

The alfalfa weevil was found in the upper corner of East Tennessee during the summer of 1959. Three counties were involved: Johnson, Sullivan, and Carter. The population was rather high in Johnson and Sullivan Counties with smaller numbers collected in Carter County. The size of the area involved as well as the population size would lead one to believe that the weevil was present in 1958.

In 1960 weevils were collected from eight additional upper East Tennessee counties. In 1961 weevils spread through all of East Tennessee and into three Middle Tennessee counties along the Tennessee-Alabama line. In 1962 they spread to all Plateau counties and into the central Middle Tennessee counties. In 1963 they spread across the State with only three counties in the northwest corner not reporting an infestation. In 1964 the weevil was collected in Lake, Obion, and Weakley. Thus, the weevil in 4 or 5 years had spread over the entire State (see Figure 1).

Movement has continued northward and westward since the initial invasion of Tennessee and is now all across Arkansas and Missouri and northward into Wisconsin. Some investigators estimate movement at about 50 miles per year. The author feels it should be from 75-100 miles per year based on observations in Tennessee.

The alfalfa weevil feeds on a large number of host plants in addition to alfalfa, such as sweet clover, ladino clover, and vetch. The eggs have been found in henbit and chickweed when an infestation is extremely high. When the weevils emerge from cocoons in large numbers, they have been observed imbedded in snap beans and strawberries in East Tennessee. This could have been

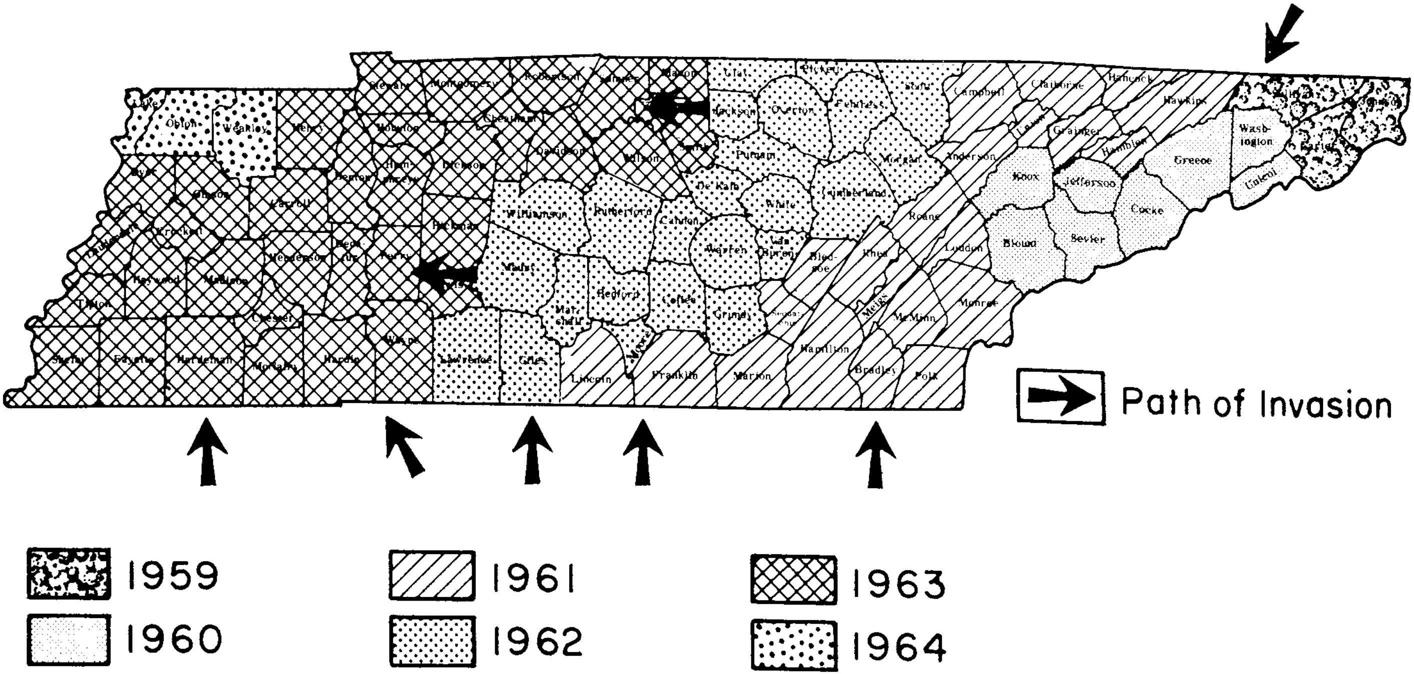


Figure 1. The paths of invasion and spread in Tennessee by the alfalfa weevil, geographic distribution within the State by year, and the present infestation.

simply an escape habitat because it was extremely hot and the alfalfa had just been cut, which exposed the weevils to an unfavorable situation. However, damage to the snap beans in a garden next to the alfalfa field did occur. Other host plants have been recorded by investigators through the years. However, these are the most important ones to Tennessee alfalfa growers.

DESCRIPTION OF STAGES AND SEASONAL CYCLE

Egg

The eggs can be found in the stems from mid-October through the following spring. Eggs are oval in shape, light yellow in color —later turning a dark brown as they approach hatching (see Figure 2A). They are about 1/32 inch in size and are found in the pith area of the stem. The feeding punctures prior to egg deposition can be found on the stems by the trained observer. The number of eggs in a stem varies from 1 to 49 with 3 to 15 eggs in a mass. If stems that contain eggs are brought into the laboratory during the winter and kept at room temperature, hatching will occur in from 48-72 hours.

Larva

The larva after hatching is yellowish-tan in color with a black head capsule. The larvae pass through four larval instars becoming green colored as they get larger with a white line down the middle of the back (see Figure 2B). When full grown, the larvae are about 3/8 inch long. The duration of the larval period varies, depending on temperature, and may be as short as 2 weeks or less in late spring.

