THE EFFECT OF SOIL MOISTURE ON THE BIOLOGY AND DISTRIBUTION OF THE LARVAL STAGES OF THE BLACK CUTWORM (*AGROTIS YPSILON* ROTT.)

by

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INTRODUCTION

This paper is an attempt on the part of the author to determine the economic distribution within the United States, of the larval stages of the black cutworm, Agrotis ypsilon Rott., by a study of the effect of soil moisture on the biology of the larvae and the correlation of these data with known facts occurring in literature.

The determination of the potential distribution of an insect by the careful study of certain ecological factors such as temperature and moisture, which limit its distribution, is a rather new development in the field of insect ecology. It need not be stated how important this development is in the study of economic insects, especially those which are introduced.

A review of the literature shows that outbreaks of the black cutworm, Agrotis ypsilon Rott., occur only on lands which have been overflowed recently, and that their distribution in the United States is limited mainly to the states east of the Mississippi River where there is usually abundant rainfall and numerous overflows. In India, where this cutworm is a major pest, it occurs in outbreak numbers each year on the "overflow" or "tal" lands of the Ganges River immediately following the receding winter overflow.

ACKNOWLEDGMENT

Acknowledgment is here made to Dr. R. C. Smith of the Department of Entomology, under whose direct supervision the work was done, for his helpful instructions and criticisms.

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DISTRIBUTION

The black cutworm is universally distributed. It has been reported from North, South and Central America, Europe, North Africa, South Africa, Syria, Japan, China, Tibet, Kashmir, the Himalayas, Ceylon, Java, Australia, New Zealand, British Honduras, Hawaii, and India.

It is usually associated with regions of high rainfall, but it has been taken in arid regions, the moth probably having flown there from nearby regions which have considerable precipitation.

HOST PLANTS

A species of cutworm which has world-wide distribution would of necessity have numerous host plants. Such is the case with the black cutworm, which can maintain itself upon a variety of hosts. The following are the plants upon which it has been observed to feed: corn, wheat, tobacco, cotton, cabbage, potato, squash, beans, onions, cucumber, radish, lucerne, alfalfa, mustard and all other cruciferous vegetables, flax, barley, oats, peas, hops, opium, mangel wurzel, gram, poppy, groundnut, grass, asparagus, tomato, apple, grape, strawberry, and other fruits and vegetables. Since corn appears to be its favorite food plant, considerable damage to this crop occurs in local areas of recent overflow. Maxwell-Lefroy and Ghosh (1907) state that, in India, poppy appears to be the preferred host plant, and to be a very nourishing food for the larvae, developing them quickly.

INJURY AND LOSS

Outbreaks of this species appear to occur only in areas of recent overflow and unless immediately checked, considerable damage to crops may occur.

Davis and Turner (1918) state that, "in southern Indiana the bottom lands along the Wabash river and tributary streams are subject to an infestation of what are commonly termed "overflow worms" (Agrotis ypsilon). Some injury occurred the past season, but the insects were not nearly so general as in 1917. They invariably appear following a late spring overflow, that is, on land which is covered with water as late as early June. As the water leaves the ground the moths make their appearance from the higher surrounding land and lay their eggs in the wet soil, and any crop planted on this ground, which is usually corn, is likely to be damaged, if not completely destroyed by these cutworms. In general, it is unusual for a cutworm moth to deposit her eggs in moist soil but this appears to be the usual habit of this species (Agrotis ypsilon), which has already been recorded as a serious pest in the areas overflowed by the Ganges and other rivers of India."

Published records indicate that damage by the black cutworm may be said to be more or less chronic, varying somewhat from year to year, but seldom attaining the degree of destructiveness, which we term an outbreak.

This species is especially destructive to young field crops, because the larvae cut the plants off just above the surface of the soil and either partially or wholly devour them. Cut plants are sometimes dragged into the burrows of the larvae where the leaves are eaten later. Maxwell-Lefroy and Ghosh (1907) state that "cabbage stems are bored from below and the larvae may be found feeding in the bore."

