

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report
of
Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by William Carmichael Cook for the degree of Master of Science.

They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

A. W. Ruggles
Chairman

O. W. Ostlund

William Moore

May 18 1920

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given William Carmichael Cook final oral examination for the degree of Master of Science . We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

May 18, 1920

W. H. Ruggles
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LIFE HISTORY STUDIES

ON

THE VARIEGATED CUTWORM

(LYCOPHOTIA MARGARITOSA HAWORTH)

A Thesis Submitted to the
Faculty of the Graduate School of the
University of Minnesota

by

William C. Cook

In Partial Fulfillment of the Requirements
for the Degree of
Master of Science

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LIFE HISTORY STUDIES
ON
THE VARIEGATED CUTWORM
(LYCOPHOTIA MARGARITOSA HAWORTH)

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INTRODUCTION

LITERATURE OF THE SUBJECT

The Variegated Cutworm is one of the most abundant and widespread members of the cutworm or Agrotid group of the family Noctuidae, and is one of the most destructive species of the Minnesota insect fauna. Originally described from Europe in 1810 by Haworth, it was reported abundant in Massachusetts by Harris in 1841, and since that time it has been very frequently reported in American economic literature. Riley (1869) gave the earliest life history of the species, which, incomplete as it is, has been widely copied and accepted as a standard life history for the entire group. Bowles (1879) discussed this species as injurious in Ontario, quoting Riley's life history. Lintner (1889) summarized the preceding literature and added

some valuable observations of his own, including descriptions of the various larval instars. Slingerland (1895) also gave a good account of the species, mostly a summary of the work of preceding writers. Fletcher (1901a) gave a fine account of the outbreak of 1900 in British Columbia, including many pages of field observations taken from the reports of field workers. Chittenden (1901) and Doane and Brodie (1901) include much similar material gathered from field work in Washington and Oregon during the same outbreak, but add little to the knowledge of the life history. Forbes (1904) included this cutworm in the group of insects injurious to Indian Corn, and summarizes the results of many earlier writers, adding some ecological observations and recommending cultural control measures. Swenk (1913), and Lovett(1914) have made recent contributions to the literature of this pest, consisting of field observations in Nebraska and Oregon respectively. In all of the literature very little experimental work has been reported, and no account has been taken of the effects on the species of variations in environmental factors.

In the early part of August 1919, the State of Minnesota sustained a severe and widespread outbreak of the summer generation of the Variegated Cutworm, and requests for aid in its control were received from fifteen counties located in a central belt extending across the state from southeast to northwest. (See Figure 1) As material was available in great abundance, life history studies were commenced which were continued throughout the winter in the Insectary.

The data here presented are the results of rearing four generations in the Insectary, combined with field observations during the summer of 1919. The work has been carried on under the direction of Prof. A.G. Ruggles, and the writer is greatly indebted to him and also to Dr. R.N. Chapman for advice and assistance. The experiments on the attractiveness of poisoned baits were carried on under the direction of Prof. William Moore, who has also aided greatly with advice and suggestions.

SCIENTIFIC NAME

The nomenclature in the family Noctuidae has been in a chaotic state for some time, and that of this species is a typical example of this condition. The synonymy of the species as given below is taken from Smith's Catalog of the Noctuidae of Boreal America, 1890, with the more recent references added. The reference to Lycophotia by Hampson is given on the authority of Smith (Jour. N.Y. Ent. Soc., xii:101, 1904) and is, as yet, unverified. As the work here presented was performed with the true species, margaritosa, as identified by Dr. Barnes of Decatur, Ill., for the author, the synonymy of variety saucia Hübner, which is almost always found working with margaritosa in the field, will be omitted.

Lycophotia margaritosa Haworth.

1810. Noctus margaritosa Haworth. Lepidop. Britt., p.157.
1852. Agrotis saucia Guenee, Spec. gen., Noctuelites, i:271.
1875. Agrotis saucia, var. margaritosa Speyer. Stett. ent. zeitschr. xxxvi:134.

1890. Peridroma saucia, var. margaritosa Smith, Bul.38,
U.S.Nat.Museum, p.70.
1902. Peridroma margaritosa Dyar, Bul.52, U.S.Nat. Museum,
p.134.
1903. Lycophotia margaritosa Hampson. Cat. Lep.Phal.Brit.Mus.,
vol.iv, p._____

DISTRIBUTION

The Variegated Cutworm has been reported from all parts of the world north of the equator. Chittenden (1901) gives the distribution as "Great Britain and Ireland, western-central and southern Europe, Asia Minor, northern Africa, Madeira and Teneriffe." It was probably imported into North America at an early date, spreading westward as the advance of agriculture made conditions more favorable for its increase. At the present time it is present in practically every state in the Union and has spread into Canada and Mexico. It appears in large numbers wherever soil moisture conditions are favorable, being reported on irrigated alfalfa in Nevada, Arizona and Montana. Recently extensive irrigation has been undertaken in the province of Alberta, and it will be a matter of interest to learn whether the Variegated Cutworm secures a firm foothold in that region in the future.

It is primarily a species of the Boreal and Upper Austral Zones, having a rather low optimum temperature, and it is in these regions that the greatest damage is done.

DESCRIPTIONS OF STAGES

THE ADULT

The adult of this species is a rather large, obscurely marked Noctuid of a general purplish brown color, the fore wings being washed toward the costal margin with clay yellow in the typical margaritosa form. The following description is given by Dr. John B. Smith (1890):

"Peridroma saucia Huebner.

"Yellowish fuscous to purplish brown, more or less irrorate or suffused with black, the maculation often entirely obscured. Transverse anterior line geminate, lunate, upright. Transverse posterior line single, crenate, often only punctate, sometimes obsolete, rarely very distinct; evenly curved over the cell. Subterminal line indefinite, marked only by the somewhat darker shade of terminal space; a row of lunate terminal spots. Ordinary spots large, concolorous; orbicular round or oval; reniform short and rather broad; claviform short, faintly outlined; secondaries irridescent whitish, outwardly smoky, veins marked. Beneath powdery, somewhat irridescent, with a common dark outer line or shade. Expands 40-50 mm., 1.60 to 2.00 inches.....

"The term margaritosa applies to the nearly uniformly luteous specimens, rare in the United States....."

THE EGG

The egg of the Variegated Cutworm is an object familiar to all students of American entomological literature, as it has been described and figured many times in economic writings in the United States. It is

hemispherical or dome-shaped, about one-half millimeter in diameter, being attached on the flattened side. (Figure 2) The rounded side is covered with about forty radiating ribs originating at the center or apex, around the circumference of a small circle enclosing the micropyle. When first laid it is creamy white in color and is a very prominent object on the leaf, but as the embryo develops the color changes through pink and lavender to almost black, and the shell appears almost transparent just before hatching. At about the middle of the incubation period the black head of the embryo becomes visible on one side, enlarging in size until it fills one half of the egg as seen from above.

THE LARVA

Many descriptions of the mature larva have been published, and Lintner (1889) gave descriptions of the various instars, of which he found five. There really are six instars, but the changes between the third, fourth and fifth instars come very rapidly, and the instars resemble each other very closely, so that it is easy to overlook one instar. That six instars is the usual number was demonstrated by nearly fifty individual rearings, from which the cast skins were counted and measured.

Slingerland (1895) notes the conflicting statements of Riley (1869) and Lintner (1889) regarding the number of prolegs present in the different instars. Riley states that the full number of prolegs is developed in the second instar, and that in this instar the larva drops to the ground and

assumes the true cutworm habit. Lintner states that three pairs of prolegs are present in the first instar, four in the second, and that it is not until the third instar that all five pairs are developed. Careful observation has demonstrated that there are three pairs of prolegs in the first instar, the anterior two pairs being represented by tubercular swellings; four pairs in the second instar, the first pair being partly developed but not functional; and five pairs in the third and succeeding instars, the anterior pair not becoming fully developed until the fourth instar. The larva walks with a looping motion in the first two stages, and does not enter the ground until late in the third. (Figures 4, 5, and 6)

Another very interesting observation was made in regard to the body markings of the larva in the various instars. In the first instar no body markings are present, the setal tubercles being the most prominent characters. In the second stage longitudinal stripings are developed which persist through the third, and are replaced by the markings of the mature larva in the fourth instar. The third instar is evidently a transition stage, in which the longitudinal lines are present, while the transverse markings and longitudinal dashes are also indicated. The longitudinal markings are the primary markings, the others being secondary modifications, and a comparative study of these markings on other Noctuids should be of considerable phylogenetic value.

