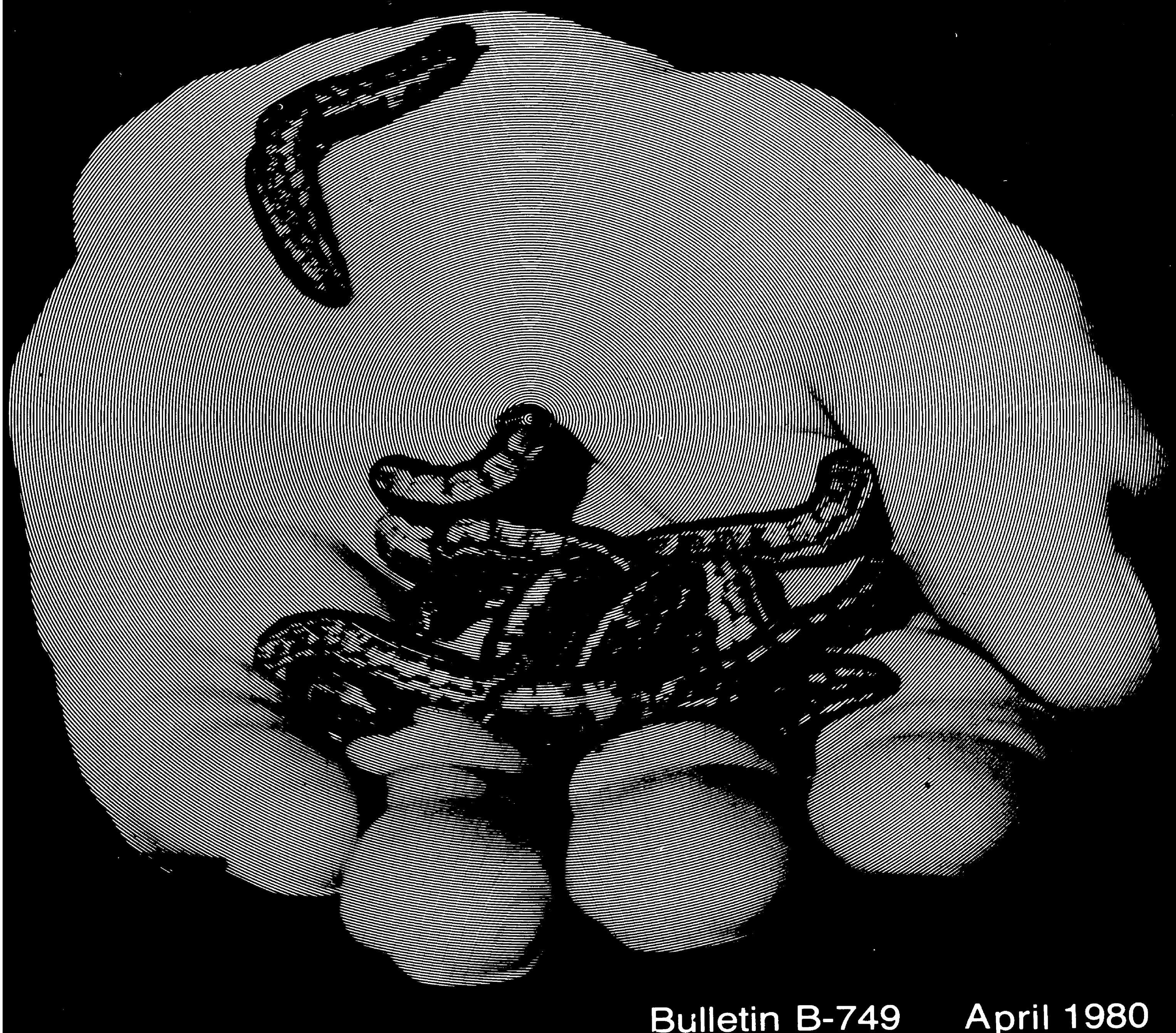
The Army Cutworm



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Introduction

The army cutworm, *Euxoa auxiliaris* (Grote), has been an important agronomic pest since the late 1800's. It is a sporadic pest that occurs in some years in unbelieveable numbers but never occurs in any one area in large numbers on a regular basis. However, the pest usually occurs in large numbers every year somewhere within its range. Therefore, we need not concern ourselves with this pest often, but during certain outbreak years when conditions are favorable we must be aware that it can devastate large acreages; 1976 was such a year. In Oklahoma alone, an estimated 2,500,000 acres were treated for army cutworm control. Overall populations and damage in 1976 were the heaviest recorded in 22 years of survey records (USDA 1951-1975, USDA 1975-1979). Obviously, the army cutworm has not succumbed to modern control or farming techniques and still poses a significant threat.

Thus, this paper has been prepared to describe this insect's potential destructive capabilities. In doing so, we have tried to cover, although sometimes briefly, most facets of the insect's existence. We have attempted to include most of the major papers and reports dealing with the army cutworm. Many brief reports and survey reports exist that only mention the army cutworm. Since the list is extensive, we have included only the ones that contribute unique or valuable information. We also hope that this paper compliments and even apotheosizes the work of the investigators who have, through the years, added to and developed the background for the paper that follows.

[1]*Euxoa auxiliaris* (Grote). Lepidoptera: Noctuidae. This paper reports the results of our literature survey and research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.

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A Brief Life History

The army cutworm is a univoltine species; i.e. there is only one generation per year. The insects spend the winter as immature larvae. In the spring the larvae feed and complete their development. It is during this time that most of the economic damage occurs. The larvae will feed on practically anything. Economic hosts are wheat and other upland small grains, alfalfa, native pastures, corn, sorghum, sugarbeets, sunflowers, sweet clover and vegetables. When growth is completed in the spring the larvae build cells a few inches below the soil surface and pupate. Moth emergence usually occurs in May or June and the majority of the adults emerge during a very short period. Numerous moths occur following an outbreak year and they may seek shelter in buildings, where they can become a nuisance. Shortly after emergence in the Great Plains, the moths migrate to the Rocky Mountains where at the higher elevations they escape the hot summer temperatures. Here they feed actively until late summer or early fall. In the fall they return to the plains. Shortly before or during their return flight, mating and egg development occur. The reproductive capacity is high; each female lays 1000-3000 eggs. Eggs are laid in the soil and vegetation in the area does not appear to be necessary for oviposition. Moisture is required for the eggs to hatch. Larvae feed entirely above the soil surface but spend non-feeding periods below the soil surface.

Distribution

Because of the army cutworm's migratory and estivation habits, distribution is directly connected with the Rocky Mountains. Walkden (1950) stated that the species was distributed throughout the semiarid region of the Great Plains, sometimes extending its range to Eastern Kansas, and that the larvae had not been recorded east of the Mississippi River. Previously, Crumb (1929) also stated it had not been found east of the Mississippi River but, except for those states joining the river on the west, it occurred throughout the remainder of the Western United States. Crumb also remarked that the species was especially injurious in the Rocky Mountains and adjacent areas of both the United States and Canada. Since 1929, the pest has been reported in all the states west of the Mississippi River except Louisiana. It has been reported east of the Mississippi River in Illinois (Hardwick 1970) and in Michigan (see map, USDA 1977), but probably as rare migrants. Based on these reports, other literature reports, and the accumulated county record map of the U.S. (USDA 1977), the probable distribution pattern is depicted in Figure 1.

In Canada, Strickland (1942) maintains that the army cutworm is widespread throughout Alberta and quite numerous as far north as the Peace River District. Beirne (1971) says that it is most important as a pest in southern Alberta, of lesser importance in southern Saskatchewan, and only rarely of any importance in Manitoba and Ontario. Hardwick (1970) posted numerous Canadian specimen examination records, including one at Fort Smith, Northwest Territories. In spite of these reports, distribution records were not as adequate for Canada as they were for the U.S. Therefore, when

