Bulletin No. 297 - Pale Western Cutworm

C. J. Sorenson

H. F. Thornley

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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Host plants</td>
<td>2</td>
</tr>
<tr>
<td>Type of damage inflicted</td>
<td>3</td>
</tr>
<tr>
<td>Distribution</td>
<td>5</td>
</tr>
<tr>
<td>Description of various life stages</td>
<td>7</td>
</tr>
<tr>
<td>Adult</td>
<td>7</td>
</tr>
<tr>
<td>Eggs</td>
<td>7</td>
</tr>
<tr>
<td>Larva</td>
<td>7</td>
</tr>
<tr>
<td>Prepupa</td>
<td>8</td>
</tr>
<tr>
<td>Pupa</td>
<td>8</td>
</tr>
<tr>
<td>Life history</td>
<td>9</td>
</tr>
<tr>
<td>Overwintering</td>
<td>9</td>
</tr>
<tr>
<td>Hatching</td>
<td>9</td>
</tr>
<tr>
<td>Larval feeding and growth</td>
<td>10</td>
</tr>
<tr>
<td>Prepupal aestivation</td>
<td>11</td>
</tr>
<tr>
<td>Pupation</td>
<td>12</td>
</tr>
<tr>
<td>Adult emergence</td>
<td>12</td>
</tr>
<tr>
<td>Moth flight and feeding</td>
<td>13</td>
</tr>
<tr>
<td>Mating</td>
<td>14</td>
</tr>
<tr>
<td>Oviposition</td>
<td>15</td>
</tr>
<tr>
<td>Oviposition period</td>
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</tr>
<tr>
<td>Sex ratio</td>
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</tr>
<tr>
<td>Control</td>
<td>18</td>
</tr>
<tr>
<td>Cultural</td>
<td>18</td>
</tr>
<tr>
<td>Irrigation</td>
<td>19</td>
</tr>
<tr>
<td>Moth trapping</td>
<td>19</td>
</tr>
<tr>
<td>Weather</td>
<td>20</td>
</tr>
<tr>
<td>Natural enemies</td>
<td>21</td>
</tr>
<tr>
<td>Arachnids</td>
<td>21</td>
</tr>
<tr>
<td>Insects</td>
<td>21</td>
</tr>
<tr>
<td>Birds</td>
<td>22</td>
</tr>
<tr>
<td>Summary</td>
<td>22</td>
</tr>
</tbody>
</table>
THE PALE WESTERN CUTWORM
(Agrotis Orthogonia Morrison)
IN UTAH

C. J. SORENSON and H. F. THORNLEY

THE PALE WESTERN CUTWORM (Agrotis orthogonia Morr.) has caused periodic damage to dry-farm grains in Utah during the past 25 years. In the spring of 1916, entomologists of the Utah Agricultural Experiment Station were asked to determine the cause of large bare spots occurring in fields of fall-planted wheat in the Indianola district of Sanpete County. A moderately severe infestation of pale western cutworm was found to be the causative agent. Pack (9) reported that during the spring of 1929 this insect had inflicted serious damage to fall wheat at Fairview, Sanpete County.

During the spring of 1924 wheat stands on several experimental plots of the Nephi Dry-Farm Substation were seriously thinned out by this pest. Throughout the Levan Ridge district damage was noticeable in 1924 and severe injury occurred in 1930.

Cutworm damage was first noticed in a few wheat fields in northern Cedar Valley, Utah County, in the spring of 1933. In 1934 approximately 25 percent of the total 9,000 acres of fall-planted wheat in northern Cedar Valley and the Lehi-West-Hills area was destroyed by this pest. During 1935 the infestation spread throughout this district, extending from Camp Williams southward to the vicinity of Saratoga and eastward beyond the Jordan River. The wheat crop on a few farms was completely destroyed in 1934, 1935 and 1936. Although the area of infestation in 1935 was considerably greater than in 1934, yet aggregate crop losses were only slightly higher. Heaviest infestations and greatest damage occurred in 1936. Crop losses of two or three successive years rendered many farmers of the Cedar-Valley and Lehi-West-Hills areas financially unable to continue operations. Resulting from this situation hundreds of acres of land were left uncultivated and soon became occupied by Russian-thistle (Salsola pestifer A. Nels.).

Since 1935 from 12,000 to 14,000 acres have been annually cultivated in the dry-farm areas of Cedar Valley and the Lehi

1 Contribution from the Department of Entomology. Report on Project 51-B.
2 Research associate professor of entomology and graduate assistant, respectively.
3 Order Lepidoptera, Family Phalaenidae (Noctuidae).
4 Unpublished report of A. F. Bracken, superintendent, Nephi Dry-Farm Substation.
West Hills. The customary practice has been to summer fallow the land in alternate years. The acreage in crops therefore, has varied between 6,000 and 7,000 acres. An approximation of the planted acreage and the degree of cutworm damage that occurred in these areas from 1932 to 1940, inclusive, is presented in table 1. It will be noted that maximum damage was done in 1936 and annually thereafter it decreased so that during 1939 and 1940 it did not exceed one percent.