The descriptions given below apply only to the true margaritosa, as the saucia form was not studied carefully.

Dyar (1890) considers the transverse diameter of the head as the most constant feature of any larval instar, and so measurements were made at various times on a large number of individuals. It was found that the instars had quite a wide range in head diameter, but that only rarely did specimens of any instar approach the next instar in this measurement. Average figures are given in the descriptions below for each instar. A table of head measurements (Table 1) will be found in connection with the life history observations in Part II.

DESCRIPTIONS OF LARVAL INSTARS

FIRST INSTAR. Newly hatched larva. Body length 1.1 mm., width 0.15 mm. Diameter of head 0.28 mm. Head very dark brown, almost black, quite deeply emarginate posteriorly; mandibles prominent, projecting forward. Ocelli, six on each side, of which five are arranged in a semicircle, the sixth appearing near the center. Thoracic shield brown, enlarged cephalad, nearly covering the dorsum of prothorax. Body translucent, colorless, the setal tubercles appearing as irregular brown chitinous blotches each bearing one, rarely two black setae 0.05 to 0.10 mm. in length. Prolegs six in number, the two anterior pairs being abortive. The anterior pair represented by a pair of tubercles about 0.02 mm. in length and the second pair being present but not functional, about 0.05 mm in length. The third pair is not fully developed, bearing but four or five crochets at the tip, while the fourth and anal pairs are well developed, being 0.08 to 0.10 mm. in length and bearing eight to ten

crochets. True legs dark brown, 0.15 mm in length. Larva feeds openly on the leaves, traveling with a looping motion.

SECOND INSTAR. Newly molted. Body length 3 to 3.5 mm., width about 0.5 mm. Diameter of head 0.51 mm. Head yellowish brown, dusky near posterior and ventral margins of epicranium, finely mottled with slightly darker brown. Occasionally the whole head is very dark. Ocelli as in first instar. Thoracic shield pale straw color, covering less than half of dorsum of prothorax, sometimes apparently divided medially into two plates. Ground color of body: dorsum brownish, becoming darker laterally, ventral aspect translucent yellowish.

Markings of body: Longitudinal lines: Median line fine, chalky white, expanding into wider spots on dorsum of segments ii, iii, iv, and v; lateral line a broad light band, located just above spiracles; midway between median and lateral lines, two fine, light, closely spaced, interrupted subdorsal lines. Transverse markings none.

Body setae stout, black, set on prominent dark tubercles. True legs yellowish. Prolegs, first pair partially developed, not functional, second pair partially developed, functional, third, fourth and anal pairs normal. Larva feeds openly on the leaves, and travels with a semi-looping motion.

THIRD INSTAR. Newly molted. Body length 7 to 8 mm. Diameter of head 0.72 mm. Head yellowish brown, two darker mottled bands just laterad of the epicranial suture forming a dark letter H with a small mark on the frons. Ocelli as

above. Thoracic shield same color as body, extending laterad to the subdorsal lines and marked with fine light median and subdorsal lines. Dorsal aspect of body light purplish gray, ventral aspect translucent yellowish.

Body markings: Dorsal line very faint, marked by small but conspicuous bright yellow dots on the caudal portions of segments ii, iii, iv, and v. Lateral line pinkish at center with yellowish stripes above and below. Subdorsal lines very faint, the second barely traceable and bordered laterally by a broad dark band extending laterad to the lateral line. A prominent, velvety black, trapezoidal mark on segment xii, narrowing cephalad.

Body setae and tubercules evident but not prominent. Prolegs all functional, anterior pair not yet fully developed. Larva walks normally and is concealed in the soil during the day, at least in the latter part of the instar.

FOURTH INSTAR. One day following molt. Length 12.5 mm. Diameter of head 1.58 mm. Head marked as in third instar, the dark markings larger. Thoracic shield as in third instar. Body marked with the complete markings of the mature cutworm.

Longitudinal lines: Median line very fine, the yellow spots prominent, emphasized laterad by black dashes which persist on all abdominal segments. Subdorsal lines lacking, their places being occupied by a series of longitudinal velvety black markings on the abdominal segments. A prominent irregular black band filling the lateral portion of the dorsal space, cut off short just above the spiracles and fading gradually toward the median line, Lateral line surrounding

spiracles, light, very faintly indicated. Transverse markings: a velvety black dash across the posterior portion of segment xii, preceded by a black triangle, which extends to the caudal border of segment xi. Body setae on black tubercles, not prominent. Prolegs all fully developed and functional.

FIFTH INSTAR. Length 15 to 20 mm. Diameter of head 2.11 mm. Markings same as in preceding instar. The whole dorsal surface of body covered with fine black mottling interspersed with a few flaky white spots. Head dark, the markings being so enlarged that the only light portions are two yellowish areas on the right and left sides of epieranium.

SIXTH INSTAR. Newly molted. Length 30 to 35 mm. Head diameter 3.2 mm. Markings same as in fifth instar, the mottlings becoming so intensified that the dorsal surface is nearly black. The black subdorsal dashes are followed laterad by a fine light line. Segment xiii is yellowish, contrasting with the black markings on xii.

SIXTH INSTAR. Mature Larva. Length 40 to 50 mm. Markings same but faded. General color mottled gray. Body wall transparent, so that internal organs and contents are visible.

SIXTH INSTAR. Just before pupation. (Prepupal Period) The body is shortened to 20 to 25 mm in length, tapering gradually caudad. Markings very faint, body opaque, color clay yellow.

THE PUPA

This is of the normal Noctuid type. No cocoon. Length 16 to 18 mm. Width at tips of wing pads 6 mm. Color light yellow

when first formed, changing to rich mahogany brown in a day or so. Eyes turn black near the middle of the pupal period, and the entire pupa turns very dark brown a few days before emergence. No cremaster is present. Two spines present at the tip of the abdomen are 0.66 mm. in length. A raised ridge is present on the dorsum of segments v, vi, and vii, and the caudal portions of these segments are finely punctate dorsally, characters of generic value according to Mosher (1916). The epicranial suture is present and distinct. (Figure 7)

LIFE HISTORY OBSERVATIONS

THE ADULT STAGE

EMERGENCE FROM THE PUPA. The pupal cell is formed an inch or so beneath the surface of the soil, and the newly emerged adult pushes up through the soil, evidently before expanding the wings, although this process was not observed in nature. In the Insectary, where the pupae were kept on the surface of the soil or in tin boxes, the process of emergence was several times observed. The moth expands the pupal skin to its fullest extent for periods of ten to thirty seconds, with an interval of rest between these efforts, finally causing a fissure in the skin on the ventral aspect of the thoracic region. It then pushes its way out and climbs up any convenient sloping surface, remaining there for a period of from fifteen minutes to half an hour. It then expands the wings, evidently pushing air in from the thorax, starting at the base and

pushing the unexpanded wing ahead of a sort of wave toward the extremity. The expanding process takes somewhat less than five minutes, and the moth rests again for five to ten minutes, when it is ready for flight. The whole process of emergence takes about one hour, including the escape from the pupal skin.

DURATION OF ADULT STAGE. The average duration of life for the males of this species was 18.4 days, as compared with 16.2 days for the females. This length of life is quite comparable with that of Feltia annexa (Jones, 1918) for which species a length of life of from 10 to 36 days, with an average duration of 22.4 days is reported. The tables given below include all of the available Insectary records, and represent the duration under temperature conditions averaging 70°F, with a humid atmosphere and an abundance of food.