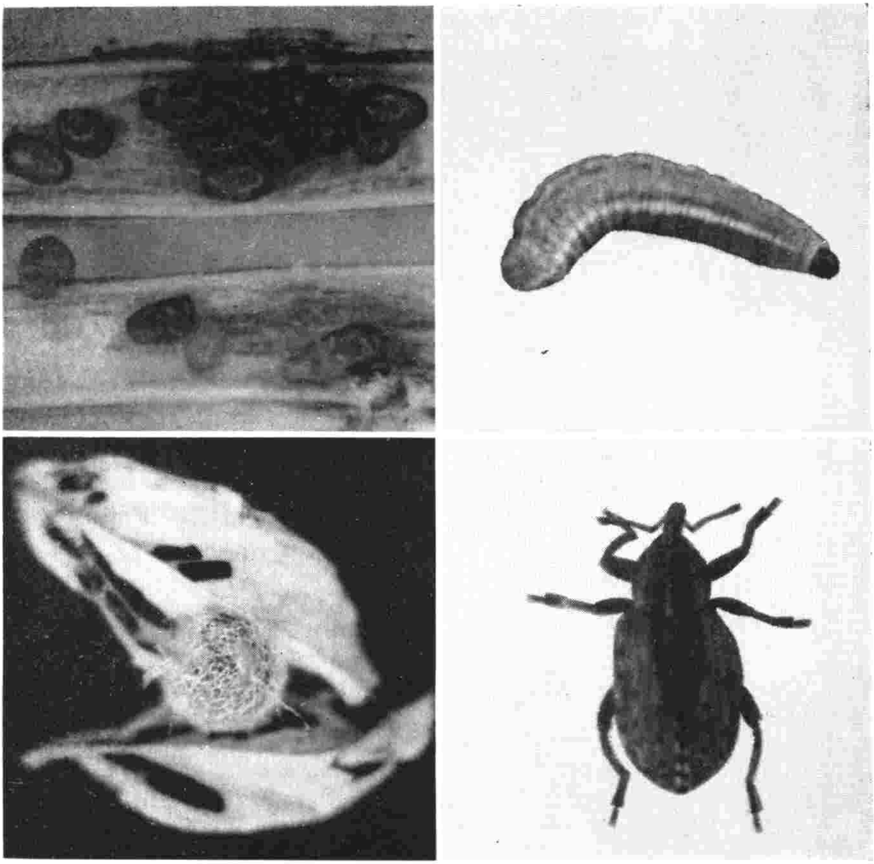
Pupa

The full-grown larva spins a cocoon of whitish, thread-like material in debris on the ground or attached to the alfalfa plant (see Figure 2C). The larva transforms to the adult within the cocoon and in late spring adult emergence may occur in as little as 4 days.

Adult

The adult is light brown with a dark line down the middle of the back (see Figure 2D). They are about 3/16 inch long, have a snout, and can be distinguished by size from other weevils that feed on

A B



C D

Figure 2. Life cycle stages of the alfalfa weevil: A, egg; B, larvae; C, pupae; D, adult.

alfalfa. The adults are active in the early fall in Tennessee, depositing eggs in early October with periodic activity throughout the winter months and into the spring. The newly-emerging adults estivate during the summer months and return to the field in early fall (see the diagrammatic seasonal cycle chart in Figure 3).

Seasonal Cycle

In general, the seasonal cycle of the alfalfa weevil in Tennessee follows a pattern similar to that in other parts of the country but differs in that larval development—hence feeding damage—is over

a longer period. The weevil overwinters in the adult and egg stages. Larvae emerge in mid-March and can be found in the field until early May. This is the stage that does most of the damage through foliar feeding on the first cutting alfalfa. The pupal stage occurs in late April and early May and adult emergence is closely corre-

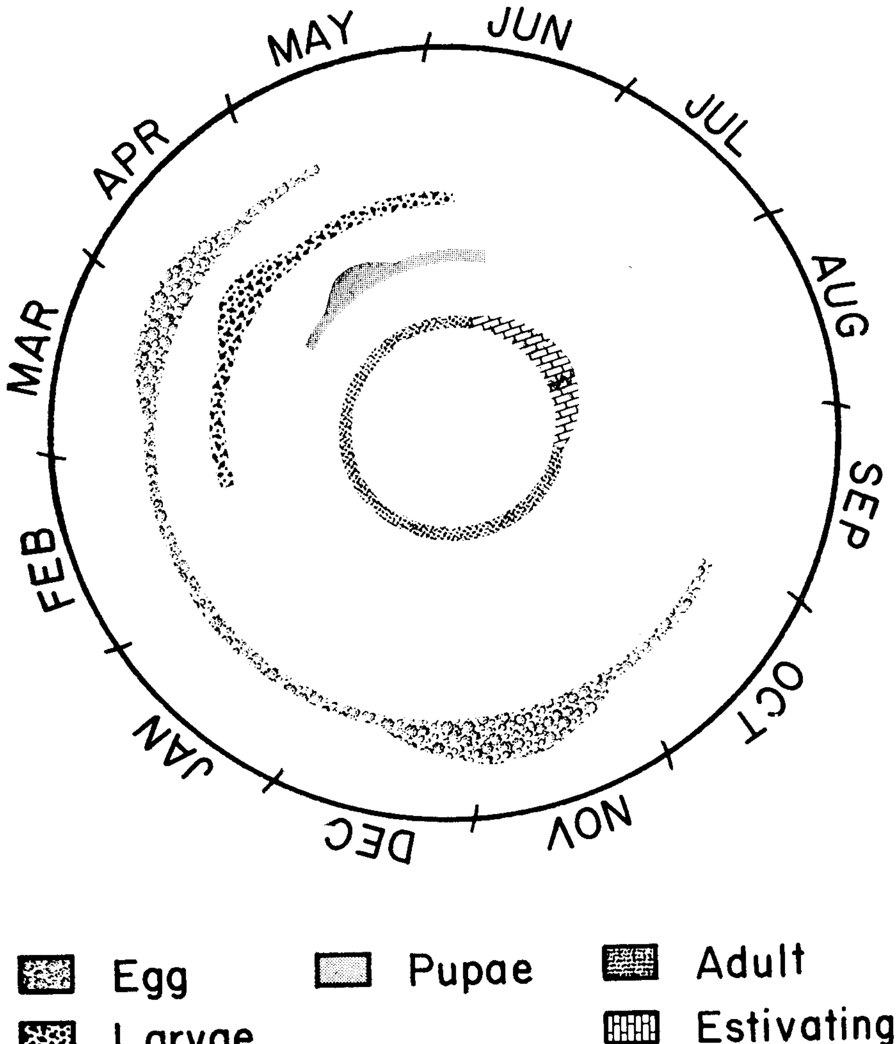


***Figure 3.** Diagrammatic chart representing the stages of the alfalfa weevil in Tennessee, when they occur, and the time of peak abundance.*

lated with the same period due to the short duration of the pupal stage. Newly-emerging adults estivate during the hot summer months and become active again in the fall. Egg deposition begins in mid-October and continues into the winter. Eggs are deposited in the alfalfa stems. Some adults do not deposit eggs until the following spring. Considerable overlap of stages does occur (see Figure 3).