Table 1. Rainfall, approximate wheat acreage, and pale western cutworm damage in the Cedar-Valley and Lehi-West-Hills dry-farm areas. 1932-40

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall Mar., Apr., and May (estimated)</th>
<th>Wheat planted (approximate)</th>
<th>Destroyed by cutworms (percent)</th>
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<tbody>
<tr>
<td></td>
<td>inches</td>
<td>inches</td>
<td>acres</td>
</tr>
<tr>
<td>1932</td>
<td>10.49</td>
<td>2.40</td>
<td>9,000</td>
</tr>
<tr>
<td>1933</td>
<td>5.94</td>
<td>2.00</td>
<td>9,000</td>
</tr>
<tr>
<td>1934</td>
<td>9.29</td>
<td>0.15</td>
<td>9,000</td>
</tr>
<tr>
<td>1935</td>
<td>7.20</td>
<td>4.06</td>
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<tr>
<td>1936</td>
<td>12.42</td>
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</tr>
<tr>
<td>1937</td>
<td>11.33</td>
<td>2.17</td>
<td>6,000</td>
</tr>
<tr>
<td>1938</td>
<td>10.16</td>
<td>4.56</td>
<td>7,000</td>
</tr>
<tr>
<td>1939</td>
<td>8.13</td>
<td>1.52</td>
<td>7,000</td>
</tr>
<tr>
<td>1940</td>
<td>9.91</td>
<td>2.00</td>
<td>9,000</td>
</tr>
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*U. S. Weather Bureau. Climatological Data, Utah Section, Vols. 34 to 42. Station: Utah Lake (Lehi).

Host Plants

During this investigation the pale western cutworm has been found feeding on the following plants in Utah: winter- and spring-planted wheat, oats, barley, corn, Sudan grass, beans, alfalfa, potatoes, tomatoes, Russian-thistle (Salsola pestifer A. Nels.), sunflower (Helianthus annuus L.), tumble mustard (Norta altissima L.), wild lettuce (Lactuca scariola L.), prickly poppy (Argemone hispida A. Gray), round leaf mallow (Malva rotundifolia L.), and downy chess or cheat-grass (Bromus tectorum L.). Where infestations were heavy on dry farms not only was the wheat crop destroyed but also all weeds and other annual plants.

Concerning food plants, Seamans and McMillan (11) make the following statement:

In its native habitat the pale western cutworm feeds on the stems of grasses and where these grasses have been destroyed by agriculture, it has turned its attention to a wide variety of plants. In Canada practically every field and garden crop is attacked as well as many of the common weeds. There seems to be little food preference except that stink weed (Thlapsi arvense L.) and veined dock (Rumex venosus Pursh.) are only eaten sparingly even when no other food plants are available. The larvae have also been found feeding on decaying straw or other vegetable matter after all green vegetation was destroyed.
Cook (2) in Montana found the insect feeding on all small grains, corn, native grasses, tumbledmustard, Russian-thistle and dandelion (*Taraxacum* spp.). Gillette et al. (8) reported some loss of winter wheat and sugar beets from this pest in northern Colorado during 1923.

The following economic plants have been reported by various other investigators as having been attacked by the cutworm under discussion: alfalfa, barley, beets, cabbage, carrots, corn, flax, millet, native grasses, oats, onions, rye, sweet clover, and winter- and spring-planted wheat.

**Type of Damage Inflicted**

The Pale Western Cutworm is particularly destructive to fall-planted wheat. It burrows through the soil, feeding on the wheat plants from about one-fourth to one inch below the soil surface. A short section of the underground portion of stems is either partly or wholly eaten through. Damage is soon indicated at the surface by wilting and ultimate death of the plants. In its foraging this cutworm usually follows along the drill rows where the soil is looser than elsewhere in the field, cutting off each plant that is encountered. After the damaged plants die, they dry up and are often blown away leaving either bare spots or the entire field devoid of vegetation (fig. 1). This habit of eating only a small portion of each plant accounts for the serious damage often inflicted by a heavy infestation. Each larva destroys many wheat plants.

Fig. 1. Fall-planted wheat field in which most of the grain has been destroyed by pale western cutworms.
Fig. 2. Areas in Utah where serious damage by the pale western cutworm to dry-land wheat has occurred and localities where either larvae or adult moths of this pest have been collected.

Newly-hatched cutworms are to be found in early spring almost as soon as the snow disappears from the grain fields. Because of their small size and early appearance, they are seldom observed; neither are the results of their early feeding evident without close examination. Damage first becomes noticeable on sandy spots about the first of May, at which time the worms have attained a length of
approximately one inch. If the infestation is heavy, large bare spots will appear in the fields by about May 15. Between the latter date and the first of June most of the cutworms reach maturity, having attained a length of about 1½ inches. It is during the latter period that extensive and serious damage occurs. Hundreds of acres of grain are often destroyed in a few days. On May 15, 1936 a field of 313 acres of fall-planted wheat in the Lehi-West-Hills district appeared to be in a thrifty condition. However, a few damaged spots were beginning to show on sandy south slopes. Within a week great patches of wheat were destroyed and by June 1 the grain in the entire field was almost ruined. Only 27 acres were harvested and these were so badly damaged that they yielded but 6 bushels of grain per acre. Seamans (12) found that 15 or more cutworms per square yard will destroy a crop. In one wheat field on the Levan Ridge, 103 cutworms were counted on May 9, 1936 from one square yard of soil at the junction of destroyed and uninjured grain. Within a few days all the wheat in this 80-acre fall-planted field was ruined by the cutworms.