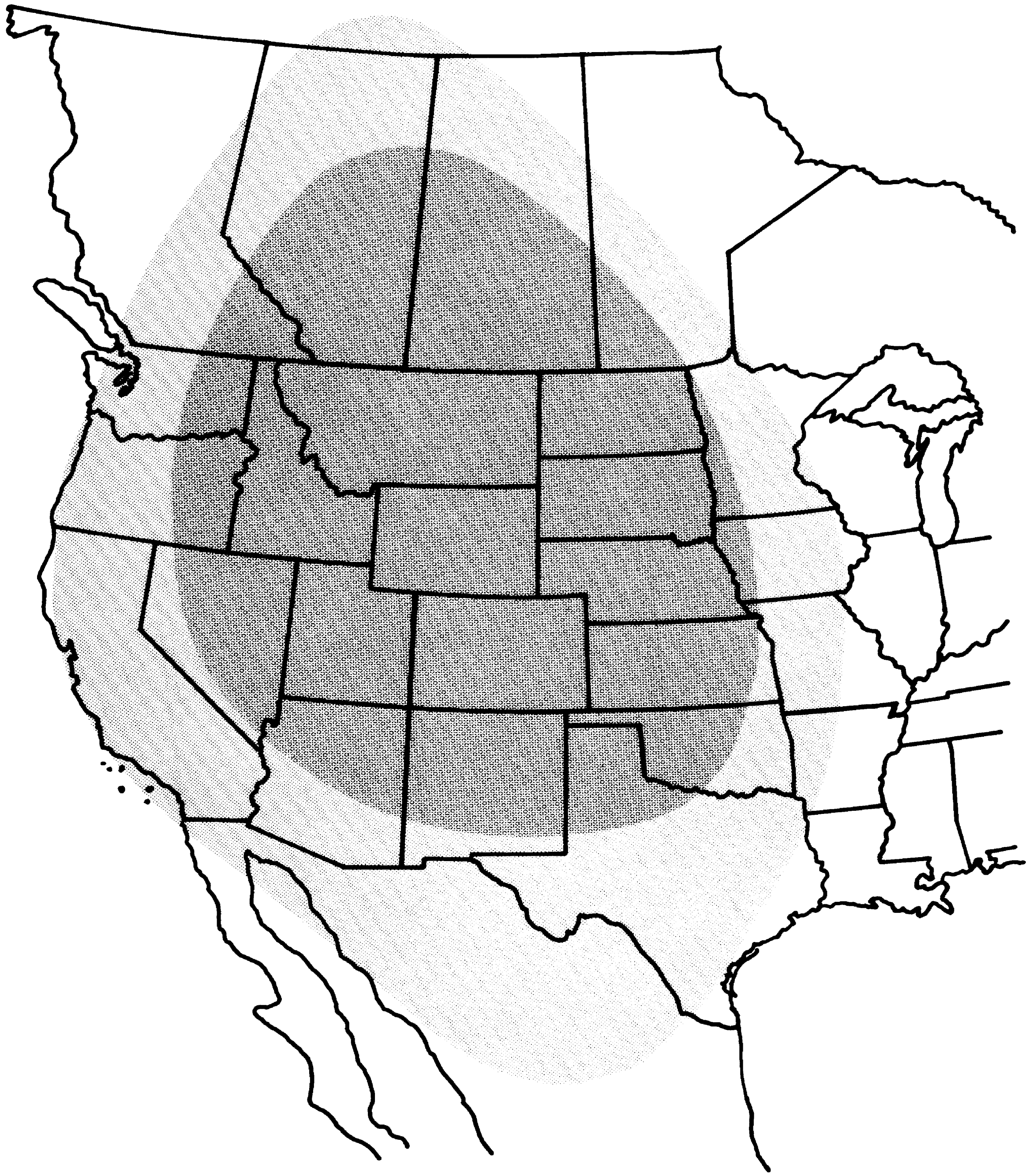


Figure 1. Distribution of the army cutworm in North America. Lighter shaded area indicates the probable maximum range (see Distribution section). The darker shading represents the area where possible outbreaks could occur (see Outbreaks section).

the distribution pattern map (Figure 1) was devised, all available reports were used and extrapolations were made of the U.S. pattern width where it stops at the Canadian-USA boundary.

The pattern for Mexico is extrapolated from the records from southern Texas and southern California and one report of a specimen examined from Laredo, Durango, Mexico (Crumb 1929).

There may be some locations outside the Fig. 1 distribution pattern where the army cutworm has been detected of which we are not aware. We do know that there are numerous counties within the pattern where the pest has not been reported (USDA 1977).

Outbreaks

Outbreaks of the army cutworm occur somewhere each year, depending on the definition of an outbreak. Beirne (1971) states that the first reported outbreak in Alberta in 1915 covered 3000 square miles. In the United States, at times, entire states are covered. Certainly heavy infestations with some economic damage take place annually somewhere, though it may be in only a few isolated fields. This can be seen when examining the USDA Cooperative Economic Insect Reports (1951-1975) and its replacement publication, the Cooperative Plant Pest Report (1975-1979). The reports in these documents are much too extensive to be included here but we have used them in preparing the map in Figure 1 to depict the possible outbreak areas of this pest. The outbreak area is based on reports of actual damage, not just detection of the insect. The outbreak area in Canada was less documented and was developed mainly from extrapolation of the U.S. pattern.

The long-range population incidence for a particular area includes years of abundance and more years of scarcity. Beirne (1971) says that each outbreak year was usually immediately preceded by one or more years in which the species was scarce and followed by one in which it was more than average in abundance. The yearly pattern for Oklahoma for the past 22 years (Figure 2) may show the opposite, since the outbreak is preceded by an abundant year or two and followed by years of scarcity. The pattern in Figure 2 was developed by assigning arbitrary values (20 larvae/sq. ft. = heavy, 10 = moderate, 5 = light, and 0 = no infestation) to the six crop reporting districts in the northwest part of Oklahoma. All the district values were totaled for an annual value, which was plotted by year in Figure 2. The 22-year data on which this figure is based come from the Oklahoma Cooperative Economic Insect Survey and Detection Report and from the Oklahoma Survey Entomologist (D. C. Arnold, personal communication).

Figure 2 might suggest an outbreak on a six-year basis, although there are deviations in the trend. Beirne (1971) states that the first three outbreaks in the Prairie Provinces of Canada (1915, 1926, 1937) were separated by 11-year intervals but the regularity did not persist and is probably coincidental. He mentions that the subsequent chief outbreak years were 1941, 1955 and 1963. He does not include the less serious outbreak years but only those that were very extensive.

Normally two outbreak years do not occur in succession. Walkden (1950) states that during his investigations of this species, outbreaks never occurred in two successive years. Strickland (1916) and Cooley and Parker (1916) also made this statement. However, Seamans (1928) speaks of the 1926 and 1927 outbreaks as the first of any

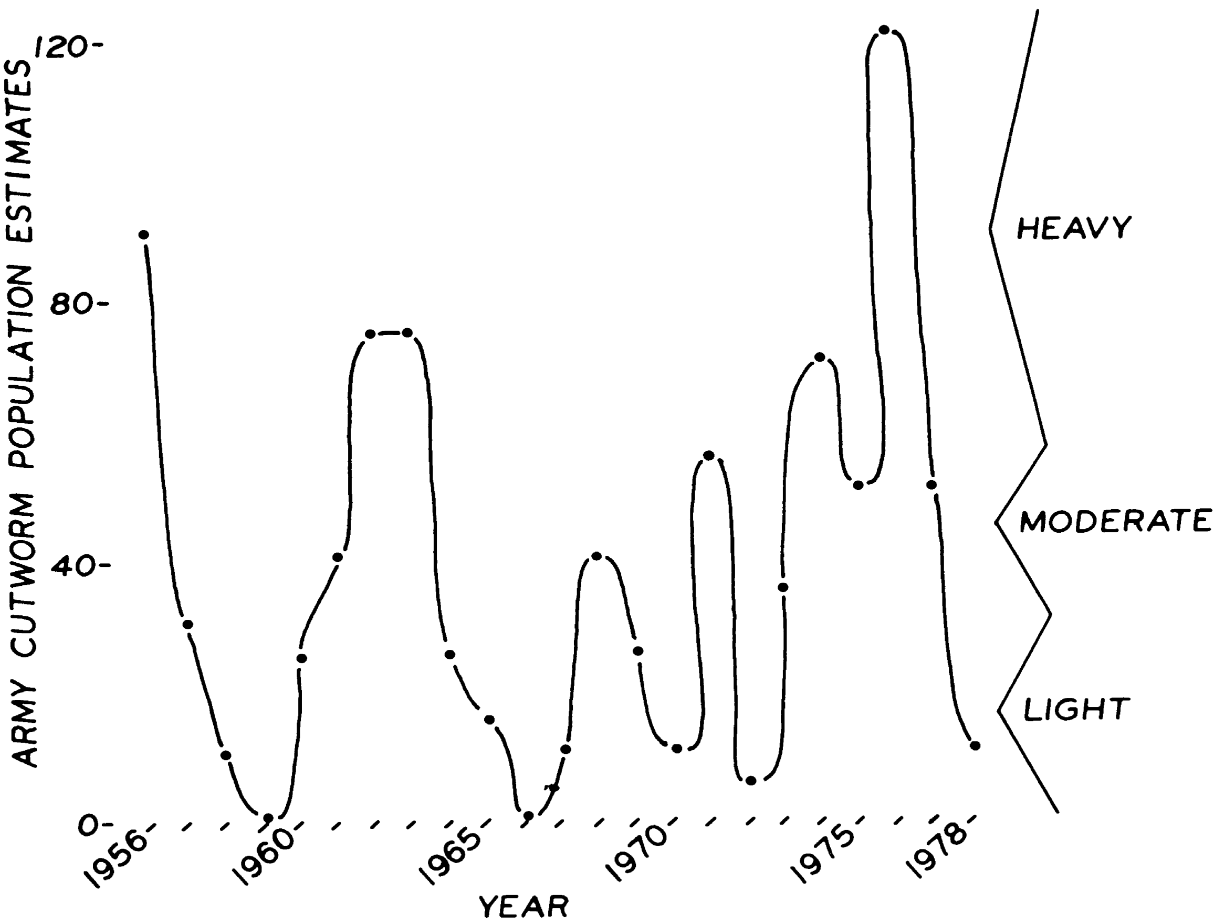


Figure 2. Yearly population estimates of the army cutworm in Oklahoma (see Outbreaks section).

magnitude that continued for two years in succession. Dean and Smith (1935) noted that more or less extensive outbreaks occurred during the springs of 1925 and 1926 and Strand (1932) noted that the insect had been much more abundant in 1931 and 1932 than during the preceding 10 years. These instances are rare, however, and are probably the exceptions.