These two workers by careful investigation found that a single larva may devour approximately 35 grains of green feed during its entire feeding period, and if each female moth laid an average of 350 eggs, the larvae hatched from them would, during their life time, destroy about 1 3/4 pounds of green leaves. The damage actually done is considerably greater because the larvae are in the habit of cutting down whole plants.

DESCRIPTION OF LIFE STAGES

Egg

The egg is dome-shaped, about 1/2 mm. in diameter and creamy white in color when freshly laid. There is a small circular depression at the top and from its periphery, ridges run down the sides to the basal circumference. The color of the egg undergoes some change after a period varying from 12 hours to 3 days depending upon the temperature.

Larva

When newly hatched the larva is about 1 1/2 mm. long, its head is shiny black, the prothorax bears a small black shield, the body is cylindrical, and the general color is slightly yellowish-gray.

The full-grown larva varys in color from grayish-brown to blackish-brown. The entire body, under moist conditions, appears greased. The full grown larva is plump-bodied and measures about 44 mm. or 1 3/4 inches. The head is shiny, slightly reddish-black and compressed dorso-ventrally and bears an inverted V-shaped mark. The prothorax bears a slightly reddish-black shield. On the upper part of the dorsum there is a broad, longitudinal, whitish space transversed by a more or less interrupted median line. The rest of the upper side of the body is dark or blackish.

The ventral color is dull gray. The five pairs of prolegs are thick and fleshy. At rest as well as in locomotion, the ventral surface of the body is always in contact with the ground. When touched, the larva coils up in the form of a disc with its head in the center of the circle.

Pupa

When first formed the pupa is yellowish white in color, but in about 12 hours it hardens and becomes red-brown in color. The pupa is about 20 mm. long and is of the noctuid type. The abdomen is segmented, the segments telescoping into each other. The abdomen is pointed at the posterior end and bears small needle-like processes. The anterior end is obtuse. In the advanced stage of the pupa the black eyes become prominently noticeable and the wings folded on the ventral side show distinct dark markings.

Adult

The adult is a typical owlet moth. The general color of the forewings is light brown to dark brown shaded with dark brown to black along the outer thick edge and in the middle also, in the female. The forewings are divided into three nearly equal parts by two transverse bands, each composed of two wavy brown lines. In the middle space are situated the two ordinary spots, together with a third oval spot, which touches the anterior band. These spots are encircled with dark brown, and the kidney spot bears a dark brown lance-shaped mark on its hinder part. The posterior third of the wing is crossed by a broad, pale brown band and is ornamented by a narrow wavy or festooned line, and several small blackish spots near the margin. The hind wings are usually pearl white and semi-transparent, shaded behind and veined with dusky brown. The thorax is brown or gray-brown, with the edge of the collar blackish. The abdomen is gray. The wing expanse is 2 inches or more.

LIFE HISTORY

In the field the eggs of the black cutworm (*Agrotis ypsilon* Rott.) are laid either singly or in groups usually on the underside of leaves and parts of stems of plants which are near the ground. Woodhouse and Dutt (1913) state, however, that "in India the eggs are laid chiefly in newly ploughed or irrigated soil."

In the greenhouse the author has found that the moths appear to prefer something soft on which to oviposit, for when the lantern globes were covered with cheese cloth the eggs were deposited upon it, but when blotting paper replaced the cheese cloth, eggs were seldom laid upon it. Leaves of plants and dead bodies of their companions were preferred next to the cheese cloth for oviposition.

The length of the egg stage which varies with climatic conditions, is from 2 days in summer to about 8 or 9 days in winter. In the greenhouse where the mean temperature was 81°F, they hatched in from 2 to 4 days.

Upon hatching the larvae, unless disturbed, devour part of the egg shells. At the slightest disturbance they immediately coil up, which results in their falling to the ground. The young larvae feed upon fallen leaves and leaves of branches which happen to lie on the ground. They do not show the cannibalistic habit of the advanced larvae. As they grow their habits change. They live in cracks or holes which they make in the ground, and very seldom come out during the day, although occasionally one may crawl from one place to another.

They are active principally at night, and fell the plants by cutting their stems either below the surface of the ground or above the ground. Cut branches are sometimes dragged into the holes, where the leaves are eaten later.