Distribution

The Pale Western Cutworm was first recognized in 1876 from specimens collected by G. M. Dodge at Glencoe, Nebraska. Smith (13) in 1890 recorded it from New Mexico, Arizona, and Utah and in 1902 Dyar (5) specified its range as being the Rocky Mountain region. In 1911 Gibson (7) reported the destruction of large areas of wheat in southern Alberta, Canada.

In 1921 Parker, Strand, and Seamans (10) reported extensive injury to grain crops by A. orthogonia in north central Montana from 1915 to 1920. In the same publication reference is also made to a list of western noctuids collected by Dr. William Barnes in which adult moths of this species were taken from the following localities: Arizona: Redington; California: Kern County; Colorado: Alamosa, Denver, Lavetta and Oak Creek Canyon; New Mexico: Deming and Fort Wingate; Nevada: Reno; Utah: Eureka, Provo, and Vineyard; Wyoming: Yellowstone National Park.

Corkins (3) in 1922 stated that this pest had been known to occur in Colorado during the preceding 25 years at least.

Ainsle (1) in 1928 found the insect destroying grain crops in North Dakota. Eshbaugh (6) reports that, so far as is known, the pale western cutworm first invaded the panhandle of Oklahoma in 1928 and that injury to wheat occurred there in 1929 and 1930; also in northwestern Texas during 1932.

Although a state-wide survey for this pest in Utah has not been possible during this investigation, nevertheless specimens have
Fig. 3. The pale western cutworm (Agrotis orthogonia Mozz.). A, adult female; B, egg (dorso-lateral view); C, egg-mass; D, mature larva; E, pupa; F, head of a fifth-instar larva showing markings resembling a narrow-waisted H; G, head of a mature larva showing inverted V-shaped head-markings.
been collected by entomologists of the Utah Agricultural Experiment Station in the following localities: Arcadia, Bluffdale, Cedar Fort and other points in Cedar Valley, Eureka, Fairview, Farmington, Indianola, Jordan Narrows, Juab, Lehi, Lofgreen, Logan, Manila, Mapleton, Murray, Myton, Naples, Nephi, Richfield, San Rafael Swell, Scipio, Spanish Fork, Springville, Tooele, and Vernal.

Areas in Utah where serious damage has been done by *A. orthogonia* to dry-land wheat and localities where either larvae or adult moths of this pest have been collected are indicated in fig. 2.

**Descriptions of Various Life Stages**

**Adult**

The wing spread of pale western cutworm moths ranges from 1 to 1 ½ inches, mean 1 ¼ inches. Front wings vary from yellowish-gray to dark-gray, or in some specimens to yellowish-brown. A dark egg-shaped spot is found near the center of each front wing. These two spots are dark-gray at the center, fading to white at the periphery and are inclosed by a black ring. A second kidney-shaped spot is found slightly nearer the tip of the wing. It has the same color as the egg-shaped spot but is not so clearly defined. A third elongate club-shaped spot is located just below the egg-shaped spot. Its end nearest the body is enlarged and its color resembles that of the other two marks. In addition to these three spots, the fore wings are mottled with light and dark areas and five irregular crosslines are usually evident. It is only in moths with unrubbed wings that the marks described above are clearly defined. Hind wings are dull white near the body, gradually deepening to gray or brown at the outer margins. In some specimens the hind wings are entirely white. The body of the moth is robust and clothed with long hairy scales, especially on the anterior part.

**Eggs**

Eggs are more or less spherical in shape but somewhat flattened at the top and bottom. They are slightly less than one-sixteenth inch in diameter, white when first laid but soon change to yellowish-gray. There are 27 to 32 ridges on the dorsal surface of the egg. These ridges extend radially from the apex to about the middle of the egg where they fade out. The opposite surface is smooth and unmarked.

**Larva**

The newly hatched cutworm is approximately one-eighth of
an inch long. Its head varies from dark-brown to black and the general body color is yellowish-brown. The fore part of the body possesses three pairs of jointed legs (true legs), whereas after the fifth molt the posterior two-thirds portion has three pairs of fleshy prolegs.

As the cutworm grows, its skin becomes very tight about the body and in order to continue its growth the insect must periodically shed or molt this outer body covering and obtain a new, larger one. Cutworms reared in the laboratory molted their skin either seven or eight times before reaching larval maturity.

Fully matured cutworms vary from light bluish-gray to yellowish-gray. In length they vary from 1¼ to 1½ inches. The skin is transparent and without markings except for three pairs of faint greenish-gray stripes along the back and sides. The transparent skin makes visible many of the internal organs. This is especially true with respect to the heart which can be seen pulsating in living specimens. Distinctive marks are present on the front of the head which may be used in field identification of the species. These markings consist of two black lines that follow the grooves of the head. In mature cutworms these black lines resemble an inverted V, whereas in younger cutworms they more closely resemble a narrow-waisted H. The body is sparcely clothed with hair which is not noticeable except by close examination or with magnification.

**Prepupa**

After reaching its maturity, the larva burrows deeper into the soil where it forms an earthen cell. All feeding ceases and undigested food material is voided leaving the cutworm much lighter both in weight and color. Its skin color fades out, becoming yellowish-white and all body markings disappear: the body shortens and wrinkles greatly. Average length of the cutworm during this prepupal stage is approximately seven-eighths inch. While in this stage the insect is very sluggish showing few signs of life.