Why no two successive outbreak years occur has apparently not been solved. Several authors (Johnson 1905, Strickland 1916, Snow 1925, and Walkden 1942) have attributed less frequent outbreaks and reduction of populations to natural enemies such as parasites, diseases, and predators. However, others credit climate. Strickland (1942) speculates that since eggs need moisture to hatch and two wet falls in succession are unusual, outbreaks in succession also are rare. Seamans (1928) says that "western climate and yearly weather conditions indicated that optimum moisture and temperature for army cutworm increase is so far from the average climate that outbreaks cannot be frequent or of long duration." He then proposes that outbreaks can satisfactorily be predicted based on weather conditions. He states that outbreaks are apparently a result of a hot July with less than 1½ in. of rainfall followed by a total precipitation for August, September, and October of over 4½ in. Thus far, it has been difficult for us to make this correlation with our limited data for the Oklahoma area.

Weather Effects

Beirne (1970) has reviewed the literature and discussed the effects of precipitation on crop insects. He mentions the army cutworm several times. Beirne states, "Precipitation can be, and often is, a major factor in regulating the amount of damage caused to annual crops by insect pests." He also states, "The chief way by which pests are affected through their food plants by precipitation is that inadequate moisture can aggravate the effects of pest attacks by retarding plant growth and development." We will discuss this point in terms of army cutworm damage in another section. Some other effects of precipitation that Beirne mentions could apply easily to the army cutworm although some were and some were not discussed for this particular pest. These are: Drowning in low-lying areas; destruction of estivating adults; forcing larvae to the surface of the soil where they are exposed to attack by predators and parasites; reduction in growth, during dry periods, of native plants on which they feed; production of conditions favorable to the rapid increase of fungal and other diseases; production of conditions favorable (or unfavorable) for parasitization; and others.

Seamans (1928 and 1934) discusses the effects of weather on the army cutworm. He states that first instar larvae are very subject to being killed by desiccation and that high moisture during August, September, and October ensures good egg hatch and larval survival. Beirne (1970) mentions Seamans' (1928) attempt at forecasting outbreaks of army cutworms based on weather conditions. Beirne says that "there does not seem to be sufficient information to enable pest situations to be forecast reliably." One reason is that the timing is so critical. For example, Beirne reports for one particular insect, wet was harmful in two ways and beneficial in two, and dry was harmful in four ways and beneficial in at least one. Therefore, Seamans' forecasting procedures may not be timed critically enough or consider enough factors to separate detrimental and beneficial effects of climate.

Species Determination

The group of species to which *E. auxiliaris* belongs has presented problems of separation from the beginning (Wolley-Dod, 1905) and as new species were described the problem has become even more complex. It is a very large group. According to Hardwick (1970) the group will eventually include some 200 species. Hardwick outlined the problem of separation by saying, "The genus *Euxoa* is notable for the extreme variability of its constituent species. Probably no other genus of Noctuidae exhibits such a high degree of intraspecific variability which is often coupled with an amazing lack of structural characters by which species may be distinguished." Hardwick also said that the more common species usually show the greatest intraspecific variability. Further, he stated that the most probable cause of all this confusion is that the genus is presently in a state of evolutionary mutability. This is a good summation of separation problems experienced by all taxonomists who have worked with this group. For example Wolley-Dod (1911, 1918), who first worked with the *E. auxiliaris* complex, found that some forms, then thought to be species, could be reared from the same parent. Cook (1930a) helped to clear up the complex. He referred to "untangling the systematic puzzles involved in our cutworm studies." In 1950, McDunnough worked with the *Euxoa* group and stressed the use of female genitalia as a means of specific separation of the complicated genus. Hardwick (1970), however, bases his keys on the male genitalia. Walkden (1950) developed a larval key to important species of cutworms, armyworms, and related species attacking cereal and forage crops but, of course, incidental species could not be included. Crumb (1956) was unable to develop a satisfactory key to the species of larvae of the *Euxoa* group and wrote about strong tendencies toward uniformity in coloration and structure throughout the group. Martin and Cotner (1934) stated that their precipitin reaction is useful in determining phylogenetic relationships between genera and subfamilies of the family Phalaenidae.

Several Canadians have tackled the taxonomic problems of *Euxoa* using a number of different approaches. Some of these approaches were: egg microstructure (Hudson 1973, Salkeld 1975); electrophoresis of egg proteins and seriological relationships between egg antigens (Hudson 1973); and life history and biology (Hinks and Byers 1976). At this point, no one area has proven superior, but each seems to contribute, and perhaps the proper combinations will eventually be found.

A partial synonymy of the *Euxoa* group follows, based entirely on the complete synonymy listed by Hardwick (1970). He divided the group into six subgenera that had previously been considered as valid genera by many workers. One of these is *Chorizagrotis,* the genus that contained *E. auxiliaris,* the army cutworm. This is pointed out to the reader because, prior to Hardwick's work, the army cutworm had been found in the literature since about 1890 under *Chorizagrotis auxiliaris.* Names used from 1873 to the present time were:

1873. *Agrotis auxiliaris* Grote, *Bull. Buffalo Soc. Nat. Sci.* 1:96.
1875. *Agrotis introferens* Grote, *Proc. Acad. Nat. Sci. Philad.* 27:423
1877. *Agrotis auxiliaris* var. *agrestis* Grote, *Bull. U.S. Geol. and Geographical Surv. of the Terr.* 3:118.
1890 *Chorizagrotis auxiliaris;* Smith, *Bull. U.S. Natn. Mus.* 38:100.
1890 *Chorizagrotis introferens;* Smith, *Bull. U.S. Natn. Mus.* 38:100.

1903 *Agrotis introferens;* Hampson, *Cat. Noctuidae British Mus. London* 4:311.
1903 *Euxoa agrestis;* Hampson, *Cat. Noctuidae British Mus. London* 4:313.
1904 *Euxoa introferens;* Smith, *J. N. Y. Entomol. Soc.* 12:99.
1905. *Chorizagrotis inconcinna;* Wolley-Dod, *Can. Entomol.* 37:50.
1905. *Chorizagrotis terrealis;* Wolley-Dod, *Can. Entomol.* 37:51.
1915. *Euxoa auxiliaris* ab. *tegularis* Strand, *Arch. Naturgesch.* 81A12:144.
1917. *Chorizagrotis auxiliaris introferens;* Barnes and McDunnough, "Check List of the Lepidoptera of Boreal America." Decatur. I11:44p.
1924. *Chorizagrotis auxiliaris* form *tegularis;* Draudt, *Die Gross-Schmetterlinge der Erde.* Stuttgart. 7:50.
1930. *Chorizagrotis auxiliaris* form *montanus;* Cook, *Can. Entomol.* 62:149.
1938. *Chorizagrotis auxiliaris* form *agrestis;* McDunnough, *Mem. So. Calif. Acad. Sci.* 1:61.
1970. *Euxoa auxiliaris;* Hardwick, *Mem. Entomol. Soc. Can.;* 67:77-84.

Needless to say, positive identification of the army cutworm could certainly be hazardous. However, for the economic entomologist this may not be a serious problem in that certain behavioral characteristics of the species can be helpful. At least in the southern Great Plains, large larval populations on wheat or alfalfa during the late fall, winter, and early spring months would, more than likely, be *E. auxiliaris.* Incidental species could possibly be confused during spring moth flights but large spring flights of cutworm moths would probably be the army cutworm.