TABLE I

DURATION OF ADULT LIFE. MALES

Exper. No.	Emerged	Died	Duration of life
1796/3a	9/8/19	9/16/19	8 days
1796/3b	9/11/19	9/16/19	5 days
1796/13a	9/5/19	9/12/19	7 days
1812a1	2/10/20	3/2/20	21 days
1812a2	2/18/20	3/10/20	21 days
1812a3	2/20/20	3/10/20	19 days
1812a4	2/23/20	3/11/20	17 days
1812b1	2/21/20	3/14/20	22 days
1812b2	2/22/20	3/17/20	24 days
1812c	2/18/20	3/14/20	25 days
1812d1	2/17/20	3/12/20	24 days
1812d2	2/17/20	3/15/20	27 days
1812d3	3/1/20	3/16/20	15 days
	Average Duration		18.4 days
	Maximum	27 days	
	Minimum	6 days	

TABLE III

DURATION OF ADULT LIFE. FEMALES

EXPER. NO.	DATE EMERGED	FIRST EGGS	LAST EGGS	DATE DIED	PREOVP. PERIOD	OVIPOSITION PERIOD	TOTAL LIFE
1796/3	9/7/19	9/13/19	9/23/19	9/23/19	6 days	10 days	16 days
1796/13a	9/7/19	9/13/19	9/20/19	9/20/19	6	7	13
1802/4	9/5/19	9/10/19	9/17/19	9/17/19	5	7	12
1810/13	11/21/19	11/28/19	12/3/19	12/4/19	7	5	13
1812a1	2/17/20	2/23/20	2/28/20	3/2/20	6	5	14
1812a2	2/20/20	.....	3/12/20	3/12/20	.....	.....	21
1812b1	2/21/20	2/27/20	.....	3/6/20	6	.....	14
1812b2	2/22/20	.....	.....	3/8/20	.....	.....	15
1812b3	2/22/20	.....	.....	3/14/20	.....	.....	21
1812b4	2/23/20	.....	.....	3/14/20	.....	.....	20
1812c	2/17/20	2/23/20	3/6/20	3/6/20	6	12	18
1812d	3/1/20	3/8/20	3/13/20	3/13/20	7	5	12

SUMMARY

	PRE-OVIPOSITION	OVIPOSITION	TOTAL LIFE
MAXIMUM	7 days	12 days	21 days
MINIMUM	5 days	5 days	12 days
AVERAGE	6.12 days	7.28 days	15.75 days

The life of the adult female may be divided into two distinct periods as above; the pre-oviposition period, when the female is actively feeding and developing her eggs, and the oviposition period, when she is actually laying the eggs. The death of the female usually takes place at the end of the oviposition period, although an occasional specimen lives a day or two after she has ceased ovipositing. Unfertilized females lived as long as twenty days, when they deposited a small number of infertile eggs and died. Copulation takes place during the entire oviposition period, and there is a minimum period of four days after the introduction of the male before eggs are laid.

OVIPOSITION HABITS. In nature the egg is normally laid on the under side of the leaf of any one of the many larval food plants, without any apparent regard to their suitability for the younger stages. For example, eggs were found abundantly on soy bean, which is not well suited for the first two or three instars, but is devoured ravenously by the larger larva. When the moths are abundant, eggs are scattered broadcast, as in the outbreak of 1900 in the Province of British Columbia, when eggs were reported as being found in large numbers in every conceivable location. One woman reported finding about fifty egg masses on clothes hung out to dry, and another found them on a window curtain, on the window glass, and on the sides of the house. (Fletcher, 1901)

Almost all of the eggs are laid during the night hours, and in the Insectary moths were rarely found ovipositing before darkness set in. An occasional moth was found ovipositing in the twilight period, but never before sunset. The great majority of the eggs were laid between the hours of 10 p.m. and sunrise. On one occasion a spent female was found going through the motions of oviposition without laying any eggs. This was kept up during a period of about an hour and a half in the middle of the day, and the next morning the moth was found dead, no eggs having been laid in the interval.

With regard to the number of eggs laid, the Variegated Cutworm is the most prolific Noctuid of which records have been made. Available records for a few other members of the cutworm group show a relatively high rate of reproduction, but none of them compare with L. margaritosa in this respect.

Feltia annexa laid as high as 1106 eggs in captivity, and the particular female contained 268 eggs in her ovaries at death, making a total of 1374 eggs. (Jones, 1918). The Army Worm, Cirphis unipuncta, laid as high as 254 eggs, having 91 developing eggs in her ovaries at death (Davis and Satterthwaite, 1916). Strickland (1916) records an individual of the Army Cutworm, Chorizagrotis auxiliaris as having laid 1106 eggs in captivity. Compared with these records, seventeen females of the Variegated Cutworm, reared in confinement during four generations, laid 1185 eggs each, the most prolific individual laying 2349 eggs.

TABLE IV
OVIPOSITION RECORDS

EXPER. NO.	TOTAL EGGS	EGGS PER DAY			TOTAL MASSES	MASSES PER DAY	EGGS PER MASS
		MAX	MIN	AVER			
1796/3	1311	430	7	119.2	15	....	89.3
1796/13a	655	219	59	109.1	10	1.25	65.5
1802/4	470	210	10	94.0	8	....	64.1
1810/13	753	...	..	125.5	13	2.25	55.8
1812a1	862	355	55	143.6	18	3.00	49.3
1812a2	887	213	9	98.5	24	2.40	36.9
1812b*	1649	...	..	126.9	17	1.70	98.5
1812c	2349	464	12	180.7	27	2.00	87.1
1812d	<u>1940</u>	<u>651</u>	<u>141</u>	<u>323.3</u>	<u>15</u>	<u>2.50</u>	<u>129.3</u>
AVERAGE	1185	651#	7#	132.4	15	2.04	78.47

*Average for four females caged together.

#Extremes.

The eggs were deposited in masses ranging from 9 to 509 eggs, the average size being 78.47 eggs. These masses were quite comparable with those laid in the field, although previous writers, basing their figures on isolated masses found, have given the figures as from 600 to 800 eggs per mass. Lintner (1889) mentions a mass seven rows wide and sixty eggs long, laid on a

twig. Slingerland (1895) gives the size of the egg mass as about 500 eggs. Masses found in the field in Minnesota were somewhat larger than those laid in captivity, the size depending on the situation. On a clover leaf the moth will often lay a nearly continuous mass covering the under side of the three leaflets, while on a bean leaf the mass, although somewhat larger, only covers a portion of the under surface of the leaf. On grass blades, a double or triple row of eggs is laid, extending longitudinally along the blade on either side, sometimes on both sides. (Figure 3)

In regard to the size of masses and the daily rate of oviposition there seem to be two distinct tendencies present in the species, moths showing both tendencies having been reared from the same egg mass. The primitive condition in the Noctuidae seems to have been one in which each moth laid a single large mass at one time and then died. Some members of the family have become so specialized that the eggs are laid singly or in small groups, and practically all of the family lay several masses. Some individuals under observation laid quite a large number of small masses, extending the oviposition period, while others laid a smaller number of larger masses in a shorter time. These two types are quite well illustrated in the two individual egg records given below, 1812d representing the more primitive condition and 1812c the more specialized condition. The figures given opposite each date are for the number of eggs in each individual mass laid, the daily total being given at the right.

TABLE V
INDIVIDUAL EGG RECORDS

FEMALE NO. 1812c

Female emerged 2/17/20, caged with male 2/18/20.