This peculiar method of attacking the host gives this species its prominence as an economic pest. It has been observed to cut off a plant and without further feeding move on to the next one. This habit is especially evident in fields of young plants. Thus due to their wantonness in areas of heavy infestation considerable damage occurs unless control measures are quickly applied. While the length of larval life is about one month it varys with the season, being shorter in summer and longer in fall and spring. In the greenhouse under optimum conditions the length of the larval period varied from 23 to 30 days. Satterthwait (1928) found that normally there are six larval instars. He also found that a few pupated on reaching the fifth instar and that others had as high as seven and occasionally eight instars. The author observed only one case where a larva passed through seven instars.

A short time before pupation the larvae begin burrow-into the soil to varying depths and each one forms a small mud pupal cell. Here they remain quiescent from one to three days. During this rest period they undergo a marked change. They shorten longitudinally, the segments of their bodies become well marked and their forms become tapered, only slightly toward the head but more prominently toward the posterior end. Then the upper side in the region of the head and thorax, bursts longitudinally, and the soft, yellowish-white chrysalis comes out by a wiggling movement. In the course of about 12 hours the chrysalis hardens and becomes red-brown in color. The pupal stage varies from about 10 days in summer to about 30 days in fall and early spring. In regions of mild winters, generations are continuous and hibernation does not take place. In regions of cold winters it is probably that they hibernate in the soil as partially grown larvae or as pupae. In Kansas, this cutworm hibernates as a pupa in the soil.

While the moths generally emerge at night they occasionally emerge in the insectary during the day. The obtuse end of the chrysalis ruptures and the moth creeps out of the case, its soft and crumpled wings beginning almost immediately to expand and harden. The moths pair end to end. The interval between emergence of the moth and the beginning of oviposition varies with the individual moth and its environment. Female moths have been observed, however, to begin laying on the fourth day after emergence. The length of the oviposition period and the number of eggs laid also vary with the individual. The number of eggs laid in the greenhouse by a single female varied from 120 to 2,535 eggs. The average number of eggs laid in the greenhouse was about 500 and the length of the oviposition period varied from one or two days to two weeks.

The longevity of the moth also varies with the individual, the males usually dying before the females. It was noted in one case where the male and female moths were kept together in the same cage, that a male lived two days longer than the female.

NATURAL ENEMIES

This species of cutworm is heavily fed upon by ground frequenting birds and numerous rodents. The larval habit of killing and eating each other results in the destruction of a large number of worms. Where food supply is insufficient death by this means is high. Even when the food supply is abundant they are cannibalistic in habit.

The black cutworm, like most other cutworm species which spend part of their time above ground, is usually heavily parasitized by many dipterous and hymenopterous parasites.

Rockwood (1925) states that Tachinids, probably Gonia exul Will., were observed in the field. A few Gonia exul Will. were reared from collected material in the latter part of July. Sagaritis consimilis Ashm. was reared from a third or fourth stage larva.

Allen (1926) found Linnaemyia comta Fall., a Tachinid, to be a parasite of A. ypsilon.

Swezey (1914-15) reports Ichneumon koebelei Sn. as a parasite upon A. ypsilon.

Fletcher (1915) reports Broscus punctatus Kling, a carabid, feeding upon the larvae. Bowles (1879) reports the following as predators on cutworms in general: Fiery ground beetle (Calosoma calidum Fabr.), the murky ground beetle (Harpalus caliginosus Say), the spined soldier bug (Arma spinosa Dallas), the Hymenopteron (Microgaster) and the Ichneumon (Planiscus geminatus Say).

There are, in all probability, numerous other species not mentioned here, which are either predacious or parasitic upon the larvae of this species of cutworm.

REVIEW OF LITERATURE

In recent years, several workers have made efforts to correlate temperature and moisture (either humidity or rainfall) with distribution and outbreaks of insects. Temperature and moisture may act directly upon the insect or they may act indirectly by affecting the host plants.