Hardwick (1970) states that *E. auxiliaris* occurs sympatrically with *E. inconcinna*, from which it is difficult to distinguish on external features. He indicates that *E. inconcinna* may also have the same migratory habits, and that the species probably occurs from Colorado southward. He did not mention population numbers or if this species occurs on economic hosts or in economic numbers. Wolley-Dod (1918) made a similar statement in reference to distinguishing this species: "I have little faith in the distinctness of *inconcinna*, but must let that stand for the present."

The Eggs

Description

Good descriptions of *E. auxiliaris* eggs are given by Strickland (1916), Cooley (1916), and Crumb (1929). In short, the egg is slightly flattened, when viewed from the side, so that it is wider than high, that is, about 0.6 x 0.43-0.52 mm. The upper portion of the egg has a definite reticulation with the pattern radiating from the micropylar region. When laid, the egg is white to yellow and darkens during embryonic development from gray to brown. Just prior to hatch the fully formed embryo is visible through the chorion, giving the egg a bluish-black appearance.

Oviposition

All oviposition is in the fall. Moths were observed laying eggs by Cooley (1916), who describes the process and conditions in detail. To his suprise, the eggs were being laid directly upon the soil in freshly plowed fields, not on plants as had been expected. Egg laying was confined to the warm afternoons with most activity from 3 o'clock until sunset. The moths walked or flew along the surface of the soil and the eggs were placed on the surface. Sometimes the moths tucked the eggs beneath clods. One or two eggs were usually laid at each location. If the soil were pulverized some of the eggs were laid just beneath the surface. Eggs were difficult to find in the field because of adherent soil particles. Temperature during oviposition generally ranged from 12.8° to 21° C. Egg laying ceased at about 4.4° C.

Apparently army cutworm adults will lay their eggs on barren soil and no plants in the area seem to be required. This might help to explain the susceptibility of fall planted alfalfa and why late planting of small grains is not an effective control procedure. However, some ovipositional preference for some crops has been shown (see section on Host Plants). Since moisture is required for hatch, germination of seed and egg hatch probably coincide to some extent, providing food for the new larvae. Females lay about 1000-3000 eggs each, a large factor contributing to the outbreak potential of this species.

Evidently, the period of oviposition can extend from late summer until early winter. Light trap collection reports (mostly from Kansas and Nebraska) (USDA, Coop. Econ. Ins. Reports 1972-75), show that some collection dates extend from late August until late October. Light trapping reports usually terminate about this time although some army cutworm moths are still being caught. The reports are, in general, too sketchy to determine any trends that might occur. Evidently, eggs can be deposited and will hatch throughout this period. This could be an explanation for the large variation in larval size and development usually found in the field. Small mid-summer flights are recorded in North Dakota, South Dakota, Minnesota and at Mesa, Arizona. These moths are probably in the pre-oviposition stage (no developed eggs). Cooley (1916) recorded the last of the emerging moths in Montana during the middle of July.

The Larvae

Description

Walkden (1950) prepared a key to the larvae of cutworms and armyworms most likely to be encountered in the central Great Plains. He admitted, however, that many species of cutworms resemble each other so closely that structural characters for distinguishing them are difficult to find. Crumb (1956) had the same problems and was unable to develop a satisfactory key to the species of larvae in the *Euxoa* group. For extensive descriptions of the larvae see Strickland (1916) and Crumb (1929). These descriptions and Walkden's key generally describe the larvae as follows: Newly hatched larvae are 1.5-2.7 mm long, light cream colored, with a shiny black head; the body of a mature larva is about 40 mm long. General color is a pale grayish, much splotched with white, the dorsal area is usually somewhat paler than the subdorsal areas. There is usually a narrow pale mid-dorsal stripe (see Figure 3). An indistinct band of white splotches occurs just below the spiracles. The head is light brown with small dark brown spots. The claws on the legs bear a very distinct basal tooth, and setigerous tubercle II of the abdominal segments is distinctly more than twice as large as tubercle I.

The means of identifying larvae that should not be overlooked is their seasonal occurrence which, of course, in the case of *E. auxiliaris* is very distinctive (see section: Species Determination).

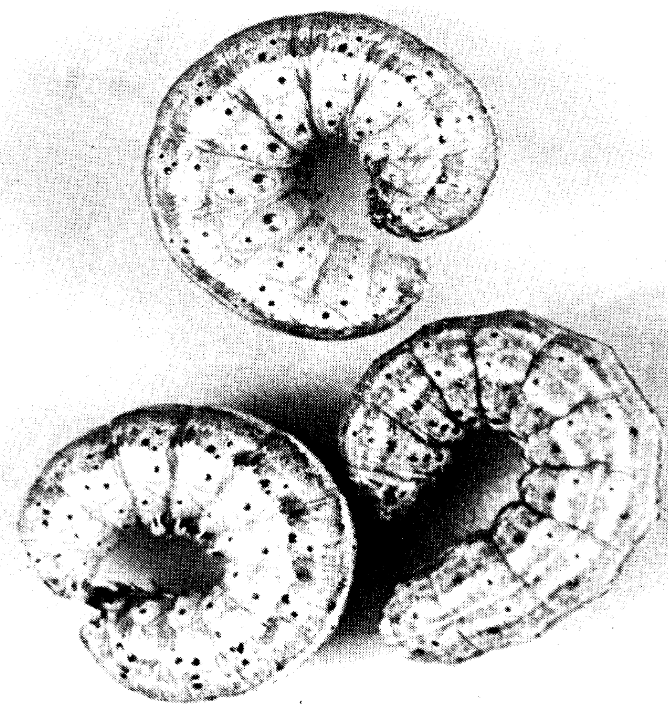


Figure 3. Large army cutworm larvae, showing typical markings.

Walkden (1950) recorded seven molts by the larvae before pupation and listed these stages, their duration, and the width of head capsule for each instar:

Instar	Period (days)	Width of head capsule (mm)
First	16-48	0.30
Second	13-73	0.40-0.50
Third	4-70	0.50-0.80
Fourth	3-42	0.75-1.10
Fifth	6-11	1.10-1.65
Sixth	4-18	1.50-2.50
Seventh	9-25	1.90-3.00

Seasonal Occurrence

During the winter of 1978, while searching for army cutworm larvae in a wheat field, we noticed that many had crawled upon clods and were evidently sunning themselves, since all larvae were on the side of the clods facing the sun. The temperature was about 10° C., with a wind blowing from the south at about 10 mph. Aggregations of the larvae were common with up to 12 larvae occurring intertwined or positioned very close to each other. This habit made collection of larvae simple and on December 15, 100 larvae were collected and on December 26, 150 were collected, both within a few minutes. Similar collections were also made in February and March. As daytime temperatures increased, the larvae remained beneath the soil.

There are exceptions (Daniels 1964), but usually the army cutworm does not make itself known until spring even though all of the eggs hatch in the fall. In the fall the young larvae are very small, dark colored and very difficult to find. Cooley (1908) says they hide in the crown of wheat and nearby soil but do not avoid the light as do older larvae. The small larvae pass the winter hibernating beneath the soil. Neither snowfall nor frozen soil seems to have any effect on them. When larvae were collected from beneath the snow they warmed to a very active state within a few minutes (Cooley 1908). As the weather warms during the day in late winter and spring, the larvae resume their feeding and growth. Cook (1927a) has shown, in the laboratory, that alternating temperatures may help maintain an accelerated growth rate. Sudden low temperatures during the spring development seemed to have no permanent effect on the larvae. During the 1933 outbreak in Kansas, March 20 temperatures dropped to -25.5° C but the larvae later reduced the wheat crop by 75% (Smith 1934). Hinks and Byers (1976) indicated that development can probably be suspended in any instar at the onset of unfavorable low temperatures. It is common for several instars to occur in a field simultaneously. This may be partly due to widely different dates of oviposition and hatch (see section on Oviposition).

During some years mild weather extended into or throughout the winter in Oklahoma promoting good larval growth much earlier than usual. This was true of the fall-winter seasons in Oklahoma during the 1975-76 outbreak of army cutworms. Fully developed larvae were found as early as the middle of February. In spite of this abnormally advanced growth, the actual life cycle did not appear to be accelerated since the first pupa was not found until April 5 and the first moth a month later. It is probable that this univoltine species has other means of controlling its developmental time. Then again, cold soil temperatures (Figure 4) could have extended the prepupal and pupal periods. In spite of any delayed development that might have occurred, the cycle was still a month to two months ahead of that found in Canada, the northern more colder areas of the insect's range (Strickland 1916). Crumb (1929), in contrast, recorded mature larvae in the latter part of January in southwestern Texas. He collected moths in small numbers at the beginning of March but they then extended their emergence into May.