DATE	INDIVIDUAL MASSES				DAILY TOTAL
2/23/20	138	134	154		426
2/24/20	243	107	114		464
2/25/20	168	148			316
2/26/20	88	73	36	63	260
2/27/20	none				0
2/28/20	177	52	123		352
2/29/20	76	42			118
3/1/20	119	58			177
3/2/20	35	70			105
3/3/20	45				45
3/4/20	28	28	3		59
3/5/20	12				12
3/6/20	15				<u>15</u>

Female dead 3/6/20 Total Eggs.....2349

FEMALE NO. 1812d

Female and male emerged and caged together 3/1/20.

DATE	INDIVIDUAL MASSES					DAILY TOTAL
3/8/20	231	44	38	20	31	364
3/9/20	393	75	49	134		651
3/10/20	46	509	82			637
3/11/20	none					0
3/12/20	141					141
3/13/20	135	12				<u>147</u>

Female dead 3/14/20. Total Eggs.....1940

As shown in Table IV, the average number of masses per female was 15, laid at the rate of 2.04 masses per day, containing a total of 132.4 eggs.

THE EGG STAGE

TIME OF EGG LAYING. In the field, the eggs are found at irregular intervals during the course of the summer,

but the greatest numbers of eggs are present during the times of the two flights of adults, namely, early in July and early in September. In some seasons the broods are not so well defined as in 1919, and consequently eggs are found at all times.

DURATION OF INCUBATION PERIOD. In the Insectary, under a temperature condition of about 70°F, subject to diurnal variations, the average length of the incubation period, for four generations, was 7.6 days, with a range from 5 to 11 days, as is shown in the table below.

TABLE VI
DURATION OF EGG STAGE - INSECTARY CONDITIONS

EXPER. NO.	NO. MASSES	MAXIMUM DURATION	MINIMUM DURATION	AVERAGE DURATION
1796	1	.....	.....	5.0 days
1810	12	11 days	5 days	7.5 days
1812	20	9 days	6 days	7.3 days
1813	13	10 days	7 days	<u>8.4 days</u>
Average Duration				7.6 days

Due to the thick membranous egg shell, outside influences other than temperature have very slight effects. An increase in the moisture content of the soil prolonged the egg stage slightly, as will be brought out later. The effect of temperature was a decrease in the length of the stage with an increase in temperature, up to a certain point, beyond which an increase in temperature prolonged the egg stage slightly. Between the developmental zero and the optimum, the rate of development practically doubled for each rise of 10°C. in

temperature, in accordance with the temperature laws as stated by Sanderson (1910) and by Sanderson and Peairs (1913). The results are shown in tabular form in the table below.

TABLE VII
DURATION OF EGG STAGE
CONTROLLED TEMPERATURE CONDITIONS

TEMP. IN °C	NO MASSES	MAXIMUM DURATION	MINIMUM DURATION	AVERAGE DURATION
23°	10	5.5 days	5 days	5.2 days
27°	3	4.0 days	4 days	4.0 days
30°	5	4.5 days	4 days	4.1 days

THE LARVAL STAGE

HEAD MEASUREMENTS. As referred to above in connection with the descriptions of stages, measurements of the transverse diameter of the head in the various larval instars were taken, which are given in tabular form below. The series as a whole is quite uniform, but occasional individuals occur with head measurements which would place them between the instars, so that it is not an exact criterion for determining the instar of larvae as found in the field.

TABLE VIII
HEAD MEASUREMENTS OF LARVAE

	INSTAR					
	I	II	III	IV	V	VI
NUMBER OF INDIVIDUALS	9	7	10	17	14	9
Maximum Width	0.31*	0.58*	0.79*	1.84*	2.40*	3.40*
Minimum Width	0.26	0.47	0.68	1.00	2.10	2.90
Average Width	0.28	0.51	0.74	1.37	2.20	3.19

*millimeters.

FOOD PLANTS. A complete list of all of the food plants of this species would include practically all of the common cultivated plants. From this number, however, Chittenden (1901) selects the following as having been reported as badly attacked at various times:

Greenhouse and Ornamental Plants: Violet, pansy, carnation, smilax, rose, sweet pea, hollyhock, sunflower, nasturtium and chrysanthemum.

Garden Vegetables: Cabbage, turnip, celery, lettuce, carrot, radish, beet, rhubarb, asparagus, onion, squash, potato, tomato, bean and pea.

Bush and Small Fruits: Currant, gooseberry, raspberry, blackberry, strawberry.

Trees: Cherry, apple, pear, peach, prune, plum, cedar, mulberry and box elder.

Field Crops: Corn, wheat, timothy, alfalfa, clover, hops, tobacco.

Weeds: Nettle, thistle, dogweed, fireweed and others.

In the Insectary, we found escaped larvae attacking geranium voraciously, ruining the foliage. The field observations of 1919 lead to the belief that this species is partial to legumes and truck crops, as some of the most severe attacks were on field peas, beans, clover and alfalfa, and it attacked tomatoes extensively in the gardens. (Figure 8)

The feeding habits of this species are somewhat peculiar, in that it is not at all times a true cutworm. It belongs to the group of climbing cutworms, and this climbing habit is a very constant character, larvae that had been reared on leaves

laid on the surface of the soil immediately climbed plants when the entire plant was placed in the cage. In the outbreak of 1919 this climbing habit was very marked, the larvae climbing tomato plants and eating ragged holes in the developing fruits. When onions were attacked, the larvae cut off the top of the leaf and crawled down inside, coming out in the evening.

DURATION OF LARVAL STAGE. During the months of July and August the larval stage lasts from four to six weeks in the field, while in the spring it is much longer, the larvae working from early in April until June before pupating. In the Insectary the following records were made:

- (1) July 15 to August 14.....30 days
- (2) September 25 to November 2....38 days
- (3) December 6 to January 27.....52 days

Under controlled temperature conditions the development is slightly more rapid, the length of the larval stage at a constant temperature of 23°C being 32.4 days. Experiments were also started at 27°C, but this temperature was too high for the species, a single larva from fifty being able to pupate, the length of larval life being 34 days.

Other factors influencing the duration of the larval stage are the food supply, the type of soil and the moisture content of the soil. Irregular feeding or the use of an undesirable food plant prolong the duration of the period, while an abundance of the proper food produces rapid, steady growth. The soil type influences the duration, evidently in connection with the soil texture, as sand produced a slow development and a fine loam a rapid development. In general, the greater the

moisture content of the soil, the more rapid the development, while complete development was impossible on a soil whose moisture content was less than 35% of saturation. These points are treated more fully later.

ASSOCIATES IN THE FIELD. In two instances the summer generation of L. margaritosa was found working in the field in company with the Army Worm, C. unipuncta. In one case the two species were working in a mixed stand of oats and field peas, with the oats predominating, and the proportions of the two species were roughly proportional to the amounts of the two food plants present. Knight (1916) reports that the Army Worm feeds on grasses, rarely touching legumes, while the Variegated Cutworm is partial to legumes, as noticed above. In the other instance, the two species were found working together in field peas, and the Army Worm was apparently eating the peas, although it manifested a decided tendency to migrate, while the Variegated Cutworm remained in the field and pupated. Small numbers of an unidentified Noctuid resembling Agrotis c-nigrum were also found in the latter association, making about one percent of the total number, while L. margaritosa composed about eighty percent of the number.

NATURAL ENEMIES. Two parasites were quite abundant in the field during 1919, although no definite observations were made as to their effectiveness. A species of Tachinid fly was abundantly found in infested fields, ovipositing on the thorax of the cutworm larva. Larvae so attacked were able to pupate, but the Tachinid consumed the pupal contents and pupated inside

the pupal skin of the Noctuid. The fly emerged at about the same time as the normal adult Noctuids from the same field. A considerable number of parasitized larvae were collected from which small Braconids emerged, spinning their silken cocoons on the outside of the dead larva. The adults of this species emerged several days in advance of the adult Noctuids. Neither of these species has as yet been determined. (Figures 9 and 10)

Numerous specimens of Calosoma calidum, both adults and larvae, were found feeding on the cutworms. In one instance a larva was found feeding on the contents of a pupa through a round hole which it had cut in the side. Several smaller species of Carabids were abundant about the infested fields and must have devoured large numbers of the cutworms.