An exception to the described general pattern can be found within the State. Larvae are present throughout the year in Johnson County, with the population being large enough to cause easily discernible foliar damage in early September. It is undetermined whether these larvae are the result of multiple generations or just overwintered females depositing eggs on into the summer months. However, the same phenomenon does occur in New Jersey and several theories have been proposed to account for the unusual behavior (Barnes, 1, 1967).

CHEMICAL CONTROL INVESTIGATIONS

Fall Applications

In the fall of 1960, experimental fall treatments of heptachlor were made on fields in upper East Tennessee. Heptachlor was used in granular form and impregnated on fertilizer. Effective control (Figure 4) was obtained which led to more extensive tests in the fall of 1961. Three rates were used: ½, ¾, and 1 pound of active material per acre and in three forms (2½% granules, 5% granules, and impregnated on 0-9-27B fertilizer). Tests were placed at 12 locations in East Tennessee. Good results were obtained as the summary of data in Table 1 indicates. In the fall of 1962, tests were placed on branch stations at Greeneville, Crossville, Spring Hill, Lewisburg, and Knoxville. The results again were very good as indicated by data in Table 2, which is for Greeneville and typical of results from the five stations. In the fall of 1963, heptachlor granules impregnated with Chloro-IPC were applied at Greeneville with resulting good weevil and chickweed control. However, this combination of weevil and weed control was never used later because the heptachlor label was withdrawn for use on alfalfa in the

spring of 1964. Weevil resistance to heptachlor had been detected in Virginia and North Carolina before then. However, there had been no reported or detected weevil resistance in Tennessee.

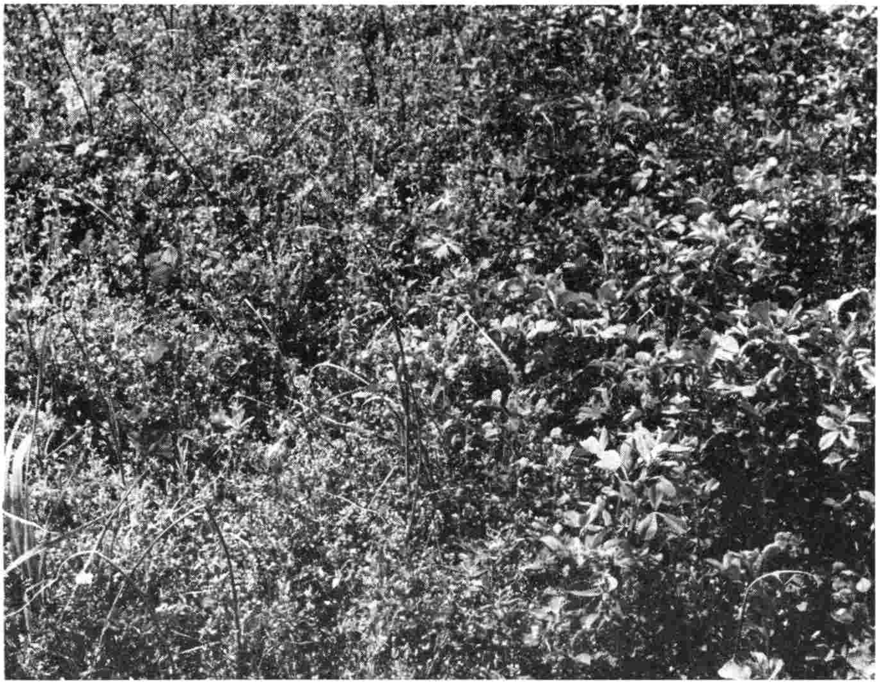


Figure 4. Alfalfa on the right was fall treated with heptachlor-impregnated fertilizer; damaged plants on left were untreated.

Spring Sprays

Each year during the period that effective control was obtained from fall-applied heptachlor, various spring sprays were tried because it was realized that resistance to heptachlor might develop. The results of one of these tests are given in Table 3. During the tests conducted over the period that the weevil has been in Tennessee, very few insecticides have been found which give satisfactory control with one application. Very few materials will protect for the long larval period without leaving appreciable residues in the harvested crop.

Table 1. Summary of data on yields, residues, and insect abundance at 12 locations in East Tennessee for 1962 following 1961 fall applications of heptachlor for control of alfalfa weevil

	Treatments	Active rate per acre*		Total no. (4 counts)		Av. hay yield[3]/A. 1st cutting	Residue	
				Egg masses[1] per sq. ft.	Larvae[2] per sq. ft.		Heptachlor	Heptachlor epoxide
		Mo.	lb.	No.		lb.	p.p.m.	
(1)	No heptachlor (check)			147	599	646	0	0
(2)				111	539	692	0	0
(3)	Heptachlor-impreg. fertilizer	Oct.	.5	11	71	1,535		
(4)	" " "	Nov.	"	5	94	1,214		
(5)	" " "	Oct.	.75	5	44	1,520		
(6)	" " "	Nov.	"	2	49	1,665		
(7)	" " "	Oct.	1.0	4	31	1,736	[4]<.10	[4]<.10
(8)	" " "	Nov.	"	0	46	1,620	[4]<.10	.10
(9)	2½% Hept. granules	Oct.	.5	4	42	1,387		
(10)	" " "	Nov.	"	4	54	1,569		
(11)	" " "	Oct.	.75	2	21	1,590		
(12)	" " "	Nov.	"	3	20	1,817		
(13)	" " "	Oct.	1.0	4	8	1,944	[4]<.10	.10
(14)	" " "	Nov.	"	7	4	1,958	.10	.09
(15)	5% " "	Oct.	.5	9	32	1,537		
(16)	" " "	Nov.	"	2	53	1,554		
(17)	" " "	Oct.	.75	4	31	1,724		
(18)	" " "	Nov.	"	2	32	1,576		
(19)	" " "	Oct.	1.0	2	13	1,874	[4]<.10	[4]<.10
(20)	" " "	Nov.	"	7	35	1,933	[4]<.10	.10

*Total fertilizer applied: 500 pounds per acre.

[1] Egg counts were made for November, December, 1961, January, and February, 1962.

[2] Larvae counts were made on March 12-15, April 9-12, and April 23-26, 1962.

[3] Hay yields were taken early in May, 1962.

[4] Less than.