**Pupa**

The prepupa transforms to the pupal stage still within the earthen cell. Color of pupae varies with their maturity: newly formed ones are light-yellow, whereas more mature ones are dark-brown. Length ranges from one-half to three-fourths inch with an average of five-eighths inch. Mouth parts, legs, and wings are all visible and are confined beneath the transparent body covering (cuticula). In this stage the cutworm is immobile except for the abdominal segments.
Life History

Overwintering

This insect overwinters in the egg stage. Adult moths lay their eggs during September and early October in soft well-pulverized soil. Summer-fallowed land that has been thoroughly cultivated in late summer and early fall furnishes ideal conditions for egg-laying moths. Eggs are placed approximately one-fourth inch below the soil surface. Embryonic development soon begins and is completed by late fall. In the autumn of 1939, eggs taken from the soil were dissected at regular intervals to ascertain the progress of embryonic development before the appearance of heavy fall frosts. This study revealed that embryos were fully formed on November 13. Mean temperature for the period October 1 to November 13 of that year was 48.90 degrees F. On November 6, 1940, some fully developed embryos were found within the egg shells. Mean temperature from October 1 to November 6, inclusive, of this year was 50.86 degrees F. First frost of the season occurred on November 3 when the minimum temperature fell to 32 degrees F.

Hatching

Although cutworm eggs are ready to hatch in late fall yet all available evidence indicates that the usual time for hatching in Utah is either late winter or early spring. In the autumns of 1936 and 1937 eggs were collected and placed near the surface in soil-filled flower pots in the entomological insectary at Logan where the temperature and soil moisture were kept approximately equivalent to that occurring in the field. These eggs began hatching on February 25, 1937 and January 15, 1938, respectively. In each of these years the hatching occurred during a period of mild weather. On April 20, 1937, larvae were found on dry farms in the Lehi-West-Hills area. Length of these larvae varied from five-sixteenths to one-half inch. They were in approximately the fourth instar and had evidently hatched several weeks earlier. In this same district on January 16, 1938, during an unusually mild period, first-instar larvae were found in open cages in which eggs had been placed during the preceding October. Samples of soil from these egg-cages were immediately examined under a microscope to determine the percentage of hatching that had then occurred. Sixty-two percent of the eggs were found unhatched, 30 percent hatched, and 8 percent infertile. Mean length of the 25 larvae measured was 2.87 mm. (approximately one-ninth inch). They were in the first instar and hatching had probably just begun.
In 1940 egg-hatching occurred about March 1 in the Lehi-West-Hills district. Although this date of hatching is considerably later than that found in previous years of this investigation, yet it is probably nearer the usual time of hatching in Utah following a normal winter season. In the same locality, on March 18, 1940, numerous young cutworms were found feeding on the leaves of fall-planted wheat or crawling about on the surface of the ground. Some of them were in their second instar whereas others were in the third.

On February 25, 1937 the process of hatching was observed with the aid of a binocular microscope. A fully-developed embryonic larva could be seen through the transparent egg-shell where it formed a complete circle within. The black head was seen moving slightly from side to side. The egg-shell was soon ruptured by means of the larval mandibles. The unhatched larva seized and tore off fragments of the shell which were quickly discarded. When a hole of sufficient size was made to permit its exit the larvae crawled out. The time required for hatching in this case was 52 minutes at a room temperature of 68 degrees F.

Larval Feeding and Growth

For a few days immediately after hatching, cutworms feed on the surface of the soil (fig 4). They soon burrow into the

Fig. 4. Young wheat leaves showing areas fed upon by first-instar larvae.
soil, however, to continue feeding and complete their larval development. After going underground, the cutworms burrow through the soil, following the drill rows and cutting off the wheat plants as they go. They avoid areas where the soil has become packed, such as in roadways, fence lines, and even tracks of farm implements and livestock.

This cutworm has never been observed on the soil surface except for a short period immediately after hatching and during heavy rains. Larval migration is accomplished by burrowing through soft soil. An example of this striking habit was observed in the Lehi-West-Hills area in 1936. A field heavily infested with cutworms was separated from an uninfested field by a dirt road. The grain in the infested field was completely destroyed, whereas, that in the adjoining field was untouched. This case, as well as others observed in Utah, seems to indicate that this cutworm will not come to the surface to migrate and that it avoids hard-packed soil.

Occasionally the cutworms are forced to the surface by heavy rainfall. This phenomenon was observed during an intense thunder shower in the Lehi West Hills on June 5, 1936. Following the storm, mature larvae were observed on the surface. After the excess water had drained away, the cutworms began burrowing back into the soil. On the following morning only a few that had died from exposure or other causes were to be found on the soil surface.

Larval development is mostly completed by the first of June. Collection records from 1936 to 1938, inclusive, show that no larvae were found feeding after June 11, except on spring-planted wheat or on wheat that had been reseeded after the fall-planted crop had been destroyed. On reseeded fields larval development is delayed owing to lack of food during preparation of a new seedbed.