Two forms of disease were common in the field, but no attempts were made to isolate or study the causal organisms. One form, evidently a fungus, left the dead larva rigid and light in color, the outer surface being covered after a few days with a powdery coating of spores. The other form, probably a bacterium or virus, liquefied the body contents and turned the skin brown, the dry skin being left hanging on the leaves of plants. It bore some resemblance to the wilt of the Gipsy Moth.

THE PREPUPAL PERIOD. This period is not a definite stage, but covers a period of four to six days at the end of the sixth instar, during which the larva takes no food, but descends into the soil, forms its pupal cell, and prepares for pupation. The larva digs out an oval cell about an inch from the surface of the ground, never further than three inches in the soil.

The cell is formed either horizontally or at a slight angle, rarely nearly perpendicularly. It is smooth and hard, with no traces of silk, and is merely an oval cavity somewhat larger than the pupa. After the cell is formed the larva shrinks in size, becomes opaque and remains quiescent. Toward the end of this period it is incapable of much movement, and can merely move the abdomen slightly as is the case with the pupa. The larva takes on the shape of the pupa, and finally sheds the last larval skin, which remains in the bottom of the cell, at the anal extremity of the pupa. When the cell is horizontal, the pupa lies normally with the dorsum upward, and when the cell is formed at an angle, the pupa is always head upward. (Fig. 11)

THE PUPAL STAGE

DURATION OF THE PUPAL STAGE. Under natural conditions the pupal stage varies from fifteen to thirty days in length during the growing season, although occasional specimens spend the entire winter as pupae. In the insectary the average duration of this period was 24.9 days for 33 individuals, with a maximum of 46 days and a minimum of 19 days. Within natural limits, moisture has a very slight effect on the duration of this stage, but extreme dryness retards development to a considerable extent, while extreme moisture accelerates development. The color changes noted in the description of this stage are interesting and indicate roughly the degree of development reached. Thus, when the eyes turn black, the period is more than half completed, and when the entire body becomes black, emergence will take place in a day or two at most.

III. STUDIES ON THE INFLUENCE OF SOIL MOISTURE

OBJECT. In view of the fact that the cutworms in general are inhabitants of the soil during the larval and pupal periods, and that their distribution seems to be contingent on proper conditions of soil moisture, it seemed very desirable to determine the optimum and limiting soil moisture conditions for the Variegated Cutworm. This was particularly desirable in that the outbreak of 1919 was coupled with somewhat abnormal conditions of precipitation during the summer months.

METHODS EMPLOYED. The cages used were flower pots of about five pounds capacity, over which lantern globes were placed, the top of the globe being closed by muslin. The egg masses were placed on the soil under the globes as soon as possible after they were laid, and observations were made at least once daily, at 9 A.M., during the whole course of the life history. A second observation was often made at about 5 P.M. In the early instars the larvae were fed on leaves of red clover, which were picked and placed on the soil, during the third instar the clover supply ran out, and from this time on the larvae were fed on leaves of bean, grown in the Insectary. They fed very readily on the bean, and as all were treated alike, this factor should not have influenced the experiments. After the larvae had matured sufficiently to dig into the soil during the day, the observations were made by digging them out, recording changes of instar and mortality. During the prepupal period they were allowed to form the pupal cell, and were not disturbed until nearly ready to pupate, when they were dug out and placed

on the surface of the soil for more accurate observation.

The method of controlling the soil moisture conditions was as follows:

The flower pot and lantern globe were weighed, and a weighed amount of soil with a known moisture content was added. Then sufficient water was added to bring the moisture content to the desired figure, and the total weight of soil, pot and globe noted. This was taken as a constant, as experiments showed that the total weight of larvae and food present in a cage at any given time was insufficient to be recorded on the balance used. Each morning the whole series was weighed, and water added to bring each up to the constant weight. It was determined by preliminary experiments that a single weighing each day kept the variation in moisture within limits of variation of between one and one and one-half percent.

The soils chosen were taken as being fairly typical of conditions where cutworms were abundant, and were, (1) a coarse limestone sand, (2) a mixture of equal parts of this sand with a leafmold soil as furnished to the greenhouse, and (3) the leafmold alone. The sand was a sort of check, the mixture represented a light loam in texture, while the leafmold represented a rich, heavy loam. The water holding capacity of these soils, or their saturation point, was, in terms of the dry weight of the soil, for the sand 31.8%, mixture 41.0%, leafmold 52.1%.

The percentages of moisture used were computed on the dry weight of the soil, and were so chosen as to give a range of conditions from very dry to very wet. They were as follows:

- I Sand 5, $7\frac{1}{2}$, 10, $12\frac{1}{2}$, 15, 20 percent of dry weight.
II Mixture 5, 10, 15, 20, 25, 35 percent of dry weight.
III Leafmold 10, 20, 30, 40 percent of dry weight.

Two cages were run at each moisture content, and the results averaged in obtaining the data presented in Tables IX, X, and XI. In explanation of these tables, it may be said that the figures for the number of larvae present represent first instar larvae one day old, as there was a high mortality in the first day, due to failure to find food, in all cages. Also, the figures for the total length of life are based only on those individuals which emerged as adults, and do not represent the sum of the average figures given for egg, larva and pupa. The duration of adult life was not included in these studies.

OTHER ENVIRONMENTAL CONDITIONS. The attempt was made to secure uniformity in all other environmental conditions, so as to leave soil moisture and soil type the sole variants. The experiments were all run at one time, in one room, and in a compact group on the center bench of the Insectary room used, so that there was no heating from beneath. Slight inequalities in heating due to the southern exposure of the room were balanced so far as possible by using the radiators on the north side of the house for heating on sunny days. A thermograph was kept close by, and the records are available at the University Farm. The mean temperature was not far from 70°F., while the diurnal range averaged about thirty degrees.

RESULTS. In determining the effects of an environmental factor on development, the most useful criterion is the rate of metabolism as expressed in the speed of development, while

the rate of mortality gives an insight into the optimum conditions as well. The numbers used in these experiments were too small to have mortality percentages of any value except in indicating the limiting conditions, so that the figures are given for rate of development and the mortality figures included in the tables but not used in the graphs. There are three methods of presentation of these data; first showing the effect of soil type regardless of moisture; second, the effects of moisture variations as shown on each soil; and, third, the effects of moisture regardless of soil type, which is done by arranging the data for the entire experiment on the basis of percent of saturation.

EFFECTS OF SOIL TYPE ON DEVELOPMENT. These data are shown in Table IX and Figure 12, which is a graph of the same data.

TABLE IX
EFFECTS OF SOIL TYPE

SERIES	NO EGG EGGS	EGG PERIOD	NO LARVAE	LARVAL PERIOD	NO PUPAE	PUPAL PERIOD	NO ADULTS	TOTAL LIFE
I	196	7.29	141	56.9	13	20.93	6	91.15
II	191	7.49	78	52.2	19	24.26	15	84.35
III	98	7.72	54	48.3	6	23.95	4	83.00

A study of these data brings out the following points in regard to the effects of soil type on development.

1. The influence of soil type was most marked during the larval period, when the insect was actively working in the soil.
2. Of the three soils studied, sand was the least favorable.

both from the standpoint of mortality and rate of growth. The mortality was considerably greater on the sand, and the total length of life was prolonged seven days beyond that on Series II. The number of adults developed in the three series stands 3:8:4 for Series I, II, and III, respectively.

3. The mixture of sand and leafmold furnished the most favorable condition studied. The total life was 1.35 days longer than on the pure leafmold, but the mortality rate was only half that in Series III.

4. From the standpoint of growth alone, the leafmold supplied the most favorable condition, but fungous diseases were very prevalent in this soil, and so the mortality rate was high.