Table 2. Larval counts[1], percent control, and hay yields on fall-treated (October 1962) alfalfa, Tobacco Experiment Station, Greeneville, 1963

Treatments	Counts: Av. of 4 reps	4-9-63 % control	Counts: Av. of 4 reps	4-18-63 % control	Counts: Av. of 4 reps	4-26-63 % control	Counts: Av. of 4 reps	5-7-63 % control	Yield: Av. lb. per acre
1. Check	27	----	573		924	--	650	----	1477
2. 0.2% heptachlor impregnated on 0-9-27 fertilizer @ 500 lb. per acre	0	100	1	99+	35	96	30	95	2461
3. 2½% heptachlor granules @ 40 lb. per acre[2]	0	100	0	100	1	99+	9	99	2435
4. 5% heptachlor granules @ 20 lb. per acre[2]	0	100	0.7	99+	15	98	44	93	2435
5. 1% Telodrin granules @ 25 lb. per acre[2]	0	100	10	98	14	98	43	93	2015
6. 2½% heptachlor granules @ 40 lb. per acre[3]	0	100	0	100	4	99+	14	98	2390
7. 0.5% heptachlor impregnated on 0-0-60B fertilizer @ 200 lb. per acre	0	100	38	93	272	71	388	40	1616
LSD .05									698

[1] Number of larvae per 25 sweeps on four sampling dates at Greeneville Station, old stand alfalfa.

[2] Plus 500 pounds per acre of 0-9-27B fertilizer applied separately in fall of 1962.

[3] Plus 500 pounds per acre of 0-9-27B fertilizer applied separately, March 1963.

Table 3. Larval counts[1] and percent control on spring-treated alfalfa[2], Tobacco Experiment Station, Greeneville, 1963

Treatments	Rate per acre actual lb.	Counts: Av. of 4 reps	4-18-63 % control	Counts: Av. of 4 reps	4-26-63 % control	Counts: Av. of 4 reps	5-7-63 % control
1. Imidan 3E	1	3	99+	109	83	335	62
2. A.C. 47,031 3E	1	14	99+	133	79	158	82
3. A.C. 43,064 4E	1	11	98	52	92	341	61
4. A.C. 47,470 4E	1	1	99+	18	97	56	94
5. Thimet 4E	1	0.5	99+	69	89	831	6
6. 10% Thimet granules	1	11	98	321	50	499	43
7. Telodrin 1.2E	⅛	0	100	0	100	0	100
8. Telodrin granules	⅛	4	99	17	97	18	98
9. Guthion M.E. 2E	½	12	98	11	98	19	97
10. Bayer 39007 1.5E	1	3	99+	121	81	925	0
11. S.D. 7438 1.6E	1	17	97	213	67	320	64
12. Guthion 2E	½	19	96	309	52	706	20
13. Diazinon 4E	1	18	97	104	84	733	17
14. Endrin 1.6E	¼	2	99+	14	98	24	97
15. S.D. 7438 Impreg. 0-9-27B	½	0	100	40	94	41	95
16. S.D. 7438 Impreg. 0-9-27B	1	0	100	0	100	0	100
17. Check	None	530	—	638	—	883	—

[1] Counts based on number of larvae per 25 sweeps. Pre-treatment counts, 300 larvae per 25 sweeps.
[2] All treatments applied April 11, 1963 except 15 and 16 which were applied March 18, 1963.

Table 4. Low volume spring spray test at Greeneville, April 22, 1965[1]

Trt. No.	Type equipment	Treatment	Av. No. of larvae[2]	% control
1	Jeep	Thimet EC .5 lb./active per acre	0.3	99
2	"	Malathion EC 3 pts./A.	0.3	99
3	"	Malathion Tech. 16 oz./A.	1.0	98
4	"Stretch" (a boom)	Malathion Tech. 16 oz. 1 gal. H_2O/A.	17	82
5	Jeep	Malathion Tech. 16 oz. 1 gal. H_2O/A.	2	97
6	"Stretch"	Malathion EC 3 pts./A.	9	90
7	"	Cygon 12 oz. + Mala. Tech. 2 oz./ 1 gal. H_2O	12	87
8		Control	97	—

[1] Pre-treatment counts averaged 40 larvae per square foot.

[2] Average number of larvae per 10 sweeps (four replications) 7 days after treatment.

Figure 5. An innovation in low volume sprayers designed for cotton spraying but used in alfalfa weevil control research. Capable of applying as little as 1 gallon per acre.

Low Volume Sprays

During 1964 and 1965, the low-volume method of application was being tried in Tennessee for cotton insect control. This method is a great labor and time saver because of the small amount of liquid necessary to cover 1 acre and the speed with which materials can be applied. It was tried at Greeneville in April of 1965. The results of the test are presented in Table 4 and the equipment used to apply the insecticides is shown in Figures 5 and 6. The resulting control was good but more than one application was necessary for satisfactory control.

Figure 6. A jeep equipped with buffalo turbine for air blast and a mini-spin nozzle for low-volume application. It can apply as little as 8 ounces per acre.

The Correlation Between Lipid Content and Percent Mortality of the Alfalfa Weevil Using Heptachlor and Malathion

It was found through a preliminary study in 1961 that the weevils were much easier to kill with a low insecticide dosage when newly emerged than after a brief period of maturation. A study

was begun in the spring of 1962 to relate seasonal development and seasonal inactivity of the adults to weevil mortality after treatment with heptachlor and malathion (Bennett and Thomas, 2).

Fat and mortality studies were conducted on weevils 1 to 54 days old (Table 5). From 1 to 7 days of age, percent mortality remained fairly constant even though percent fat increased slightly. With heptachlor, the percent mortality decreased as the percent fat increased in weevils 10 to 35 days of age. From 35 to 45 days of age

Table 5. Body fat and mortality of the alfalfa weevil to heptachlor and malathion

	Percent		Percent kill	
Age (Days)	Fat (Dry weight)	Moisture	Heptachlor	Malathion
1	5.6	76.9	90	95
2	...		90	95
4	6.3	72.3	90	90
6	9.4	63.7	95	95
7	...		95	95
10	...	...	70	80
14	31.4	49.3	30	75
23	...	...	30	70
35	30.9	47.8	20	75
54	30.0	46.3	20	75

[1] Heptachlor—50 μg./μl. dose per weevil.
Malathion—100 μg./μl. dose per weevil.

the percent fat and the percent mortality remained constant with both heptachlor- and malathion-treated weevils. With malathion, mortality decreased slightly as percent fat increased up to 35 days of age. From 7 to 14 days of age, the greatest change in mortality as well as fat occurred. In this period the fat increased from 9.4% to 31.4% (dry weight). The percent mortality decreased from

95% to 30% with heptachlor and 95% to 75% with malathion. As the percent fat increased, the percent moisture decreased. Regression of mortality on lipid content is presented in Figure 7.