Prepupal Aestivation

Fully developed larvae are plump and shiny, having much stored fat needed for further development. From about June 1 to 15 these mature cutworms enter a long resting or aestivation period which according to Crumb (4) enables them to escape the extreme heat of summer. In entering this quiescent period the larvae burrow from 2 to 6 inches into the soil where each forms an earthen cell. They do not build cocoons but each apparently secretes sufficient saliva with which to form a smooth-walled chamber in the soil. When this moisture dries, the cell wall becomes hard, affording a well insulated, well protected cavity in which the insect passes the remained of the summer (fig. 5).
The cutworm undergoes a marked change in its transformation from the larval to the inactive prepupal stage. Larvae are very active and when picked up, will flip their bodies backward and forward quite vigorously. Following these few quick movements they will usually "play possum." In the prepupal stage, however, little response is made when they are handled. They will, nevertheless, slowly endeavor to dig back into the soil when unearthed. Torpidity lasts from $1\frac{1}{2}$ to 2$\frac{1}{2}$ months. The prepupal period of *A. orthogonia* is unusually long in comparison with that of other cutworm species.

**Pupation**

Pupation is accompanied by shedding of the last larval skin which process takes place within the underground earthen cell. The skin splits dorsally in the region of the head and by a series of muscular movements the pupa emerges. The procedure begins with the release of the head and ends when the caudal portion of the body is drawn out of the old larval skin (exuviae).

In 1936 pupation within field cages took place between August 10 and 26; and in 1937 between August 11 and 18. The length of the 1936 pupal period ranged from 15 to 31 days, mean 24.07 days; in 1937 its range was from 23 to 37 days, mean 31.4 days. These rearing records correlate closely with records of pupae collected annually in the field from 1936 to 1940, inclusive, as well as with adult emergence indicated by light-trap records for these years.

**Adult Emergence**

In 1936 moths emerged in field cages from September 5 to 23. Adult emergence was first observed in the open field on September 7 of that year. Within field cages adults began emerging on September 15, 1937 and continued until September 23. Light-trap records obtained and field observations made during the fall-flight period of the moths for each season from 1936 to 1940, inclusive, indicate that adult emergence begins in early September and continues until about October 25, varying somewhat according to weather conditions (fig. 6 and 7).
Moth Flight and Feeding

Moths of *A. orthogonia* are mostly nocturnal. Males begin feeding on rabbitbrush blossoms near sunset, whereas female moths are busy ovipositing in the fields during late afternoon and early evening and start their feeding about dusk. The daily period of activity for both sexes extends from approximately 5 p.m. until midnight, although weather conditions may alter this somewhat. Maximum numbers of moths were found flying between 8 and 9:30 p.m. On cloudy days moths were observed feeding throughout the afternoon and on rare occasions an individual was seen flying and foraging in the morning. Likewise during warm nights activity may continue until the early hours of morning. Moths seek shelter during stormy weather and are seldom seen when the vegetation is wet. They appear to be more active on dark than on moonlight nights. Few adults have been observed feeding when the temperature falls to 45 degrees F. or below, although on several occasions they have been observed feeding actively when the temperature was 50 degrees F.

After the nightly feeding period is over these moths seek seclusion, crawling into protected places where they spend the daylight hours. During this time they most commonly have been found concealed under debris at the base of rabbitbrush. In cultivated fields they crawl into crevices of the soil or hide under clods, weeds and other objects that afford protection.

In the area under investigation adults have been found to feed almost exclusively upon the nectar of rabbitbrush blossoms. The most prevalent species of this plant is *Chrysothamnus nauseosus* Nutt. Its season of blossoming is very irregular and consequently it provides food for the moths over a considerable period of time. First blossoms usually appear around the first of September about the same time that cutworm moths begin making their first appearance for the season. Cook (2) reports that the favorite food of these moths is the nectar of various species of goldenrod (*Solidago* spp.), and that when moths were extremely abundant, they
were observed feeding upon the blossoms of snakeweed (Gutierrezia sp.) and Russian-thistle (Salsola pestifer A. Nels.). Although these two plants are common in the Lehi-West-Hills area, A. orthogonia moths have never been observed feeding on them in this locality. This may be owing to an abundance of the more attractive rabbitbrush on uncultivated lands throughout the latter area.

Adults are energetic feeders. They crawl about on the blossoms, quickly uncoil their long sucking tubes (proboscis) and with great dexterity insert them into blossom after blossom. Occasionally a moth finds one floret apparently more satisfactory than another; in such a case it remains on the former for several minutes. During daylight hours the moths are extremely wary, taking flight at the slightest disturbance; after dark, however, they may be observed and captured with little difficulty while feeding.

Relative abundance of adults, duration and peak of annual moth activity for each of the five years, 1936 to 1940, inclusive, are indicated graphically in figure 8.

It will be noted that the period of moth activity extends from about September 1 to October 15 or 25 varying with weather conditions in different years. This period was found to be almost a month later in Utah County than Cook (2) reported it for Montana. This variance is probably owing to a difference in ecological factors in these two localities.

Mating

Careful observations in the field throughout the daily activity period of adults were made over a 5-year period without noting any mating. In 1936 adult males and females were confined in wire-screen cages and observed at regular intervals throughout the day and night but none were seen mating. Cook (2) reports that mating pairs were observed on rabbitbrush plants after midnight.