EFFECTS OF SOIL MOISTURE ON DEVELOPMENT. These data are presented for the separate series in Table X, and for the three series combined in Table XI. The graph, Figure 13, is a combination of the data of the two tables, being charted on the basis of percent of saturation of the soils, and giving first the curve for the three series combined and then the three curves separately, except for the pupal period, when the variations were so slight that the three curves practically coincided.

TABLE X

(Given on next page)

TABLE X

SOIL MOISTURE ON EACH SOIL TYPE

SERIES I SAND

%H ₂ O	NO EGG EGGS	EGG PERIOD	NO LARVAE	LARVAL PERIOD	NO PUPAE	PUPAL PERIOD	NO ADULTS	TOTAL LIFE
5	50	6	30	53*	--	--	--	53.0*
7 $\frac{1}{2}$	17	8	14	36.5*	--	--	--	44.5*
10	24	7	13	22.3*	--	--	--	29.3*
12 $\frac{1}{2}$	18	8	12	59.6	2	24.5	2	89.5
15	60	7	52	58.1	7	22.3	3	92.3
20	27	9	20	52.5	4	32.0	1	91.0

SERIES II MIXTURE

5	30	7	2	8.0*	--	--	--	15.0*
10	30	7	14	47.1*	--	--	--	54.1*
15	36	6	23	55.6	4	23.2	4	81.2
20	31	7	19	51.9	9	23.0	8	85.1
25	28	9	14	53.8	4	32.0	2	89.0
35	36	9	6	52.7	2	22.0	1	82.0

SERIES III LEAFMOLD

10	27	7	10	56.5	1*	--	--	63.5*
20	28	8	22	50.6	1	25.0	1	92.0
30	26	8	12	33.0**	--	--	--	39.0**
40	17	8	10	48.0	4	23.6	3	80.0

*Larvae died from lack of moisture

**Larvae attacked by fungous disease in fourth instar.

These data show that the soil moisture had an unequal effect on the three soil types, but that the general tendency was the same on all three, namely, to lengthen the egg stage, shorten the larval stage, and to slightly prolong the pupal stage with an increase in moisture content. These tendencies are more clearly shown in Table XI, where the entire experiment is listed in the order of percent of saturation.

TABLE XI

THE EFFECTS OF SOIL MOISTURE, REGARDLESS OF TYPE

% OF SATURATION	NO EGGS	EGG PERIOD	NO LARVAE	LARVAL PERIOD	NO PUPAE	PUPAL PERIOD	NO ADULTS	TOTAL LIFE
12.4	30	7	2	8*	--	--	--	15.0*
15.4	50	6	30	53*	--	--	--	59.0*
19.4	27	7	10	56.5	1*	--	--	64.5*
23.6	17	8	14	36.5*	--	--	--	44.5*
24.8	30	7	14	47.1*	--	--	--	54.1*
30.8	24	7	13	22.3*	--	--	--	29.3*
37.2	36	6	23	55.6	4	23.2	4	81.2
38.8	28	8	22	50.6	1	25.0	1	92.0
39.3	18	8	12	59.6	2	24.5	2	89.5
46.2	60	7	52	58.1	7	22.3	3	92.3
49.6	31	7	19	51.9	9	23.0	8	85.1
58.2	26	8	12	33.0**	--	--	--	41.0**
61.6	27	9	20	52.5	4	32.0	1	91.0
62.0	28	9	14	53.8	4	32.0	2	89.0
77.6	17	8	10	48.0	4	23.6	3	80.0
86.8	36	9	6	52.7	2	22.0	1	82.0

*Larvae died from lack of moisture.

**Larvae attacked by fungous disease in fourth instar.

CONCLUSIONS. The results of the experiments on the effects of soil moisture on development may be summarized as follows:

1. The minimum water requirement of this species is 37% of saturation, and 12½% of the dry weight of the soil with the smallest water-holding capacity.

2. Due to the thick membranous covering of the egg, the soil moisture had but a slight influence on the duration of this stage, but an increase in the moisture content prolonged this period considerably. A part of this prolongation, at least, may be attributed to the decrease in temperature following a high rate of evaporation from those soils containing a high moisture content. While no extensive records of soil temperatures were kept, readings taken at various times showed a variation of from one half to one degree in favor of the

dryer cages.

3. In the larval stage, an increase in moisture decreased the length of the period on all soils studied (Figure 13, C and D) The effects are more marked when the three soils are graphed separately, in Figure 13, D.

4. The effects of soil moisture on the pupal stage were indicated only in a prolongation of the stage at slightly above sixty percent of saturation, the other points showing only a slight variation. (Figure 13, E) As the points on this curve are grouped very closely, no curves were constructed for the separate soils.

5. Due to the conflicting effects of moisture on the various stages, the curves for the effect on the total life (Figure 13, F and G) are very irregular, but they show a general tendency to decrease the length of the life with an increase in moisture.

6. Near forty and sixty percents of saturation are critical points, as it is in these parts of the curves that the greatest departure from the normal usually occurred. These may be taken as the upper and lower limits of the optimum condition, between which the curves run smoothly, and below and above which the variations may be attributed to stimulation and depression, corresponding to abnormal conditions.

7. A general corollary to be drawn from these experiments is that a factor may act differently on different stages of an insect, even reversing itself, as on egg and larva.

As a basis for comparison with field conditions, it may be stated that in appearance and texture the soils below 40% of saturation were dry and crumbly, those between 40% and 50%

moist and in a good condition for field cultivation, and those above 60% wet and soggy, too wet for cultivation.

IV. FIELD LIFE HISTORY AND CONTROL MEASURES

FIELD LIFE HISTORY

NUMBER OF GENERATIONS. The Variegated Cutworm has been studied over a wide range of climatic conditions in America, and consequently there are considerable data concerning its life history and seasonal activities. Riley (1869) reported that there were probably two broods in Missouri, the insect hibernating either as a chrysalid or adult. Gillette (1891) states that in Kentucky the eggs are laid in the spring, the moths being abundant early in the spring and from July 11 till the approach of winter. Slingerland (1895) states that the probable mode of hibernation in New York is either as pupa or moth, while Chittenden (1901) confirms this statement for the northern part of the range of the insect, while further south they probably hibernate as partly grown larvae. Two and a partial third broods are indicated for the vicinity of Washington, D.C. Forbes (1904) states that there are probably two generations in Illinois, the insect hibernating as larva or pupa. Swenk (1913) indicates two generations for Nebraska, hibernation taking place as pupae in the northern part of the state and as larvae in the southern part. Lugger (1895) gives the dates on which the moth was captured in Minnesota as "March 15, July 25, August 3, 11, September 1, 19.....Very Common." This would indicate two

flights of moths, late in July and early in September, while the capture of a specimen on March 15 would indicate the possibility of isolated specimens hibernating in this stage.

Field observations made during 1919 make it probable that there are normally two more or less distinct generations each season in Minnesota, the adults of the first brood flying during July, and those of the second generation in September. Larvae were found in the field during May, and again very abundantly during the first ten days of August, and finally, small specimens of about the third instar were found in October. No adults were caught in the early spring in 1920, and the general indications are that the majority of the species hibernated as partly grown larvae. Luggers record of March 25 for the adult must have been for an isolated specimen, probably a straggler from the normal September brood.

The entire seasonal history may be summarized in the following statement. The insect hibernates as a partly grown larva or pupa. In the former case the larva works during May, pupating in June. In the latter case, the moth emerges early in the spring and deposits eggs from which comes a partially overlapping brood. The adults are on the wing in July and deposit their eggs for a second generation working during the early part of August. The adults from this generation lay their eggs during September, and the larva work in October, hibernating in one of the earlier instars. It is possible that a portion of the second brood does not emerge in the fall, but winter over. That hibernation is not possible in the egg stage was shown by experiments in which eggs exposed to temperatures below 10°F

for twenty-four hours failed to hatch.

Two well defined flights of moths were caught on sugar in 1919, the first from July 1 to 15, and the other from August 25 to September 15. Stragglers were caught during the entire summer, but these were mostly in a badly worn condition, and doubtless belonged to the flights above indicated.