Fitch (1865) was one of the earliest workers to realize the probably effect of climatic conditions on distribution of insects. He advanced the following hypothesis to account for army worm outbreaks in cultivated fields:

"..., my view is this - a dry season and dry swamps multiplies this insect. And when it is thus multiplied a wet season and overflowed swamps drives it out from its lurking place in flocks, alighting here and there over the country. But on being thus rusticated, it finds our arable lands too dry for it and immediately on maturing and getting its wings again, it flies back to the swamps, whereby it happens that we see no more of it."

Criddle (1917) in considering the relation of precipitation to insect distribution cites the Rocky Mountain locust, Melanoplus spretis, as an example of an insect which is increased greatly during dry seasons. He states that the Rocky Mountain locust "always invaded western Canada during a dry season, arriving in swarms from elsewhere in July or August. As this was the time of oviposition, eggs were soon deposited in vast numbers, and as a result, crops naturally suffered much more during the following year than they did on the insect's first appearance. While the locusts were able to breed for a season or so in the invaded territory they seldom remained long. Frequently an excess of moisture to what they had been accustomed, produced sickness from which many died, while others, taking advantage of sunny days and favorable breezes, drifted to parts unknown. In other words, dry weather had enabled them to be driven out or killed by a return to normal climatical conditions." He also states, that the western wheat-stem sawfly (Cephus sp.) is controlled by conditions of humidity alone. "In this instance a lack of precipitation causes a dearth of the flowering stems of grasses in which the larval life is passed, resulting in a decrease of the species in proportion to prevalence of suitable grass stems for breeding purposes." The hessian fly is checked by lack of moisture. Criddle states, "Dry seasons are generally recognized as anti-fly years and in Manitoba the partial second brood is frequently destroyed outright by a premature ripening of the grain, due to dry, hot weather conditions in late July."

Marcovitch and Stanley (1930) found that the distribution of the Mexican bean beetle is limited by droughts occurring during the summer months, June, July, August and September.

Cook (1930) in working with the pale western cutworm, Agrotis orthogonia Morr., came to the conclusion that in Montana "the total rainfall in May, June and July was a very definite indication of cutworm probabilities for the next year. If the total rainfall for these three months was less than 4 inches, cutworms would increase, while, if this rainfall was more than 5 inches, cutworms would decrease." The same general relations was found to hold for other localities.

GREENHOUSE STUDIES

In order to determine the optimum soil moisture for the black cutworm, experiments were carried out in the greenhouse with varying amounts of soil moisture. Since atmospheric humidity probably has very little influence on this insect during the larval stages, which are spent mainly below the surface of the soil, the moisture of the direct environment, namely, soil moisture, was studied.

Methods and Equipment Used

The method used in determining the relations of A. ypsilon to soil moisture was similar to that used by Cook (1923) with the variegated cutworm, Lycophotia margaritosa, Hub., in which method the cutworm was reared in a cage of soil where the known moisture content was held approximately constant by the daily addition of sufficient water to maintain a constant weight.

The equipment used in the experiment consisted of 10 glazed, one-half gallon crocks (each crock containing 8 screen compartments made of "milk strainer" screening, Plate I); a hygrothermograph for recording daily temperature and humidity; and a pair of grocers' scales weighing in pounds and ounces, for checking daily evaporation of soil moisture. Each crock was filled with 50 ounces of oven dry soil (soil subjected to 100°C. for 24 hours). The crocks were numbered consecutively from I to X. To Crock I and Crock II were added 12.5 ounces of water or the amount equivalent to 25 per cent of the dry weight of the soil. To Crock III and to Crock IV were added 7.5 ounces of water or 15 per cent of the dry weight of the soil. To Crock V and to Crock VI were added 2.5 ounces of water or 5 per cent of the dry weight of the soil. To Crock VII and to Crock VIII were added 15 ounces of water or 30 per cent of the dry weight of the soil. To Crock IX and to Crock X were added 29 ounces of water or 58 per cent of the dry weight of the soil.