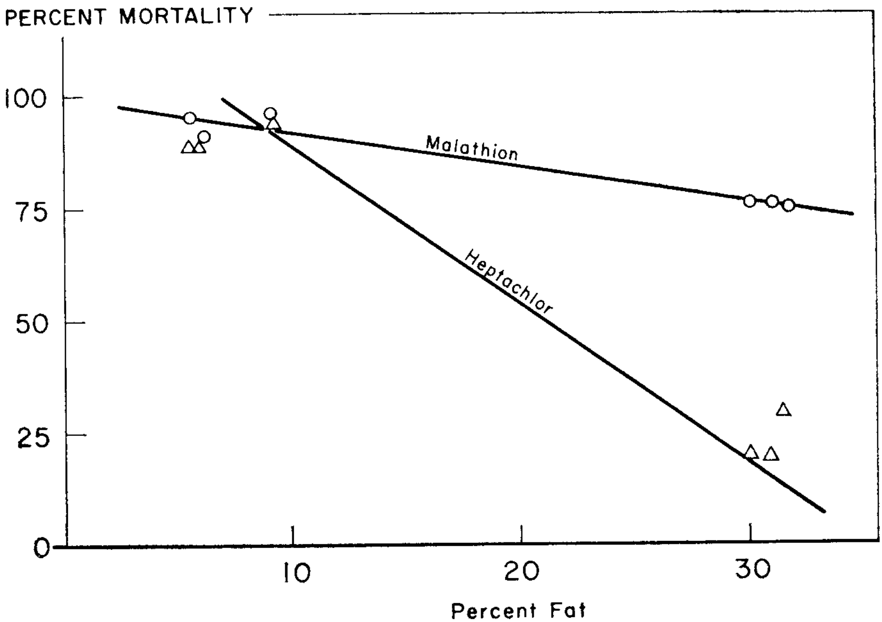


Figure 7. Correlation between percent fat and percent mortality of weevils treated with heptachlor and malathion.

In the Tennessee alfalfa weevil control program, fall treatment was formerly the method most widely used. From previous work in 1961, we found that in the fall when weevils return to the field after a long period of estivation, they have a low lipid content. This study has demonstrated that the weevils are more susceptible to insecticides when the lipid content is low. Munson and Gottlieb (3, 1953) demonstrated that the resistance of cockroaches to DDT shows a high correlation with their lipid content. Reiser et al. (4, 1953) showed that the percent mortality of the boll weevil decreased as the percent fat increased when using chlorinated hydrocarbon insecticides. It seems probable that this lipid contact is a basic reason why the fall treatment was so successful in alfalfa

weevil control. In future control work, it may be possible to achieve more effective insecticidal control by utilizing this susceptible period in the life cycle of the alfalfa weevil.

Tannic Acid as a Repellent and Toxicant to Alfalfa Weevil Larvae

A peculiarity in the larval feeding pattern of the alfalfa weevil was noted near Greeneville, Tennessee (Bennett, 5) in 1964. The larvae had devoured all alfalfa in an untreated field except for an area at one end where some fallen oak tree tops lay. Around these tops the alfalfa was undamaged by the weevils; however, some

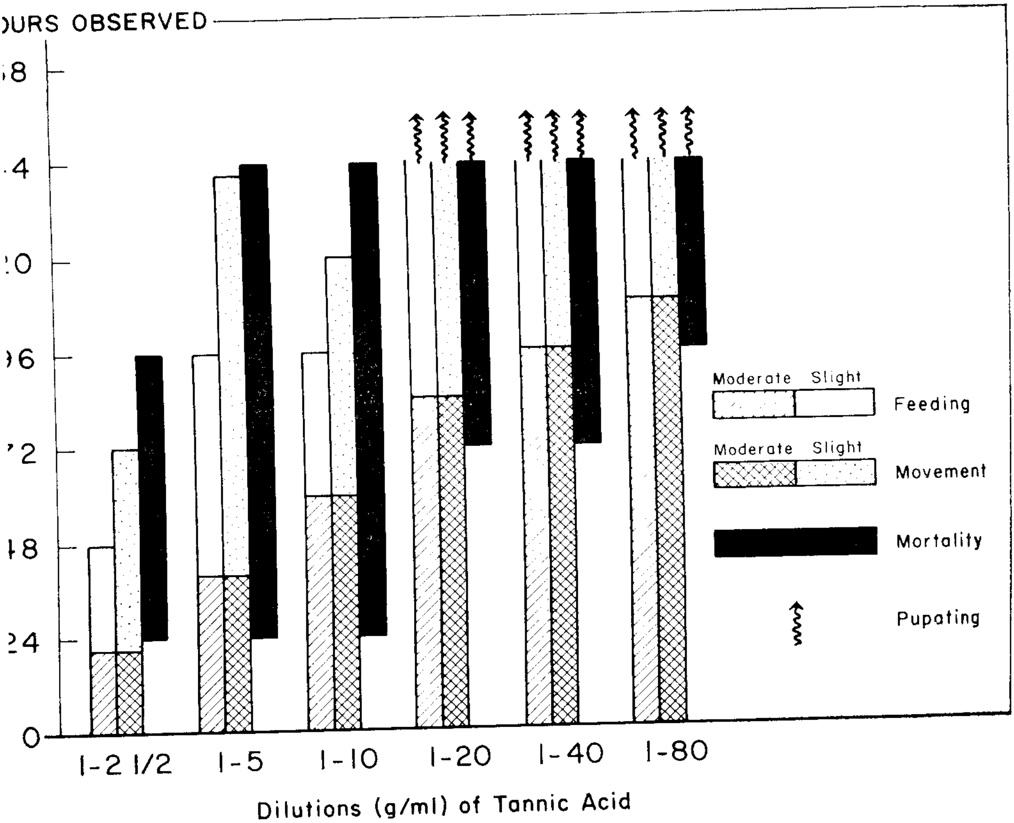


Figure 8. Feeding, movement, and mortality of alfalfa weevil larvae when fed on alfalfa for 6 days) sprayed with different dilutions of tannic acid.

leaves were mottled with what appeared to be exudate from the tree. This finding suggested that tannin, a well-known constituent of oak, possibly afforded the alfalfa protection against the weevil. Consequently, tests were initiated in the laboratory to determine if the larvae would feed on alfalfa sprayed with tannin.