CONTROL MEASURES

POSSIBLE POINTS OF ATTACK. These life history studies were made with the object of determining possible points in the life cycle at which control measures might be directed, as well as a general study of the relations of this insect to its environment. From the standpoint of control, the pupal stage may be eliminated, as it is not practical to reach the pupae in the soil. The only consideration in regard to the egg stage is the possibility of removing vegetation and compelling the moths to lay their eggs elsewhere. Fall plowing is a measure frequently recommended for treating cutworms, and the proper dates for the control of this species would be in the period of the second flight of moths, as early in September as possible.

The length of the pre-oviposition period of the adult makes this seem a logical point of attack, but no work has been done with this species as yet. Woodhouse and Dutt (1913), and Woodhouse and Fletcher (1912) report results on a series of campaigns against the Greasy Cutworm, Agrotis ypsilon, in India, in which they secured almost complete control by trapping the adults on baits. Work along somewhat similar lines has been successful in Russia (Sopotzko 1914, 1915) against Euxoa segetum, in which the traps were replaced by long open

troughs filled with fermented molasses. This mixture is very attractive and also very sticky, so that the moths were caught in it and drowned. From these results it seems quite possible that traps might be used to advantage in Minnesota against our common cutworm moths, as these are all very readily attracted to sugar baits, and during 1919, by far the greater majority of the moths caught were freshly emerged females. A few experimental traps have been constructed and will be given a trial during 1920.

Most of the work done toward controlling this species in America has been in the nature of attracting the larvae to a poisoned bait, which is a very practical measure, but is merely temporary at best, as the larvae are not caught until they have done at least a portion of their feeding. A few preliminary experiments have been performed with these baits, which are treated below.

THE LITERATURE ON THE USE OF POISON BAITS. The literature on the use of poison baits has been very well summarized recently by Merrill (1919), particularly that portion of it referring to the use of molasses in baits. Smith (1894) made the first mention of baits against cutworms in a paper before the American Association of Economic Entomologists, in which he produced evidence of the successful use of a dry mixture of paris green and bran against cutworms working in sweet potatoes. Subsequently he recommended the addition of molasses, for the purpose of keeping the bait in an attractive condition for a longer period. In 1896, F.A. Sirrine reported the use of the dry bran-paris green mixture against Euxoa messoria on onions in

New York state, stating that the dry mixture was more attractive and remained effective for a longer period than the mixture moistened with water. Since this time various experiments have been reported with somewhat conflicting results.

Surface (1906) performed some experiments with the standard bait as now recommended*, in which he found that the bait was much more effective if concealed under boards and clods than if sown broadcast, which is quite logical, as the cutworms seek such places during the daytime and would find the bait at that time as well as during the night. In 1911, Smith reports an instance of the complete failure of poisoned baits, against Agrotis ypsilon on lettuce, stating that the attack was finally controlled by the use of lettuce leaves poisoned with paris green. Caesar (1912) reported a similar failure of the poisoned bait against Agrotis fennica in Ontario, when the outbreak was checked by rolling the fields and crushing the worms. Gibson (1914) reported that only about 25% of Porosagrotis orthogonia, the Pale Western Cutworm, were reached by ordinary baiting methods, but that 80% control was secured by harrowing the bait into the soil. Dean (1915) describes experiments against L. margaritosa in Kansas, in which the poisoned bait was not of much use as ordinarily made, but proved very attractive when orange or lemon juice was added. Strickland (1916) recommends the substitution of shorts for bran in the formula as proving of greater value for the dry conditions of Alberta. Davis and Turner (1918) performed some laboratory experiments with larvae of Cirphis unipuncta, in which they found that sawdust had a slight value as a carrier, although bran was much

more attractive, and also that lemon extract seemed to be of greater value than lemon juice. Morrill (1919) in the article referred to above, concluded from the evidence available that molasses is ordinarily unnecessary in cutworm baits.

*The standard bait, as recommended by the U.S. Bureau of Entomology, consists of:

Bran	50 pounds
Paris green	2 pounds
Molasses	1 gallon
Water	enough to moisten, about 2 to 4 gal.

EXPERIMENTS ON THE ATTRACTIVENESS OF VARIOUS BAITS. The evidence on the subject is so conflicting that it was decided to commence experiments with the object of determining definitely which substance in the bait is the attractive agent and in what relation various attractive substances stand with regard to each other. So far a few preliminary experiments have been run, which give some quite definite evidence on the subject with regard to this species.

As the object of these experiments was merely to determine the attractiveness of the various substances, no poisons were used in the baits. A round cage was used, about eighteen inches in diameter, around the inside of which alternate small piles of two baits to be tested were arranged in a circle. The cutworms were liberated in the center of the cage, and observations taken at various intervals, counting the number of larvae on each pile of bait. The first series of experiments were run with piles of dry bran alternating with leaves of bean, the food plant used in the Insectary, and these showed a total

of 66 larvae visiting the dry bran to 17 on the leaves. In several cases the leaves were not touched, all the larvae visiting the dry bran. With this as a basis, the other mixtures tested were checked with dry bran, and in some cases rechecked against leaves. As a result of this series of preliminary experiments, the substances tested arranged themselves about in the order given below, the most attractive mixture being placed at the top of the list:

Bran and fermented molasses*
Bran and molasses
Bran, wet
Shorts, dry
Bran, dry
Leaves
Cornmeal, dry
Paper and molasses**

*This was prepared by adding a yeast cake to about a pint of molasses and allowing the mixture to ferment for about forty-eight hours, when there was considerable alcohol present.

**This consisted of small bits of paper (confetti) moistened with molasses.

A few field experiments during the spring of 1919 against Agrotis fennica on peas indicated that for this species the molasses is the attractive agent to a large extent, and a bait containing twice to three times the normal amount of molasses gave the best results.

ADULT CONTROL. Concerning the possibility of trapping the adult moths on sugar baits, no definite work has been done as yet, but from the results of sugaring for moths during the summer of 1919, this would appear practical if the right attractive agent were used. The bait used in 1919 was fermented molasses, smeared on the trees, and the adults were picked off the trunks with a cyanide bottle. Of the adults so

secured, over sixty percent were females, and most of these were freshly emerged, few, if any, of their eggs having been laid. In fact, females caught on sugar early in the summer laid the eggs from which the Insectary experiments were started. Several traps, constructed on the principle of fly traps, have been made, and they will be tested in the field during the summer of 1920.

V. GENERAL SUMMARY

FIELD LIFE HISTORY

The seasonal history of the Variegated Cutworm for Minnesota has been determined from Insectary and field observations to be about as follows: Hibernation takes place in the larval or pupal stages, larvae from the September generation and pupae remaining from the July generation going over the winter. The larvae work in the spring, pupating about June 1, and emerging early in July. The second or summer generation, from the eggs of these females, works late in July and early in August, pupating by August 15 and partially emerging in September. Some of these pupae remain in the ground over winter, the greater part of them emerging and laying eggs for a hibernating generation of larvae.

REACTIONS TO ENVIRONMENTAL FACTORS

The two limiting factors for this species are soil moisture and temperature. The requirements are a rather moist soil with a medium range of temperature, the larvae not developing very well in soils whose mean temperature is above 75°F., which limits the southern range of the species. The

western range of the species is limited by soil moisture conditions, the insect appearing in the far western states wherever the soil is brought into proper condition by irrigation.

THE OUTBREAK OF 1919

The outbreak during the summer of 1919 in Minnesota was correlated with rather abnormal weather conditions, which approximated the optimum for the species. The months of June and July, and the first part of August were slightly warmer and considerably wetter than usual, giving the insect a warm, moist soil environment, which endured throughout the larval period. The latter part of August was rather cool and dry, but the insect was in the pupal stage, so the influence was slight, causing merely a prolongation of this period.

The following data, from the "Climatological Data - Minnesota Section" published by the U.S. Weather Bureau, for June, July and August, show the general character of climatic conditions as compared with normal conditions.