Feeding Habits

The army cutworm feeds entirely above the soil surface and was classified by Walkden (1950) as one of the surface feeding cutworms. Strickland (1916) and other writers have noted that, unlike many other cutworms, it has never been observed to attack a plant from below the surface of the soil. This is unique considering it spends much of the time beneath the soil surface. When food is scarce, it will sometimes follow the plant on which it is feeding down into the soil, but otherwise, the larvae feed above ground. As to plant parts, larvae prefer the leaves and only eat stems and other parts when food is scarce.

Feeding occurs from late afternoon until dark on most days. The fields during midday may appear rather normal although a heavy infestation may be there. When food is plentiful and the temperature is relatively high the larvae hide under clods and in the soil during hours of bright sunshine. Occasionally, burrowing holes may be seen in moist, tight soil. Even under fairly heavy infestations, surface activity may be hard to detect. But when food is scarce and on dark cloudy days, the larvae often feed both day

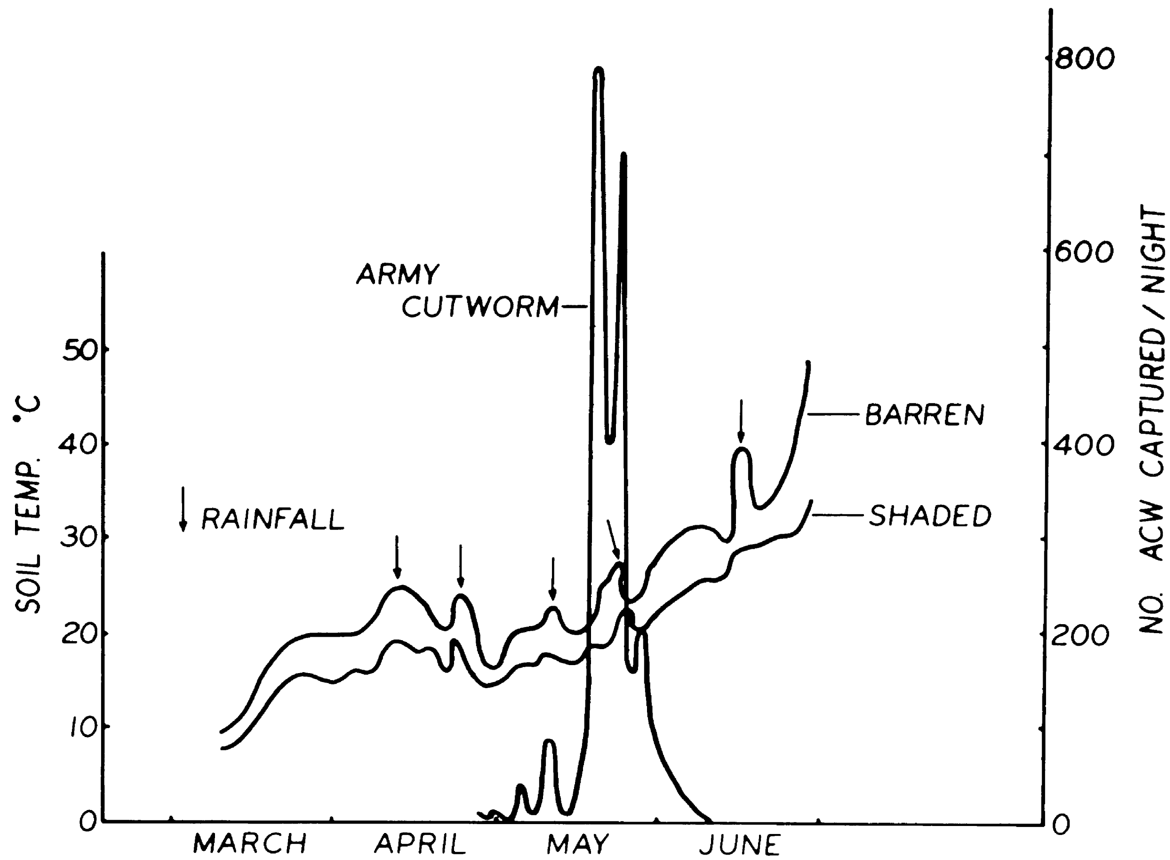


Figure 4. Army cutworm emergence in relation to soil temperature and rainfall.

and night. The simplest, most effective way to determine the presence of larvae, especially in pliable soil, is to run the fingers through the upper two inches of soil between the rows and around the plants. This stirring action will expose many of the larvae.

Host Plants

In 1908 Cooley observed that army cutworm larvae fed upon a wide range of plants and did not refuse to eat any kind of food placed in their cages. In 1910 he stated: "We do not consider any crops, with a possible few exceptions, are free from them." Strickland (1916) agreed by saying, "The army cutworm will feed upon practically all green growth." Wilcox (1898) was actually the first to realize the wide range of food plants and the army cutworm's "by no means fastidious tastes." He listed over 40 host plants and remarked that their diet is not even confined to green plants, and that he found them eagerly devouring dry grain stubble and the exposed dry roots of various weeds. Strickland (1916) extended the host list to 51 and Crumb (1929) also created a list. The three lists are combined below, and other host plants we have noted in the literature have been added:

Alfalfa, apple, apricot, avens (*Geum triflorum* Pursch), *Balsamorhiza sagittata* (Pursch) Nutt., barley, little barley, beet, blackberry, blue joint, bluegrass, bromegrass, buffalograss, cabbage, cactus, celery, cherry, clover, corn, currant, dandelion, flax, fruit trees, gooseberry, dry grain stubble, gramma, prairie grasses, horseradish, lamb's quarters, larkspur, lupine, maple seedlings, all mustards, oat, onion, peas, peach, plum, potato, prune, radish, raspberry, redtop, rhubarb, Russion olive, rye, willow sage, sanfoin, shepherd's purse, stinkweed, strawberry, sugar beet, sunflower, sweetclover, thistle, timothy, tomato, turnip, all vegetable crops, vetch, dry weed roots, and wheat.

It appears that these host records were made in the northern areas of the Great Plains and the list could probably be expanded by including a study on the host range of the pest on more southerly plant species.

Although army cutworms feed on practically everything, a few preferences have been noticed. Strickland (1916) stated that all weeds, particularly tansy mustard and stinkweed, were completely consumed before fall wheat and tumbling mustard were attacked. We have also observed larvae feeding heavily on treacle mustard, *Erysimum repandum L.*, that was growing immediately adjacent to wheat plants that showed little damage. However, Cooley (1908) remarked that in grainfields he observed that the larvae showed a distinct preference for the grain, paying little attention to the various weeds found there in abundance. Some workers (see Oviposition Section) noted that plants were not required for egg laying, but Gillette (1904) observed that barley was the grain that attracted the moths for deposition of their eggs far more than any other. Pruess (1961a) showed that populations of army cutworm larvae tended to be greater in winter barley than in adjacent fields of winter wheat, which indicates an ovipositional preference. This was later attributed by Pruess (1961b) to the lighter color of barley. He observed that the factor responsible for population differences operated more stongly along the boundary of the two crops and diminished rapidly going away. Walkden (1943) showed that in 14 different habitats, a greater percentage of army cutworms occurred in little barley pastures than other types of pasture grasses. Overgrazed pasture also had a higher percentage infestation.

It should be stated that, in terms of food for the larvae, if nothing else is available they will feed on each other.

Damage

The first indication of army cutworm injury to plants appears as more or less semicircular areas eaten from the edges of the leaf or as holes eaten through the leaf. Total damage to a crop depends, of course, on the number of larvae, the size of the plants, and the susceptibility of the crop to damage. Wheat, because of its widespread planting, is the crop most damaged by this pest. Wheat is not particularly susceptible to damage since it can stand considerable defoliation and survive, although some retardation of the plant may occur. Under good growing conditions some damage may not even be noticed. However, if large numbers of larvae occur in the field and/or if the plants are small, damage of varying degrees, up to total destruction, can occur. If the growing point of the seedling is damaged the plant is destroyed.

When food for the larvae is scarce, the larvae will follow the plants on which they are feeding down into the soil, completely destroying the plants. Other small grains are also damaged in this manner. When a plant is completely eaten the larva moves to another and so on until bare spots appear in the fields, much like greenbug damage in small grains. The spots continue to grow as the larvae advance, and the outer edges of the spots are usually heavily infested. When fields are denuded, the larvae move to other fields. Reports of damage and destruction to several hundred thousand acres are common during outbreak years. When the larvae complete their development, feeding may come to an abrupt halt in spite of population size.