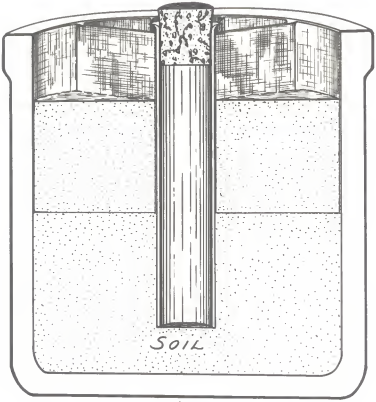
In each compartment of the 10 crocks (there being 80 compartments in all) was placed a newly hatched larva. Individual records were kept and these were recorded upon

PLATE I

A. Transverse section of crock showing arrangement of compartments.

B. Rearing crock.

PLATE I



A

B

standard record sheets. The time of each moult was recorded to the nearest day, also the time of pupation and time of emergence.

DISCUSSION OF DATA

Table 1 is a tabulation of survival records for the first experiment. This is graphically represented in Plate II, figure 1.

These data serve to indicate why this species of cutworm occurs in outbreak numbers only in moist situations. Why the mortality was higher in the crocks at 15 per cent soil moisture than those in the crocks at 5 per cent soil moisture is at present unexplainable. The negative result obtained at 58 per cent soil moisture indicates that there is a maximum for the prepupal and pupal stage although it appears to be the optimum for larval development. The sudden increase in mortality between the third and fifth instars may be due to the change in the greenhouse temperature. The greenhouse temperature during the early larval stages averaged about 78° F. while the temperature in the later stages averaged about 70° F.

Table 2 is a tabulation of survival records for the second experiment. This is graphically represented in

Table 1

A tabulation of survival records for first experiment.

Per Cent Soil Moist.	Number of individuals to reach each stage							Per Cent Mortality
	1st. Instar	2nd. Instar	3rd. Instar	4th. Instar	5th. Instar	Pupae	Adults	
5	16	15	13	6	6	5	4	75.00
15	16	16	13	6	3	3	2	87.50
25	16	16	15	9	8	8	6	62.50
30	16	16	16	11	8	8	6	62.50
58	16	16	16	15	12	8	0	100.00

Table 2

A tabulation of survival records for the second experiment.

Per Cent Soil Moist.	Number of Individuals to Reach Each Stage								Per Cent Mortality
	1st. Instar	2nd. Instar	3rd. Instar	4th. Instar	5th. Instar	6th. Instar	Pupae	Adults	
5	16	7	6	5	4	4	3	3	81.25
15	16	12	9	8	8	7	6	5	68.75
25	16	13	11	11	11	11	11	10	37.50
30	16	12	9	9	9	8	6	6	62.50
58	16	12	11	11	10	9	5	0	100.00

PLATE II

Figure 1 Graph showing cutworm survival in first experiment.

Figure 2 Graph showing cutworm survival in second experiment.

PLATE II

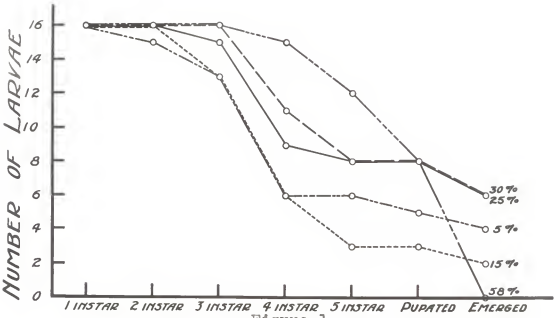


Figure 1

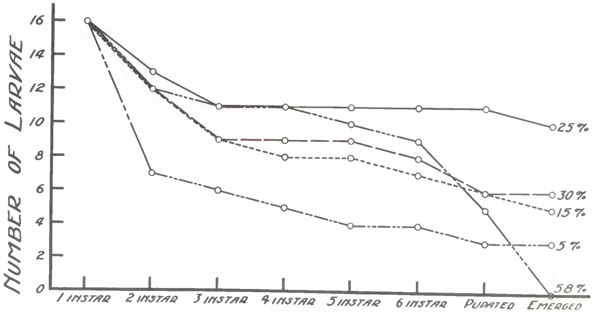


Figure 2

Plate 2, figure 2.

The data in table 2 were obtained by a duplication of the first experiment. The temperature of the greenhouse however, varied somewhat differently than in the first experiment, averaging below 70° F. during the greater part of the first stadium and then changing suddenly to a temperature averaging about 80° F.