MONTH	TEMPERATURE			PRECIPITATION		
	MEAN	NORMAL MEAN	DEPARTURE FROM NORM.	TOTAL	NORMAL TOTAL	DEPARTURE FROM NORM.
June	67.9	64.7	3.2	5.22	4.17	1.15
July	71.7	69.5	2.2	4.83	3.63	1.20
August*	71.1	71.1	0.0	1.68	1.74	0.06

*Figures for August 1 to 15 for Minneapolis, from same publication.

The conclusion to be drawn from these data, which should be checked by data from other outbreaks, is that an outbreak may be predicted in a warm, wet summer, and should be prepared for.

CONTROL MEASURES

In regard to control of the larvae, poisoned baits are the best emergency means, and it was demonstrated in the preliminary experiments that dry bran is of great value for this species. Molasses adds considerably to the attractiveness of the bait, but the bran is in itself so attractive that the extra expense of the molasses is hardly justified by the increase in effectiveness. The bait recommended for this species in Minnesota is

Bran.....50 pounds
Paris green..... 2 pounds

used either dry or moistened with water.

Trapping the adults on sugar baits appears to be a promising measure, possibly altered by omitting the traps and substituting a poison such as sodium arsenite in the bait. Further studies are being made on this point.

CONCLUSIONS

This study is planned as the first of a series on the outworms of Minnesota, with the object of bringing out their ecological relations so that these may be utilized in planning control measures. A great deal more time can be profitably spent in further study of this same species, or related species, especially in regard to their associates and parasites, which may give a clue to the ecological factors that have been unbalanced through the introduction of agriculture, making these cutworms so abundant and destructive.

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PLATE I



Figure 1. Map of Minnesota showing the distribution of damage by the summer generation of Lycophotia margaritosa in 1919.

Shaded areas indicate the areas affected.

Dots indicate stations from which reports were received.

PLATE II



Figure 2. Egg of Lycophotia margaritosa,
enlarged forty times. Original.



Figure 3. Egg mass of Lycophotia margaritosa
on under side of a clover leaf. Enlarged three
times. Original.

PLATE III

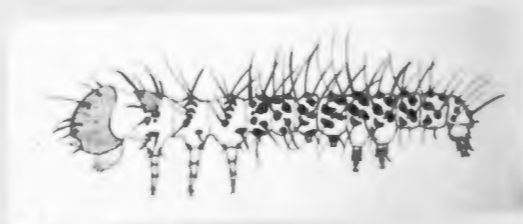


Figure 4. Lycophotia margaritosa, first instar larva, lateral view. Enlarged fifty times. Original.



Figure 5. Lycophotia margaritosa, second instar larva, lateral view. Enlarged thirty times. Original.



Figure 6. Lycophotia margaritosa, third instar larva, lateral view. Enlarged twelve times. Original.

PLATE IV



Figure 7. Pupae of Lycophotia margaritosa, male. Dorsal and lateral views. Enlarged twice. Original.



Figure 8. Tomatoes injured by the summer generation of Lycophotia margaritosa at St. Paul, Minn., August 4, 1919. Original.

PLATE V



Figure 9. Cocoon of Braconid parasite of L. margaritosa, with three newly emerged adults. Original.



Figure 10. Puparia of Tachinid parasite of L. margaritosa inside pupal skin.
A. Pupa with pupal skin removed.

PLATE VI



Figure 11. Pupa of L. margaritosa in cell, viewed from above. Enlarged two diameters. Original.

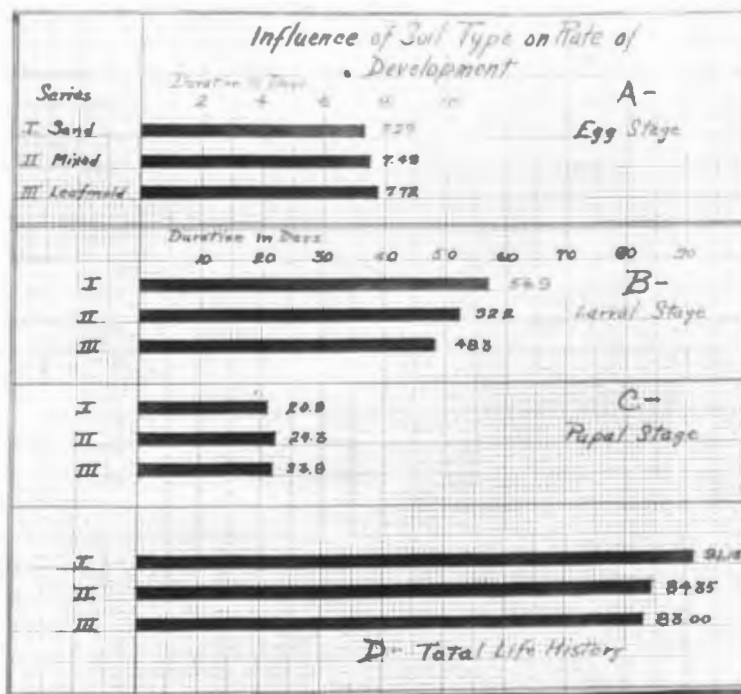


Figure 12. Graph showing the influence of soil type on rate of development of L. margaritosa.

PLATE VII

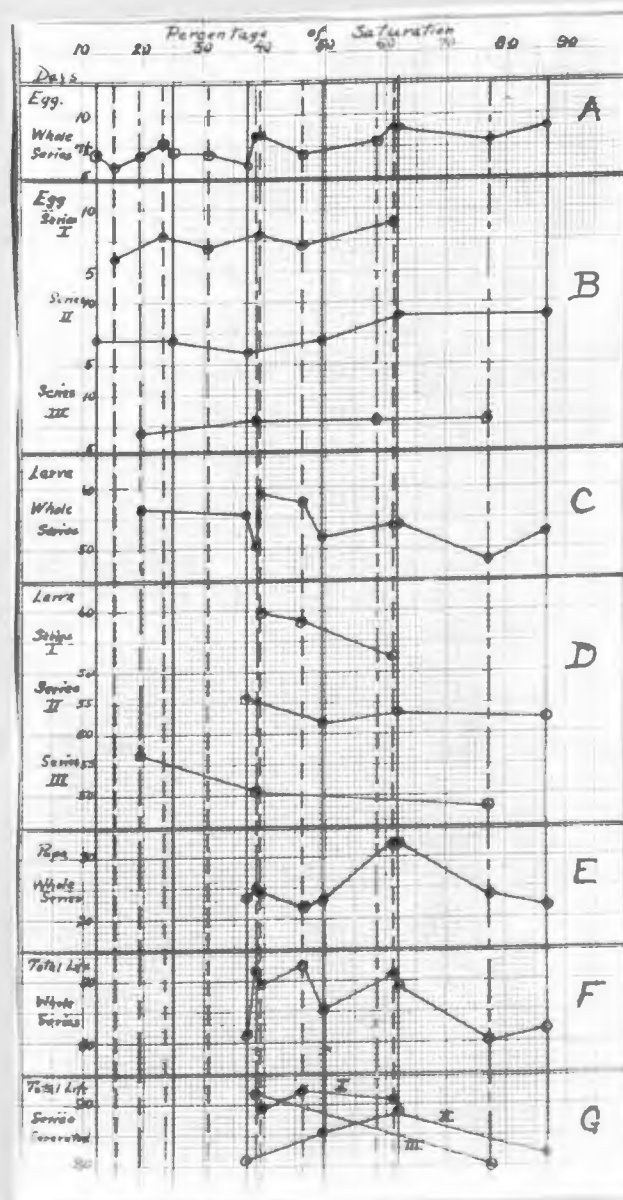


Figure 13. Graph showing the influence of soil moisture on the rate of development of *L. margaritosa*.

Data arranged on the basis of percent of saturation.

A, C, E and F, whole series combined; B, D, and G, series separated.