There is little information on damage or economic thresholds. Jacobson (1962) when discussing damage on mustard, stated that cereal crops could withstand up to five army cutworms per square foot and could often resume growth after the cutworms had fed on them. The Oklahoma Cooperative Extension Service (1979) suggests an economic threshold of 2/row ft. (approx 4/sq. ft.) in wheat depending on the size of the plants and the size of the larve. In cage studies conducted on wheat during 1976-77 we used 0, 3, 6, and 12 larvae/row ft. The level of 3/row ft. did not cause significant damage but both of the higher rates adversely affected stand and yield (Table 1). The rate of 12 larvae/row ft. caused a yield loss of over 7 bu/A. Some unpublished data found at this location (R.G. Dahms, year unknown) shows a reduction in yield of 0.6 bu/A for each larva/sq. ft., which indicates that 2-3 larvae/sq. ft. could do economic damage on wheat.

In 1979, the South Dakota Cooperative Extension Service (Kantack et al. 1979) suggested that, as a rule of thumb, when wheat is in good growing condition with 5-6 in. of top growth, 3-4 larvae/linear ft. of row can be tolerated. They recommended treatment on small wheat plants under 4 in. in height when 2 or more larvae/linear ft. are found and feeding damage is evident.

Damage to alfalfa is similar to that of wheat in that first the plants are defoliated and then further damaged by feeding on the stems and growing points. Established stands of alfalfa are more resistant to feeding damage than are the fall or spring seeded stands. Manglitz et al. (1973), in Nebraska, remarked that in the established field in their test, feeding damage was soon obscured by plant growth but in the fields seeded the previous fall, the stands were so reduced that reseeding was necessary. However, feeding on established fields may delay growth as indicated by Pfadt (1955) in Wyoming. He stated that early spring feeding on young shoots prevented the emergence of alfalfa above ground litter and caused fields to stay brown and wintery in appearance. He noted the severely attacked fields remained brown six weeks after uninfested fields began to green. Oklahoma Cooperative Extension Service (1979) recommends control if 3-4 small larvae or 2-3 large larvae/sq. ft. occur on established stands. However, even

Table 1. Effect of varying numbers of army cutworm larvae on wheat, Skedee, Oklahoma, 1976-77.

Larvae/ row ft[1]	Avg % plants survived[2]	Avg heads/ plot	Avg damage rating[3]	Avg threshed grain/ plot (g)	acre (bu)[4]
0	70.7	72.5	2.83	28.5	25.3
3	65.7	77.3	3.00	30.0	26.7
6	51.3	70.7	3.50	23.0	20.4
12	56.5	58.3	4.33	18.8	16.7
LSD (P = 0.05)	13.1 (P = 0.10)	10.2 (P = 0.01)	1.03 (P = 0.10)	5.2	—

[1]Triumph 66 under 1.8' square plastic cages infested with 1st instar larvae on Sept. 27, 1976, in 6 replications.
[2]Counts taken on Sept. 30, 1976, and again on May 2, 1977.
[3]Visual damage ratings were made Dec. 5, 1976, by using a scale of 1 = no damage to 6 = dead or dying plants.
[4]Projected.

2 larvae/sq. ft. are damaging to fall seeded stands and should be controlled.

Mustard appears to be the most susceptible crop to damage by the army cutworm. In the mustard growing area of Northern Montana and Southern Alberta, the army cutworm has been a serious annual pest since 1955, according to Jacobson (1962). The high susceptibility is caused by the small size of the plants and their inability to recover from defoliation. Jacobson stated that a mean population of less than ½ cutworm/sq. ft. was sufficient to destroy a field of mustard.

In the Northern Plains states, the army cutworm is a serious pest of sugar beets. Damage to the beets involves their complete defoliation and if heavy injury is done to the crown the plant will die (Corkins 1921). At times, complete fields have been destroyed and required reseeding (Gillette 1904). Other major crops receiving economic damage are corn, sunflowers, and sweetclover.

It is not uncommon, in outbreak years, to receive reports of damage on almost any plant. Early garden crops are damaged heavily at times. Walkden (1943, 1950) and Knowlton (1942) both report damage to pastureland and, recently, large outbreaks have occurred on rangeland in several western states. Homeowners report damage also, to ornamentals in their yards. The sudden disappearance of a crop just emerging from the soil is typical of army cutworm damage.

Larval Migration

When the army cutworm larvae consume all the food around them they move to a new area. When an entire field is denuded by a large population then the entire population moves to a new field, marching in army fashion — thus their name. The marches on cloudy days may begin almost anytime. On clear (sunny) days they begin about 4 or 5 o'clock in the afternoon (Corkins 1921). The search for food by hungry larvae does not seem unusual but what is remarkable is the fact that all the larvae move or migrate in the same direction. Wilcox's (1898) answer when asked why they all had a common direction was, "That it is the only economic way for them to march. The only method, in fact, by which they do not interfere with one another and hinder the passage of one another." Wilcox contended that they always marched in a northwesterly direction and Strickland (1916) agreed. Strickland proposed that if the march was delayed until late afternoon, their usual feeding time, they marched toward the sun — thus a westward direction. However, if due to lack of food they moved during the day when the sun was hot, they moved away from it in a northerly direction. Thus, Strickland contended the general trend is movement in a northwesterly direction. Daniels (1964) noted the larvae appeared to migrate north and in few instances they did move in another direction. Hewitt (1917) explained that in the weaker light of late afternoon they become positively phototrophic and move in a westerly direction. Yet when food is scarce and hunger overcomes their aversion to sunshine, Hewitt contended they then display a modified negative phototropism and migrate in a northwesterly direction. A study utilizing current technology seems in order.

Density of the larvae is quite great during outbreaks and migrations. Strickland (1916) reported 100-150 worms/sq. ft. Wilcox (1898), during a migration, found 15-40/sq. ft. in the upper 1 in. of soil. Smith (1934) reported 90/sq. ft. in some areas and 25, as an average, in several areas. Fields with 25/sq. ft. were not uncommon in Oklahoma in 1976.

The longest recorded army cutworm larval migration was 3 mi. (Wilcox 1898). Everything in their path was destroyed including the green covering of the graves in a cemetery along with the grain fields. Migrations are not common, particularly in recent years, probably due to modern control methods. Daniels (1964) reported a recent migration, and during the 1976 outbreak in Oklahoma and Kansas local reports of migrations were received. Other occasional reports have occurred (USDA 1951-1975, USDA 1975-1979). The following section on control discusses the early techniques used for preventing damaging migrations.

Control

The first reports of army cutworm outbreaks were by researchers devising and testing various techniques for controlling this pest. Unlike current large area controls, the majority of the earliest methods were designed only to stop migrating armies. Wilcox (1898) recommended running water in ditches that were plowed through the field ahead of the migrating larvae. The ditches were cut 1 ft. deep with one steep side and 6 in. of running water. When the ditches filled with larvae, a new ditch was cut and so on until the advancing army was stopped. Wilcox contended that this technique was much more effective than either rolling the fields to crush the larvae or irrigating in an effort to drown them. Cooley (1910, 1915) recommended ditches for large fields. For smaller areas, he suggested a spray consisting of 1 lb. of Paris green to 50 gal. of water.

Cultural Control — Early recommendations of summer fallow, early fall planting, and delayed planting of small grains could not be very effective control practices because the adults lay their eggs in barren soil, not requiring the presence of plant material. Since the moths prefer freshly worked soil, a crusted surface during the egg laying period may help to protect individual fields (Strickland 1942). Delayed planting in the spring was evidently very successful in preventing damage to mustard (Jacobson 1962). If mustard seeding is delayed until the last week in May the army cutworm larvae have reached the prepupal or pupal stages and have ceased to feed. Occasionally, larval development is retarded by inclement weather, extending the larval cycle even into late planting; thus damage may not be avoided in some years.

Baits — Johnson (1905) recommended the use of freshly cut vegetation that had been sprayed with Paris green as a bait for larvae. He also recommended a bait that was similar to the one recommended at that time for grasshopper control. The grasshopper bait included an arsenical plus sugar or molasses and bran. Strickland (1915) recommended this formula: 50 lbs shorts (better than bran); 2 gal. molasses; and 1 lb. of Paris green applied at 20 lbs/A. With variations, this bait was to be used for many years for the control of army cutworms. Smith (1934) reported that in 1934 in one Kansas county alone 5000 lbs. of white arsenic had been sold for making poisoned bran mash for army cutworm control. It was also mentioned that arsenate of lead had been sold to farmers in one district, but resulted in poor control. Success of the bait depended upon a number of factors, including: warm enough temperature for the larvae to seek food above the surface of the soil, and use of either white arsenic or Paris green (Dean & Smith 1935). Under favorable conditions, up to 95% of the larvae were destroyed with one application of the bait. Kill with slow-acting bait could not be determined for 3 days following treatment. Mills et al. (1947) wrote that the larvae readily ate the currently used sodium fluosilicate grasshopper bait and that a "considerable amount" of the bait had been used successfully against the army cutworm during the years of 1945 and 1946. As late as 1944 (Fenton and Whitehead 1944) and 1949 (Stiles 1949) the poisoned bran mash was still recommended as a control measure.