Alfalfa was sprayed to a runoff with chemically pure tannic acid powder in distilled water, then fed to alfalfa weevil larvae. The following dilutions were used to find the level that would be toxic: 1 to 2.5 (10 g. of tannic acid powder to 25 ml. distilled water), 1 to 5, 1 to 10, 1 to 40, and 1 to 80. Ten larvae were fed alfalfa treated with each dilution and a control was fed untreated alfalfa. The amount of feeding, movement, and mortality of the larvae for the different dilutions are given graphically in Figure 8.

The greater concentrations of tannin increased mortality when compared with weaker concentrations. However, all concentrations decreased feeding. Larvae fed on untreated alfalfa consumed all alfalfa foliage with no mortality. The test was discontinued after 144 hours because some larvae showed evidence of pupating. Questions arising from these exploratory data are: What form of tannin should be used? Should a sticker be added (tannin is highly soluble)? And what level of tannin will repel larvae and yet be palatable to livestock?

Control of Alfalfa Weevil Larvae with One Application of an Experimental Carbamate Insecticide

A new systemic carbamate insecticide (Nia. 10242) named Furadan has been used on alfalfa for 2 years at various locations across the State (Bennett, 6). It has shown considerable promise as a spring one-application insecticide in the control of alfalfa weevil (Figure 9).

In the spring of 1966, one application on April 15 gave protection through to a May 3 cutting date (see Table 6). In 1967 at several of the Agricultural Research Centers, one application gave protection for a period of 30 days or longer (see Table 7). Wettable powder at the rate of 1.0 pound of active material per acre was superior to granules. However, granular formulations were effective when applied early in the season.

Figure 9. The author is facing a plot treated with Furadan. One application protected alfalfa from mid-April to an early May cutting date.

Table 6. Percentage of alfalfa weevil control from a spray test at the Plant Science Farm, Knoxville, Tennessee, in 1966

	Treatments[1]						
Rep.	1	2	3	4	5	6	7
A	150[2]	11	80	335	210	500	800
B	105	3	105	325	55	600	750
C	85	21	75	250	225	400	700
D	115	28	110	180	56	250	850
Total	455	63	370	1090	546	1750	3100
Average	113	16	93	272	136	437	775
% Control	86	98	88	65	83	44	—

[1] *Treatments*	*Active per acre*
1. Niagara 10242	0.5 lb.
2. Niagara 10242	1.0 lb.
3. G.S. 13005	1.0 lb.
4. Thimet	0.5 lb.
5. H-14503	1.0 lb.
6. H-14505	1.0 lb.
7. Check	

[2] Per 10 sweeps.
Application date April 15, 1966; harvest date May 3, 1966.

Table 7. Visual estimate of foliage feeding and hay weights following the use of experimental Niagara 10242 at 7 Tennessee locations during the spring of 1967

Location	Application date	Damage Rating (Average of 4 replications)			Hay yield in pounds per acre (Average of 4 replications)		
		Niagara[1] 10242 5% granules	Niagara 10242 50% W.P.	Control[2]	Niagara[1] 10242 5% granules	Niagara 10242 50% W.P.	Control[2]
Springfield	March 16, 1967	2.5[3] a[4]	1.2 a	9.0 b	1268 a[4]	1534 a	546 b
Lewisburg	March 15, 1967	1.0 a	1.0 a	9.0 b	1304 a	2085 a	485 b
Spring Hill	March 15, 1967	2.0 a	1.2 a	7.5 b	2175 a	2103 a	1323 b
Jackson	March 14, 1967	1.2 a	1.0 a	9.0 b	2931 a	2948 a	2137 b
Martin	March 14, 1967	1.0 a	1.0 a	8.5 b	2470 a	2614 a	897 b
Knoxville	March 22, 1967	2.0 a	1.0 a	9.0 b	1211 a	1369 a	525 b
Greeneville	April, 3, 1967	4.0 a	1.0 a	9.0 b	1002 a	1285 a	219 b

[1] Both treatments using the Niagara 10242 were at 1.0 pound active per acre rate.

[2] No treatment.

[3] The average estimated foliage damage was using a scale of 1-9, 1 being free of feeding and 9 being 100% fed upon.

[4] Any two means in the same row followed by the same letter are not significantly different at the 0.1% level based on Duncan's Multiple Range Test.

Weevil Control by Flaming

Flaming for insect control began in the West during the early twenties using kerosene as a fuel to create heat. However, it was not until the winter of 1962-63 that interest was created in the use of flaming for controlling the alfalfa weevil.

An accidental fire in alfalfa plots under experimentation by Dr. Tippins of Georgia during 1963 gave good weevil control. This stimulated more intensive investigations for control of the weevil in the East. Alfalfa stubble was burned at the University of Tennessee Plant Science Farm in January, 1964, using straw for a fuel. The resulting weevil and chickweed control encouraged further investigations.

During the fall and early winter of 1964, a propane gas flamer was constructed at the University of Tennessee and a series of tests with this equipment gave satisfactory results (Bennett and Luttrell, 7).

The propane gas flamer was constructed on a 7-foot rotary mower body (Figure 10).

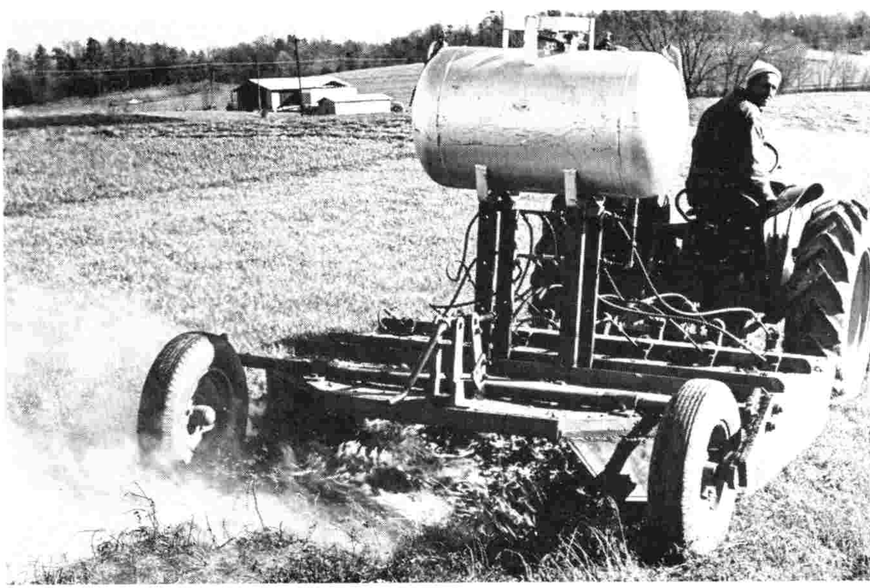


***Figure 10.** A propane gas flamer used to kill alfalfa weevil eggs in the stubble at the University's Plant Science Farm during the winter of 1965.*

Alfalfa was flamed with a gas-fired burner in February, 1965 (see Table 8). The control of chickweed was outstanding and weevil numbers were so reduced that only one insecticide spray was necessary (Figure 11). The spray was applied near harvest time, when temperatures were warm; better results are obtained with the organophosphorus insecticides when temperatures are above 60 degrees F.