It will be noticed in this experiment that the highest mortality again occurred in the crocks with 58% moisture and that although this percentage of moisture appears best for larval development it is very unfavorable to the prepupal and pupal stages.

Of the drier crocks, those containing 5% moisture show the highest mortality and over 50% mortality occurred between the first and second instars. In all of the crocks, exclusive of those at 58% moisture, the mortality was highest between the first and second instars. In the first experiment, however, the mortality was highest between the third and fourth instars. This might be due directly or indirectly to a change in the temperature of the surrounding air, but until experiments have been run under controlled temperatures it cannot be definitely stated that the change in temperature alone was the cause of mortality.

Tables 3 and 4 show the average number of days re-

Table 3

Average Number of Days and Mean Temperature for each Stage

% Soil Moisture	1st. Stadium		2nd. Stadium		3rd. Stadium		4th. Stadium		5th. Stadium		Pupal		Days to Pupate	Days to Emerge
	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.		
5	4.75	81.21	4.25	76.13	6.75	80.23	4.50	76.41	10.25	74.85	23.00	69.94	30.20	53.50
15	5.00	81.04	3.50	75.22	8.50	79.83	4.50	76.33	5.50	75.30	20.00	66.90	27.00	47.00
25	4.17	81.62	3.17	76.21	5.50	79.60	4.33	78.19	7.83	76.60	19.83	70.54	25.12	44.83
30	4.00	81.75	4.00	75.83	5.83	80.24	3.67	78.01	7.50	76.35	24.17	70.35	25.37	49.17
58	4.00	81.75	3.63	76.18	5.38	79.87	4.25	78.32	8.87	76.11	-	-	26.12	-

Table 4

Average Number of Days and Mean Temperature for Each Stage

% Soil Moisture	1st. Stadium		2nd. Stadium		3rd. Stadium		4th. Stadium		5th. Stadium		6th Stadium		Pupal		Days to Pupate	Days to Emerge
	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.	Days	M.T.		
5	7.67	68.64	3.0	81.60	4.67	79.25	3.33	83.27	4.67	82.68	8.0	82.15	14.33	85.68	32.67	47.00
15	7.4	68.88	3.2	80.86	4.2	79.54	4.6	81.93	4.8	83.73	10.2	82.60	12.2	84.56	34.33	47.00
25	6.9	68.72	3.4	80.26	4.8	79.36	4.2	80.00	4.3	84.59	7.5	82.63	13.6	85.29	30.09	44.30
30	7.5	68.85	3.17	81.03	4.0	79.55	3.67	80.93	4.83	83.50	7.5	82.85	13.0	84.96	30.33	43.67
58	8.0	69.22	2.8	81.16	4.6	79.05	3.6	80.50	4.4	84.16	6.2	82.50	-	-	29.60	-

quired for each stage of larval development and gives the mean temperature for the stages in the first and second experiments respectively. These figures are based on the number of larvae living at the end of each stage. They show that dry soil tends to lengthen the larval stages while wet soil tends to shorten them. This is more clearly indicated in the last two columns, which show the total average number of days required to pupate and to emerge.

OUTBREAKS OF THE BLACK CUTWORM

Table 5 is a tabulation of all outbreaks in the United States, recorded in the Insect Pest Survey, Review of Applied Entomology and various other sources such as State and Federal bulletins. The records are rather inadequate and too much weight cannot be placed upon them. They do serve, however, to indicate that outbreaks of this particular cutworm are concentrated east of the Mississippi River and especially in the states of Illinois, Indiana and Mississippi where overflows occur every year and where there is usually abundant rainfall during most of the growing season. It is well to state here that the outbreaks recorded from Arizona occurred in a small irrigated area near Phoenix. Previous to 1929 this area was desert land.

Table 5

Recorded Outbreaks of *Agrotis ypsilon* Rott.