Insecticides — In 1949, Stiles (1949) indicated that toxaphene and chlordane would control army cutworm larvae. Burkhardt (1954) tested several insecticides on alfalfa, and obtained good control (88%) with endrin and slightly less control with aldrin, dieldrin, heptachlor, and toxaphene. Pfadt (1955) also checked these compounds plus Dilan and DDT. Endrin was found also to be very effective for army cutworm control on sugar beets (DePew 1959), on wheat (DePew 1965), and again on alfalfa (Pfadt 1960). Although other compounds have been tested, endrin has remained the compound most effective. McDonald and Jacobson (1958) demonstrated endrin's effectiveness in the laboratory and that it was much more effective on smaller larvae. Oklahoma now (1979) recommends endrin or toxaphene as control measures but with several precautions since they are very toxic to fish. In 1979, South Dakota also recommended endrin (Kantack et al. 1979). Toxaphene, generally, has not proven as effective as endrin (DePew 1959, 1965) (Pfadt 1955), Burkhardt 1954) (Pepper et al. 1954). Lutz and Pruess, in 1959, recommended toxaphene as an alternate to endrin but commented that it was less effective. Restrictions have removed most of the other compounds for use on army cutworms. There is some indication that chemical control measures are less effective when applied during extremely dry periods and especially during dry periods when plants are small.

Natural Control — The value of natural enemies in reducing populations of army cutworms is spelled out by several workers. Strickland (1916) states that, "We are saved from considerably more extensive and frequent outbreaks of the army cutworm by its enemies." He further states that parasites, "Kill more of them every year than we can hope to with all of the means at our disposal." Johnson (1905) believed that, "So many of the worms were overcome by these agencies that there was no recurrence of the pest." Corkins (1921) also believed this when he stated, "It is perhaps as much because of these insect enemies as of any other one means that this cutworm appears in destructive abundance only at irregular intervals." Wilcox (1898) made a similar statement as well. Certainly these writers were convinced of the immensity of control by natural enemies. Perhaps they did not give credit enough, however, for benefits during the current season, for this may be greater than realized. Also, little is mentioned of weather, which may be the most important aspect of natural control. Whether or not the reduction in populations actually affects recurrence as such is uncertain. However, it would certainly seem to have a bearing on the magnitude of the recurrence.

Observations of control by natural enemies are common, as above, but actual values are rare. Cooley (1908) did state that about 5% of the caterpillars were infested by a tachinid fly. Snow (1925), in reporting outbreaks of both disease and parasites, found that 440 cutworms out of the 1478 placed in cages were killed by parasites. Snow remarked that the outbreak that occurred on alfalfa "seemed to be, but was not conclusively proven, to be controlled by parasites." Our 1976 data also show a high incidence of parasites (46%) (see next section).

Natural Enemies

Parasites — A list of reported species of army cutworm parasites follows.

Gillette (1904) — Colorado.

Hymenoptera — *Copidosoma, Pterocormus longulus* (Cresson) (cited as *Ichneumon longulus)*, and *Amblyteles subrufus* (Cresson).

Johnson (1905 — Colorado.

Hymenoptera — *Copidosma, Pterocormus longulus* (Cresson, (cited as *Ichneumon longulus)*, and *Amblyteles subrufus.*

Cooley (1908) — Montana.

Diptera — *Peleteria tessellata* (F.)

Strickland (1916) — Alberta, Canada.

Hymenoptera — *Apanteles laeviceps* Ashmead, *Meteorus* sp., *Berecyntus bakeri* Howard *var. euxoae*, and *Amblyteles* sp.

Diptera — *Phorichaeta sequax* Williston.

Corkins (1921) — Colorado.

Hymenoptera — *Copidosoma* sp., *Pterocormus longulus* (Cresson) (cited as *Amblyteles longula* Cress.), *Microgaster* sp., and *Berecyntus bakeri bakeri* Howard.

Snow (1925) — Utah.

Hymenoptera — *Berecyntus bakeri* Howard, *Apanteles laeviceps* Ashmead, *Meteorus vulgaris* (Cresson), *Diphyus nuncius* (Cresson) (cited as *Amblyteles nuncius* Cress), *Habrobracon erucarum* Cushman, and *Erigorgus* sp. (cited as *Paranomalon* sp.).

Diptera — *Ernestia* sp., *Villa alternata* (say) (cited as *Anthrax alternata)*, *Poecilanthrax willistonii* (Colquillett) (cited as *Anthrax willistonii* Coq.) *Aphiochaeta* sp., and *Phorichaeta cinerosa* (Coquillett).

Walkden (1943) — Kansas.

Hymenoptera — *Microplitis feltiae* Muesebeck, *Ophion* sp., *Ophion*, n. sp., *Apanteles griffini* Viereck, *Exetastes lasius* Cushman, *Exetastes* sp., *Paniscus ocellatus* Viereck, and *Meteorus vulgaris* Cresson.

Diptera — *Phorocera claripennis* (Macquart).

Walkden (1950) — Various locations.

Hymenoptera — All of Walkden's entries above plus: *Eubadizon* sp., *Macrocentrus incompletus* Muesebeck, *Berecyntus bakeri* var. *bakeri* How., *B. bakeri* var. *euxoae* Gir., *Rogas* sp., *Netelia ocellata* (Viereck), and *Netelia* sp.

Diptera — An unidentified tachinid, an unidentified bombyliid, *Poecilanthrax* n. sp., *Anthrax willistoni* Coq., and *Neophorocera claripennis* (Macquart).

Arnaud (1978) — Various locations.

Diptera — *Bonnetia comta* (Fallen), *Euphorocera claripennis* (Macquart), *Mericia* spp., *Peleteria "tessellata* (F.)" probably, *P. texensis* Curran, *Periscepsia cinerosa* (Coquillett), *P. helymus* (Walker), and *P. laevigata* (Wulp).

Burton, et al. (this paper) — Oklahoma.

Hymenoptera — *Meteorus leviventris* (Wesmael), *Apanteles griffini* Viereck, *Copidosoma* sp., *Zele* sp., and *Netelia* sp.

In our Oklahoma collections in 1976, the most prevalent parasite of the army cutworm larvae was *Meteorus leviventris* (Wesmael) of the family Braconidae. This was the first parasite detected early in the spring and remained the most common throughout the season. The number of *M. leviventris*/parasitised army cutworm larva ranged from 2 to about 20, but usually 10-12. The larvae emerged from the host and spun yellow silken cocoons externally. Adult emergence occurred five days after cocoon formation, contrary to the 24-28 days reported by Strickland (1916) for a *Meteorus* species. Snow (1925) recorded an average cocoon stage of 12 days for *M. vulgaris* Cresson. The adults of *M. leviventris* were small, brown-tan wasps with a dark thorax and a lighter abdomen. During 1976, incidence of parasitism by this species increased with time whereas incidence of other species collected was restricted to the first collection date (Table 2).

Table 2. Parasites from field-collected army cutworm larvae, Payne County, Oklahoma.

Type of parasite	From 1300 host larvae collected 3-23-76		From 100 host larvae collected 3-30-76	
	% of parasites	% of total	% of parasites	% of total
Meteorus leviventris	37.1	3.8	87.2	41
Apanteles griffini	34.8	3.6	-	-
Copidosoma sp.	20.7	2.2	6.4	3
Zele sp.	5.9	0.6	-	-
Microplitis sp.	1.5	0.2	-	-
Unidentified ichneumonid	-	-	4.2	2
% of army cutworms parasitized	10.4		46	

A large number of *Apanteles griffini* Viereck were collected during one period in the spring but were not detected either early or late. This braconid was smaller than *M. leviventris* and darker in color (black). The number of individuals/host was greater (average approx. 30). The larvae emerged from the host's body and spun cocoons externally, usually together, forming a mass of small white cocoons. A few *Micropletis* sp. were found. This was also a black braconid but a little larger than *A. griffini.*

The polyembryonic parasite, *Copidosoma* sp. (Encyrtidae), was frequently detected. As many as 1000-5000 adults emerged from a single host larva. Because of this interesting phenomenon, the parasite was frequently mentioned in the *E. auxiliaris* literature. Since they develop from a single egg, all of the adults from a single host are of the same sex. Unfortunately all specimens sent for identification were males, and females were needed to determine species.