Fig. 7. Light-traps and wire-screen cages used in studies of flight periods and egg-laying activities of cutworm moths
Oviposition

Female moths were found ovipositing during late afternoon and early evening in loose soil of cultivated fields and in sandy spots on uncultivated lands. After dark on September 16, 1931 in the Lehi-West-Hills district a moth was observed, with the aid of a flashlight, fluttering approximately twelve inches above the surface of the ground. It soon alighted and after several minutes of crawling about stopped on a soft spot of soil. The abdomen, by several downward thrusts, was then forced into the ground to a depth of from one-fourth to one-half inch. It could be seen pulsating rhythmically. The moth remained in this place for about 10 minutes and then moved approximately 10 inches to a second position. In moving about, the insect made no attempt to fly but crawled from place to place. Its abdomen appeared heavy and its crawling awkward. In the second position the moth again forced its abdomen into the loose soil and the pulsations were repeated. It remained there about 5 minutes, then crawled to a third place, approximately 3 feet away, where the process was repeated for 6 minutes. The female next crawled to a fourth position, some 6 feet distant, where egg-laying was continued for 2 minutes; after that it crawled to the top of a clod where it rested for 14 minutes. Without warning the moth then took wing and was soon lost in the darkness. During this investigation several ovipositing moths have been observed. The activities of all were much the same as those of the female just described.

Female moths are highly selective of the soil in which they oviposit, choosing only that which is soft and well pulverized, avoiding hard and surface-crusted soil. They also appear to select sandy knolls in wheat fields and on uncultivated lands. Moths will sometimes find suitable conditions for egg laying in surface crusted fields where weeds are present. Weeds that are vibrated by strong winds tend to pulverize the soil about their crowns and wherever the branches touch the ground. Livestock walking over fields also break the soil crust and thus form favorable places in which these insects may lay their eggs.

Oviposition period

Results of field investigations in the Lehi-West-Hills and Cedar-Valley areas during the fall seasons of 1936 to 1940, inclusive, indicate that oviposition begins about September 10, soon after the emergence of first adults of the season. Practically all egg-laying is completed by the middle of October.

In the Lehi-West-Hills district during September 1937 apparently newly emerged male and female moths, 36 of each, were
Fig. 8. Graphs indicating the number of *A. orthogonia* moths caught nightly in light traps hung near rabbitbrush which was in blossom annually in the Lehi-West-Hills district during September and October, 1936 to 1940, respectively. Legend along left margins indicates the number of moths caught. Numbers inside left margins specify a Fahrenheit temperature scale and the line extending to the right from this scale represents daily mean temperatures. Numbers along bottom indicate dates when moths were captured. Discontinuous lines indicate incomplete records.
carefully collected, paired as to sex, and each pair put into a wire-screen rearing cage. Here they were fed a honey solution and kept during the remainder of their lives to obtain an indication of the number of eggs laid by individual females and of the life-span of each sex. Under this method of collection it is quite likely that some moths were taken that had already begun to oviposit. It is also likely that normal oviposition did not occur in this artificial environment. However, first moths were encaged on September 16 and on the following day first eggs were laid in the cages. Of the 36 females, 15 did not oviposit in the cages. Each of the remaining 21 laid from one to three batches of eggs: 12 of them oviposited on one day only, 6 laid eggs on two different days, and 3 laid on three different days. Five moths laid eggs on two consecutive days and only one oviposited on three consecutive days. Other intervals between oviposition by individual females varied from 2 to 5 days. The number of eggs laid by different females varied from 1 to 115, mean 52.43.

Males lived within the cages from 1 to 5 days, mean 2.85 days; females, 1 to 10 days, mean 4.86 days. Mean temperature during this 10-day period was 58.5 degrees F.

**Sex Ratio**

Data obtained in this investigation indicate an unequal sex ratio. Rearing records of 75 moths show an emergence of 66 percent males and 34 percent females. Comparison of these emergence records with moths captured at light traps shows a distinct preponderance of males in both cases. It is assumed that both males and females were equally attracted to the light traps. A record of the number of moths of each sex captured in light traps during the fall seasons of 1936 to 1940, inclusive, is given in table 2.

<table>
<thead>
<tr>
<th>Year</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
<th>Males Percent</th>
<th>Females Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1936</td>
<td>6,701</td>
<td>1,477</td>
<td>8,178</td>
<td>81.94</td>
<td>18.06</td>
</tr>
<tr>
<td>1937</td>
<td>4,244</td>
<td>1,914</td>
<td>6,158</td>
<td>68.92</td>
<td>31.08</td>
</tr>
<tr>
<td>1938</td>
<td>14,521</td>
<td>4,292</td>
<td>18,813</td>
<td>77.18</td>
<td>22.82</td>
</tr>
<tr>
<td>1939</td>
<td>587</td>
<td>154</td>
<td>741</td>
<td>79.22</td>
<td>20.78</td>
</tr>
<tr>
<td>1940</td>
<td>1,779</td>
<td>451</td>
<td>2,230</td>
<td>79.77</td>
<td>20.23</td>
</tr>
<tr>
<td>Totals</td>
<td>27,832</td>
<td>8,288</td>
<td>36,120</td>
<td>77.05</td>
<td>22.95</td>
</tr>
</tbody>
</table>

It will be noted that in a population of 36,120 moths 77.05 percent were males and 22.95 percent females.

**Number of Annual Generations**

During this investigation only one brood of pale western cutworm has been found to occur annually in Utah County.
Control

MOST SPECIES of cutworms may be effectively controlled by the use of poisoned bran bait. In the case of the pale western cutworm, however, baits do not give satisfactory control because this species feeds beneath the soil surface where it is impracticable to place the bait.