	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total
Arizona													x	x	x					3
Arkansas											x	x								2
Connecticut									x			x								2
Idaho										x										1
Illinois						x			x		x			x	x			x		6
Indiana	x	x				x				x	x	x	x				x			8
Iowa									x											1
Kentucky													x							1
Louisiana											x									1
Maine								x				x	x			x			x	5
Massachusetts	x								x											2
Mississippi									x	x	x	x		x		x	x		x	8
Missouri																x	x	x	x	4
Nebraska										x	x									2
New York							x													1
North Carolina												x								1
Ohio														x			x			2
Oregon			x						x			x		x	x					5
Pennsylvania													x							1
South Carolina													x							1
Tennessee																x	x	x		3
Total	2	1	1	0	0	2	1	1	5	5	6	7	6	5	3	4	5	3	3	

It will be noted that outbreaks seldom occur in some of the southern states. This is probably due to the frequent droughts which occur there. Marcovitch and Stanley (1930) state, "The southeastern United States comprising Florida, Georgia and South Carolina, with a high ratio of rainfall to evaporation is nevertheless subject to frequent droughts. The measure of precipitation in this area does not give an adequate idea of the environment. The rainfall comes in torrential storms which dissipate their water in surface run-off. As high as 80% of a 2.5 inch rainfall, falling in four hours, may be lost by run-off. Columbia, South Carolina, with 47.55 inches of annual rainfall, may have 6.2 drought periods in nine years, whereas Ames, Iowa, with only 30.4 inches of rainfall, may have but 2.3 drought periods."

Dr. A. L. Strand reports[1] that an outbreak of the black cutworm, Agrotis ypsilon Rott., has never been reported in Montana, although there are several areas in the state where irrigation is practiced. The moths are very rare in Montana since only three specimens have been taken in light traps and in flower collections in the last ten years.

[1] Correspondence on April 22, 1936.

Mr. W. W. Stanley[2] reports that, although the black cutworm is always present and that it appears early in the spring and is one to remain until the last of the season, there never has been an outbreak in the immediate vicinity of Knoxville since 1928 when he began his work on cutworms there. The following is a summary of his light trap records:

1928	August 1 to November 16	58 catches
1929	April 10 to October 25	96 "
1930	April 30 to November 20	111 "
1931	May 11 to December 22	78 "
1932	April 5 to October 18	121 "
1933	April 28 to October 30	100 "
1934	May 4 to October 25	67 "

It will be noted from these data that in the period of years covered the moths were never abundant. The reason for this phenomenon is not clear since the "bottomlands" of the Tennessee River are overflowed each year. It is possible that the droughtiness of the remainder of the year holds the numbers down to such an extent that they are unable to build up to outbreak numbers in the early spring.

Mr. H. H. Walkden[3] has been studying the cutworms of Kansas for a number of years and has been running light traps in several sections of the state.

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[2] Correspondence on April 16, 1936.
[3] Unpublished data from the Bureau of Entomology and Plant Quarantine, Manhattan, Kansas.

In his unpublished data light trap collections show that the greatest concentration of the black cutworm is around Garden City, Kansas, where irrigation is practiced. No outbreaks, however, have ever occurred in Kansas to his knowledge.

CONCLUSIONS

Due to the small number of larvae dealt with in the two experiments the recorded data can only serve to indicate the tendencies and to give some idea of the effect of soil moisture on the larval stages of the black cutworm.

Judging from the data recorded, the optimum soil moisture for complete development appears to be somewhere between 25 and 30 percent. Fifty-eight percent soil moisture appears to be the maximum soil moisture for the prepupal and pupal stages although it appears to be the optimum for larval development.

In the field where the land has been overflowed, the soil moisture probably runs as high as 58%. The first stages of larval development would then occur under such conditions but since the soil gradually dries out the larvae would be able to pupate and emerge.

The data also show why the black cutworm, A. ypsilon, occurs only in areas of recent overflow or where there is abundant rainfall throughout its period of development.

The data clearly prove two points of interest. First, that there is a maximum soil moisture for the pre-pupal and pupal stages, and second, that the larvae are able to survive arid soil conditions unsuitable to the development of its host plants.

Outbreaks of the black cutworm will occur only in those localities where overflows occur each year and where rainfall throughout the year is sufficient to maintain a fairly high soil moisture, since droughtiness tends to decrease the number which survive for spring infestation when overflows usually occur. Irrigation will tend to duplicate these conditions in arid regions.

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