Table 8. Hay yield per acre from a burning test at Blount County Farm. Flamed in February, 1965

Replications	Treatment	
	Burned	Check
	Pounds alfalfa	
Average (4 subsamples)	2426	326
L.S.D. .05 132		

Figure 11. ***Area to the left was winter flamed and sprayed one time prior to harvest. Strip to the right was unflamed and unsprayed; it was largely weeds at harvest time.***

Sterilization of the Male Alfalfa Weevil by X-Radiation

The purpose of this study was to determine at what level of radiation sterility is induced in the male alfalfa weevil. Sterility was determined by observing the occurrence of viable or nonviable eggs laid after X-radiated males had mated with normal virgin females.

Unradiated females mated to X-radiated males produced eggs (see Figure 12), but most of the eggs from weevils mated with

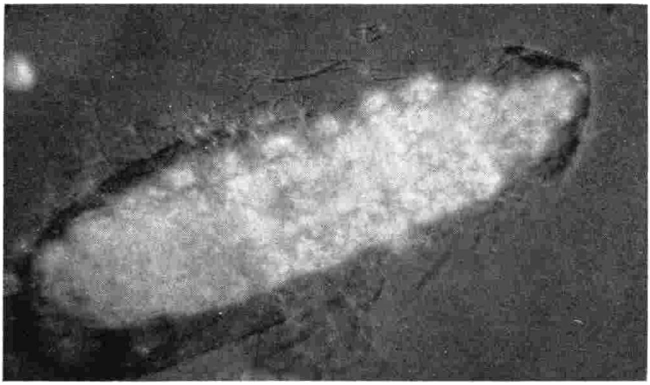


Figure 12. An embryo from an egg fertilized by a male radiated at 2000R.

males given 2000R through 10,000R failed to hatch (see Figure 13). Only 0.8% of the eggs fertilized by males radiated at the 4000R level hatched. However, no hatching occurred at the higher levels.

The lower levels of radiation produced mostly nonviable offspring, whereas eggs from the control group produced about 79% viable offspring.

A decrease was noted in the rate of development of all embryos from sperm receiving a high level of radiation. This degree of damage increased in proportion to the exposure of X-rays that the weevils received. One can conclude from these results that dosages ranging from 2000R to 6000R will not induce sterilization in the males but will produce nonviable offspring. However, at the 8000R and 10,000R levels, sterility was induced (Burgess and Bennett, 8).

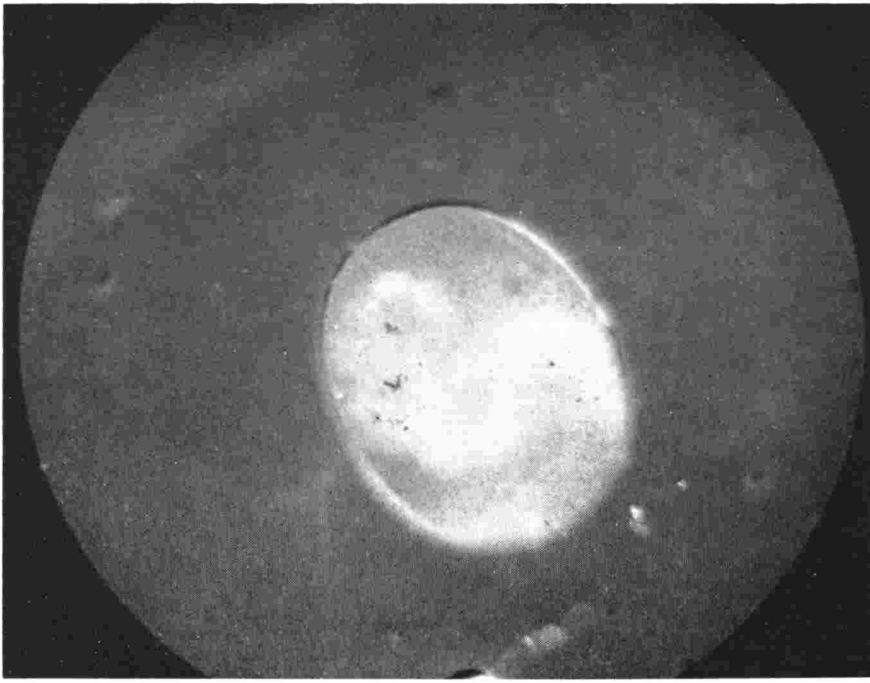


Figure 13. An embryo from an egg fertilized by a male radiated at 10,000R.

LIPID CONTENT OF THE ALFALFA WEEVIL AS RELATED TO SEASONAL ACTIVITY

The Experiment

In the spring of 1962, work was initiated to determine the lipid content of alfalfa weevils each month of the year. This was completed in the spring of 1963. The objective of this study was to determine the relation of monthly fat content to different stages of development and seasonal activity (Bennett and Thomas, 9).

Observations on the alfalfa weevil (Bennett and Thomas, 2, 1963), as well as studies on other insects (Munson and Gottlieb, 3, 1953), and Munson et al. (10, 1954), show a definite correlation between lipid content and percent mortality from insecticides. A search of the literature revealed no published information on the seasonal fat content of the alfalfa weevil.