Cultural

According to Cook (2), Parker, Strand, and Seamans (10), and Seamans (12), (all of whom are students of this problem either in Montana or Canada) one of the most successful control measures to be used against this pest consists in preventing moths from laying eggs in summer-fallowed land. This is best accomplished by plowing the land that is to be summer-fallowed in early May at which time all cutworm eggs will have hatched and the young larvae will have begun feeding on the volunteer grain and weeds in infested stubble fields. This is desirable because, according to Seamans (12), those worms that have not fed may live in the soil for several weeks without food of any kind, and, if they have not fed before the land has been plowed they may survive until green vegetation grows up again after plowing. If they have once fed, however, and then have their food supply cut off, they soon die from starvation.

After the summer fallow has been plowed it should be kept clean from all weeds and other plant growth during the summer. This may be best accomplished with a rotary-rod weeder, supplemented by hand hoeing when only occasional weeds appear in late summer. Unnecessary cultivation should be avoided. The fields should be left undisturbed from the first of August until mid-September in order to allow any showers to form a crust on the soil-surface before the moths begin laying their eggs, and the soil should be left in an unbroken condition until after they have finished ovipositing. Rain is not always necessary, however, for this development as was noted in the Lehi-West-Hills area during the summer of 1936 when several summer-fallowed fields then under observation, had moth-repelling surface crusts form on them without rain. Animals should not be allowed to run over the summer fallow, neither should machinery nor vehicles pass over it. If this is permitted the crust will be broken and favorable places will thus be formed in which moths may lay their eggs. In fields where soil-drifting occurs, this method of preventing infestation is not wholly effective.

No cultivation nor seeding should be done in cutworm-in-
fested districts until after all *orthogonia* moths have completed laying their eggs. First moths of the season begin ovipositing about September 1, whereas latest ones to emerge may continue laying eggs until about October 25. The period of moth activity varies according to the kind of weather in different years. This suggested program of control may delay planting of fall wheat until rather late in the season. However, if serious cutworm infestation threatens, it is much safer to risk late planting than the damage likely to be inflicted by this devastating pest.

Of all the control measures that have been tried out in Utah, this has thus far proved most practical and efficient. It is based upon the fact that these moths select smooth, loose soil in which to lay their eggs and are repelled by other ground conditions. Any land that has been recently cultivated or that is being cultivated during the annual oviposition period of these moths provides ideal conditions for their egg-laying, and, in consequence, cutworm infestation of such fields during the next spring and summer is proportional to the number of eggs laid.

**Irrigation**

In June 1936, a patch of potatoes and a few acres of corn were being damaged by pale western cutworms on a farm at American Fork. In an effort to stop this injury the infested land was thoroughly irrigated. Following the irrigation many dead and dying worms were found on the ground and further damage to the crops was negligible. Cook (2) states that in Montana irrigation had been reported as an effective control measure against this pest wherever infested soil could be saturated with water during the early larval stages. Following irrigation the insects appeared to be more susceptible to certain diseases which kill them.

**Moth Trapping**

Most species of night-flying moths are attracted to lights. This is also true of the *A. orthogonia* species. For the purpose, chiefly, of ascertaining the duration of the annual period of adult activity in Utah, 5 light traps were operated in the Lehi-West-Hills and Cedar-Valley areas during each of the autumns from 1936 to 1940, inclusive.

A secondary objective of this study was to learn whether or not light traps might prove a practical means of controlling this pest by destroying great numbers of ovipositing moths. The average number of moths caught per trap during the annual flight period for each of these 5 years was 1,445. This number, however constituted only a fractional part of the total moth population present in the vicinity of the light traps.
Another factor adversely affecting the practicality of light trapping as a control measure is the large acreage of nearby uncultivated lands upon which grow many host plants (chiefly Russian-thistle) of the pale western cutworm. Costs of operating sufficient light traps with which to obtain adequate control of this pest over such a large area would be prohibitive.

Weather

Of the natural factors influencing cutworm abundance, perhaps the most important one is weather. Heaviest infestations accompanied by most severe damage to dry-land grain have occurred either during periods, or following years, of subnormal rainfall. Wet weather during the egg-laying period of the moths (September and October) reduces the number of eggs laid. A rainy spring season, especially during April, May and the first half of June when the larvae are feeding underground, affects them adversely. Rains at this time, if sufficiently heavy, drive the cutworms to the surface of the ground where they are attacked by several natural predators, parasites, and diseases. Rains apparently encourage the development and spread of certain, and as yet undetermined, fungous and/or bacterial diseases which apparently constitute a factor in the natural control of this insect pest. After spring rainstorms in the area where these investigations have been made, numerous dead cutworms have been frequently found in infested fields, both on and under the surface of the soil. Evidently they had been killed by disease.

Seamons (12) after studying the relation of weather to outbreaks of pale western cutworms in Canada and Montana indicated that the intensity of infestation by this pest in any particular year is correlated with the number of "wet" days that occurred during the preceding May and June. He says that:

since weather plays such an important part in the activity of the larvae and their control by natural enemies, it can be utilized to determine whether there will be an increase or decrease during the following year. One-quarter of an inch of rainfall is sufficient to bring the cutworms to the surface of the ground... It has been found that when the fields are too wet to use a disk harrow the cutworms are likely to be on the surface, and a day with the soil in such a condition, whether raining or not, must, therefore, be considered a 'wet' day in forecasting. When it is not actually raining an observation in the field will be required to determine the moisture condition of the soil and whether or not it could be disked easily... If weather conditions, and especially the soil moisture, are observed during the period in which the majority of the cutworms are active and feeding, a forecast of the probable conditions for the next season can be quite accurately made by using the following method:

If there are less than ten 'wet' days during the period of larval activity, there will be an increase in the number of cutworms the following year.
If there are between ten and fifteen such days during the period of larval activity, there will in all probability be some decrease in the numbers of cutworms the next year.