Results

The weevils were relatively low in fat content when they returned from estivation quarters to the alfalfa in the fall. The fat continued to decrease until a low point was reached in January and February. Then began a rise in the percent fat to a peak in June as the adults entered estivation. A gradual decline in fat occurred during the summer estivation period. The line graph and diagrammatic outline, Figure 14, indicate the relation of fat content to the seasonal activity of the weevils. Table 9 gives the data

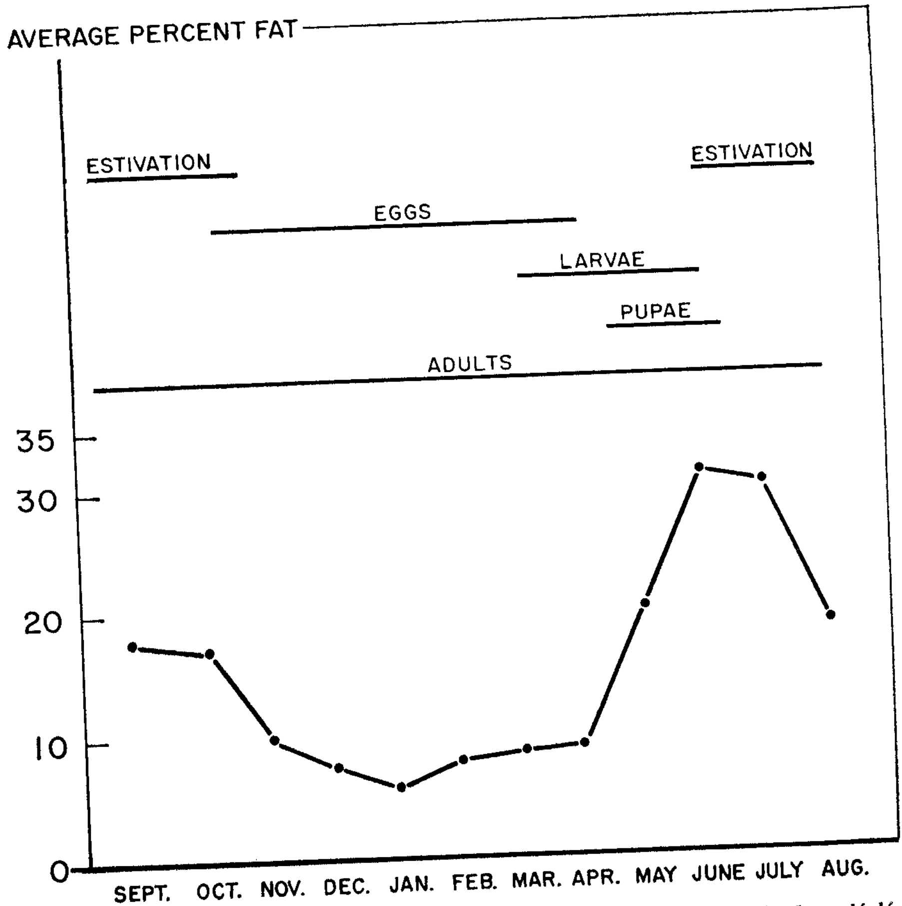


Figure 14. A comparison of the average monthly fat of the alfalfa weevil for 1 year with the seasonal life cycle.

on percent fat each month for 1 year and percent fat of estivating and diapausing, as well as sexually active weevils.

The weevils have the highest percent fat just before entering estivation. The sexually-immature weevils maintain a fairly high lipid content during this period of diapause. A more rapid decrease in fat occurs in late fall when weevils attain sexual maturity and begin copulation and oviposition in the field.

Guerra and Bishop (11, 1962), stated that the weevils are sexually inactive when in estivation. Our work in relation to lipid content reveals that fat content reaches a peak at this stage in seasonal development. Various criteria for diapause have been suggested.

Table 9. The monthly average percent fat in alfalfa weevils for 1 year in relation to their state of activity

Month	Average percent fat	State of activity
September	17.6	Diapausing
October	16.5	"
November	9.6	Sexually mature
December	7.3	" "
January	5.4	" "
February	7.7	" "
March	8.2	" "
April	8.6	" "
May	19.8	" "
June	31.0	Diapausing
July	29.5	"
August	17.9	"

Brazzel and Newsom (1959) stated that boll weevils are in firm diapause when the fat content is about 20% and the reproductive organs are non-functional. This study, therefore, adds confirmatory evidence that the alfalfa weevil is in a true diapause condition when in estivation.

When the weevils return to the field in the fall (late October), they are low in fat. Fall insecticide treatments should be more

effective against the weevils during this susceptible period in their seasonal cycle. The adult weevils continue to decrease in lipid content; thus many are killed before their eggs are deposited. The peak of egg laying in Tennessee occurs in late fall and early winter, during which period the fall treatment is most effective. In late February or early March, the percent fat begins to increase and continues to increase through the spring months—reaching a peak in June. The weevils—then in a diapause condition—enter estivation in woodland or in clumps of grass next to, or even within, the alfalfa fields.

Brazzel et al. (12, 1961) have shown that boll weevils can be prevented from entering diapause through fall insecticide treatments, thus controlling them through the next season. It is possible that future control work could be directed toward breaking or preventing diapause in the alfalfa weevil.

CULTURAL AND BIOLOGICAL CONTROL

Screening for Resistance, Spring Seeding, and Management As an Annual

In 1964 a nursery of alfalfa breeding stock was established at The University of Tennessee Plant Science Farm. This was in cooperation with Dr. Ralph Davis, Plant Breeder, and Professor M. Curtis Wilson, Entomologist, of Purdue University. The objective was to screen several thousand entries of breeding stock accumulated over a 20-year period for possible alfalfa weevil resistance. From the program, a few plants were selected (see Figure 15) that were not fed upon by the weevil. These are being continued for increase and cross-breeding purposes by Purdue University investigators.

In 1967 Dr. Gray (13), University of Tennessee Plant Breeder, in cooperation with the author, tried spring seeding at four locations in the State. Simultaneously, a cooperative program with the Universities of Kentucky and Purdue of managing alfalfa as an annual was established at Ames Plantation in West Tennessee. About 25 acres of Bonanza alfalfa were seeded in the spring and

this was plowed under after the last cutting. Based upon 1 year's results at four locations, spring seeding provided good weevil control. However, alfalfa yields were low as compared to first-year yields for fall-seeded stands.

Figure 15. The tagged plant is nearly free of weevil feeding. However, plants from clones surrounding show considerable feeding. Observe foreground.

Alfalfa Weevil Parasite Releases

During the period of alfalfa weevil investigations, several thousand parasites of five different species of Hymenoptera have been released in Tennessee (see Table 10). The parasites for release were supplied by the U.S. Department of Agriculture, Agricultural Research Service Parasite Introduction Laboratory at Moorestown, New Jersey. Several species have become established and no doubt will help in reducing the population size of the weevils, thus aiding in their control through an integrated program.

Table 10. Summary of alfalfa weevil parasite releases in Tennessee

County	*Bathyplectes curculionis*	*Tetrastichus incertus*	*Microtonus aethiops*	*Peridesmia discus*	*Bathyplectes anurus*
Blount	1963	1963			
Greene	1963				
Knox			1966* 1967 1968	1967	1967
Lincoln	1962				
Madison	1963	1963			
Marion	1962				
Maury				1966	
Marshall			1966		
Williamson	1962				

*Two releases, different fields.

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