If there are more than fifteen ‘wet’ days during the period of larval activity, little trouble may be looked for from this insect the following year.

Natural Enemies

Natural enemies observed attacking *A. orthogonia* in Utah during some stage of its development included various species of arachnids (spiders), predatory and parasitic insects, and birds.

*Arachnids.* The following species of spiders were observed to capture and feed upon cutworm moths in the Lehi-West-Hills area:

*Phidippus* spp.², (Attidae) and *Xysticus* sp.³, (Thomisidae). The spiders were observed to conceal themselves among the blossoms of rabbitbrush where they would sit and wait for the approach of a moth. When the latter came within reach it would be seized and fed upon by the spider.

*Insects.* Four species of predacious insects that were seen to capture and feed upon the moths when they came to rabbitbrush blossoms are: *Litaneutria minor* (Scudd.) ⁶, (Mantidae); *Leptoglossus clypealis* Heid.⁷ (Coreidae); *Sinae undulata* Uhl.⁷ (Reduviiidae); and *Phymata pennsylvanica americana* Mel.⁷ (Phymatidae).

Twenty-four dipterous pupae were dissected from dead cutworm pupae during the summer of 1936. The former had probably pupated about the same time as the cutworms or soon afterward. The dipterous pupae were reared to the adult stage in the laboratory during the winter of 1936-37. Under natural conditions they probably would have emerged in the spring of 1937. One of the reared specimens was identified as *Gonia longiforceps* Tolllill⁸, (Tachinidae) whereas, all of the other specimens were thought to represent a form near *Gonia aldrichi* Tolllill⁸.

Nine other tachinids (*Bonnetia compta* (Fallen))⁸ were found in a rearing cage in which pale western cutworms were being grown to maturity. Positive evidence is lacking as to whether or not these parasitic flies emerged from the cutworm larvae. It it highly probable, however, that they did, inasmuch as they emerged within the cage. Cook (2) previously reported this tachinid to be parasitic on *Agrotis orthogonia* larvae.

² Identified by Irving Fox, U. S. National Museum.
³ Identified by A. B. Gurney, U. S. National Museum.
⁴ Identified by H. G. Barber, U. S. National Museum.
⁵ Identified by Prof. H. J. Reinhard, entomologist, Tex.:s Agr. Exp. Sta.
Birds. The desert horned lark, *Otocoris alpestris leucolaema* (Coues), western vesper sparrow, *Pooecetes gramineus confinis* Baird, and the California gull, *Larus californicus* Lawr., have been observed eating pale western cutworms. The desert horned lark and western vesper sparrow seem to be particularly adept in locating these subterranean larvae and digging them out with their bills. The California gull follows plows and other farm implements while in operation on the land and devours the cutworms that are brought to the surface.

Summary

The pale western cutworm has periodically caused damage to dry-farm grains in Utah during the past 25 years. Because of the enormous numbers in which they appear during outbreak years, these insects are one of the most serious periodic pests of dry-farm grains in Utah.

This cutworm feeds beneath the soil surface, except for a short period immediately after hatching and during times of heavy rainfall. Here it attacks main stems of grain plants eating only a small portion of each plant, which accounts for the serious damage sometimes inflicted.

This pest overwinters in the egg stage in the soil. Time of hatching usually occurs about March 1 or soon after the snow disappears from infested land. The larvae attain a length at maturity ranging from 1¼ to 1½ inches.

The cutworm normally reaches maturity from about June 1 to 15. Upon completion of its feeding, it burrows into the soil from 3 to 5 inches deep where it forms an earthen cell. It remains here until the adult stage is attained, about September 1.

Adult moths vary from dark-gray to yellowish-gray with a wing expanse of from 1 to 1½ inches.

Moths live only a few days during which time mating and oviposition occurs. Egg-laying begins about the first of September and is usually completed by the middle of October. There is but one generation annually.

After a grain crop has become infested with pale western cutworms there is little or nothing that can be done to prevent damage in that particular crop, and if there are more than 15 to 20 worms per square yard, it is highly probable that the crop will be entirely destroyed.

Control consists in preventing the moths from laying eggs in summer-fallowed land because female moths select only loose soil in which to lay their eggs. Land that is to be summer fallowed
should, therefore, be plowed early in the spring and kept clean-cultivated during the summer. All cultivation should be discontinued by about August 1st in order that a crust may form on the surface of the soil before the moths begin laying eggs. Moths cannot lay eggs in surface-crusted soil.

Poison baits are impracticable because of the subterranean feeding habits of orthogonia cutworms.

Effective destruction of the egg-laying moths by means of light traps was found impractical.

Weather is the most important natural factor influencing cutworm abundance. Wet, cold storms during the annual egg-laying period (September 1 to October 15, approximately) of female moths seriously interfere with oviposition. A rainy spring season results in a heavy mortality of the larvae.

Although parasitic and predacious insects and birds destroy many larval and adult forms of Agrotis orthogonia yet, when this pest occurs in outbreak numbers, the effect of these natural enemies is inadequate to provide substantial control.

**Literature Cited**