Only eight *Zele* sp. were found in collections. This is a medium sized orange-tan braconid. Only two large ichneumonids were found. The pupa was of the exarate type, a pale mummified appearance, not covered by a cocoon. The adults were identified as *Netelia* sp. These are commonly seen around lights early in the spring.

Although there was probably some sampling error, the percentage parasitization by the above parasites was only 10% by March 23 but had reached as high as 46% only one week later (Table 2). This percentage was not completely representative of the season, however, since many of the parasites had already emerged and therefore eliminated their hosts. For example, as seen in Table 2, 90% of the larvae would survive as of March 23 and 46% of the survivors, as of March 30 would be parasitized. Walkden (1943) also showed a progressive increase with time of the incidence of parasitism and disease in cutworms and armyworms.

Predators — Johnson (1905) and Corkins (1921) state that of the vertebrate enemies of the army cutworm, birds are by far the most important. They mention that quails, meadowlarks, bluebirds, robins, blackbirds and bluejays were known to feed on them in Colorado. In Oklahoma, wild turkeys have been observed feeding on the larvae. Without question birds destroy large numbers. We found in Oklahoma that flocks of robins in a wheat field usually meant the presence of army cutworm larvae; thus, the birds helped to locate infestations. Some fields appeared almost cultivated by the birds in their pursuit of larvae. Knowlton (1942) examined the stomachs of several types of birds collected within the vicinity of infested fields. Examples were: six blackbird stomachs contained a total of 59 army cutworms and one meadowlark stomach contained 14 larvae. He stated that the influx of insectivorous birds into cutworm infested fields was a common occurrence in Utah during 1941. Along with the birds, other vertebrate enemies were apparent where army cutworms occurred. In many infested Oklahoma fields we found that large clods had been over-turned indicating perhaps the work of skunks and armadillos. Other animals mentioned as predators were chickens and hogs (Johnson 1905), the common gopher (Strickland 1916) and ground squirrels (Corkins 1921). The seemingly most unlikely predator of adult army cutworms was recorded by Chapman et al. (1955) when they found evidence that grizzly bears were feeding on large numbers of the estivating moths in the high country of Montana.

Insect predators, of course, are important in reducing the numbers of larvae. Strickland (1916) recorded two carabid beetles (*Calosoma tepidum* and *C. zimmermanni)* that were especially effective predators in the larval stage. He also recorded as predators: other ground beetles, "several of the small Harpaline species"; a black "digger" wasp (*Ammophila luctuosa)*; cicindellid adults; ants; and the army cutworms themselves (cannibalism, especially when food is scarce). Wilcox (1898) observed two species of ground beetles (*Harpalus* sp. and *Calosoma* sp.) attacking the cutworm larvae.

Diseases — Diseased specimens of army cutworms are commonly found in the field, sometimes in epidemic proportions. In comparing the army cutworm with the pale western cutworm, *Agrotis orthogonia* Morrison, Parker et al. (1921) stated that there was much more difficulty in rearing field collected army cutworms because of the high percentage that developed disease and parasites. It appears that the incidence of disease probably increases progressively with the advance of the season (Walkden 1943), as was the case for parasites. Several different diseases of army cutworms have been reported but no report indicates the level of occurrence. Strickland (1916) described two types, each common at a different location. One type attacked both immature and mature larvae and turned them to an opaque pink color. Attempts to transmit this disease to healthy larvae were unsuccessful. The other type (probably a virus), attacked only mature larvae and prepupae, causing liquification of body contents. Snow (1925) in his studies saw many cutworms "dead above the surface of the ground." He described the larvae as "black, flabby, and ill smelling, and finally exuding through the broken skin." Walkden (1950) listed several diseases that he had encountered over a 20 year span. These were: *Beauveria* sp.; *Isaria* sp.; *Metarrhizium anisopliae* (Metschnikoff), *Sorosporella uvella* (Krassilstischik), and an unidentified wilt.

Sutter (1972, 1973) isolated and described the morphological development of two viruses from specimens collected in South Dakota. One virus was a pox virus that caused mortality within 16-18 days. The other was a nonoccluded virus that caused the larvae to become lethargic and shrunken, with death occurring in 12-20 days. The pox virus or entomopox virus was further characterized by McCarthy et al. (1975) and Langridge et al. (1977).

The Pupae

Description

Strickland (1916) said that *E. auxiliaris* pupae were indistinguishable from those of other species of this genus and closely related genera. Size varies from about 17-22 mm long and about 6 mm wide. Color also varies from Chestnut brown to almost black when mature. Newly formed pupae are straw-colored. A more in-depth description was given by Crumb (1929) as follows: "Maxilliary palpi visible, labrum somewhat emarginate, prespiracular callus present on prothorax, punctures on moveably linked abdominal segments" and "spiracles broad, directed laterally, cremaster set on the tips of the abdomen without a basal process. . . ." Sex determination in the pupae is possible by locating the position of the genitalia (Figure 5).

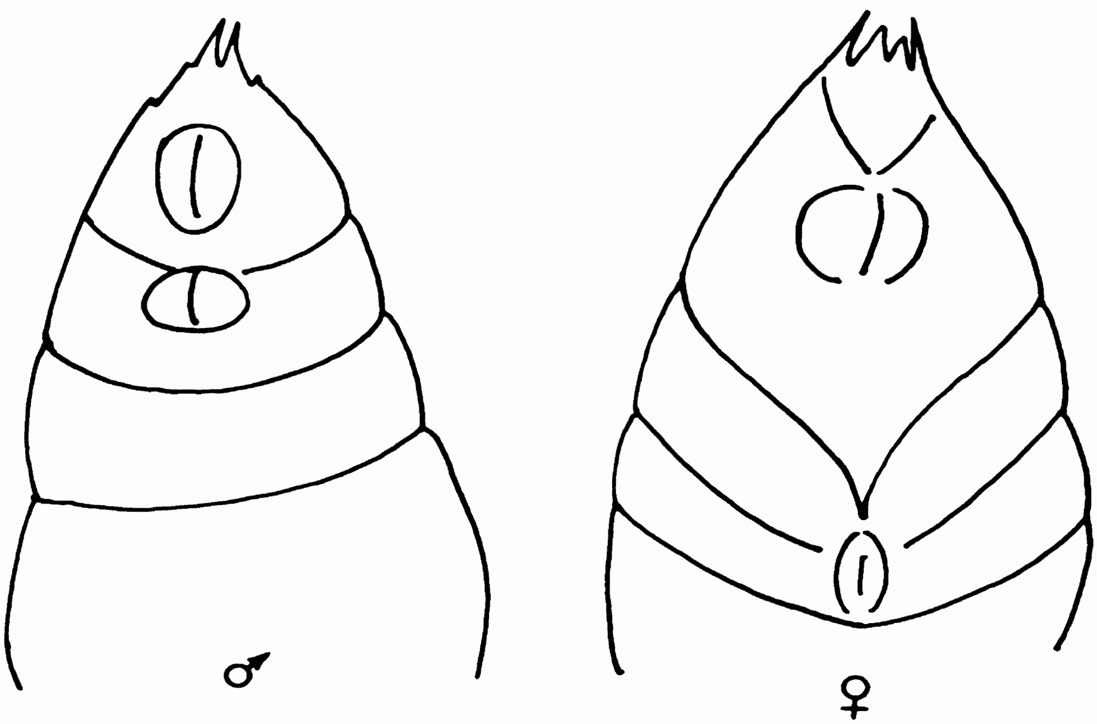


Figure 5. Posterior abdominal segments of army cutworm pupae, showing sexual differences.

Pupation

Pupation occurs in the soil. When the larvae have completed their development they burrow vertically into the soil. Recently dug burrows are visible on the soil surface as holes. Depth of burrowing varies according to the soil conditions at different levels. Strickland (1916) said that they must have either solid or moist soil for cell construction. Therefore, the level can be slightly below the surface or up to 3 in. deep. Such variations can occur in the same field. In moist sandy soil we found most of the depths to be about 2 in. At the selected level, the larvae build a vertical earthen cell. The oval cell, about 1 in. (25 mm) in length and about 0.5 in. (12 mm) in diameter, has smooth inside walls. In building the cell the larvae evidently use a salivary secretion rather than silk as expected (Strickland 1916). Snow (1925) observed the larvae exuded a liquid from their mouths and that the soil appeared dark when wet with this liquid. "The cell was not impervious to water," he stated. After adult emergence occurs, the cells deteriorate rapidly and become difficult to find.

Snow (1925) noted that several days passed between cell completion and pupation. During this time the larvae shrank to about one-half their former size. This pre-pupal period lasted about 10 days (Snow 1925) after which a newly formed pupa could be found. The duration of the pupal period in the field is 25-32 days as recorded by Walkden (1950) and 43-63 days as recorded by Cooley (1916) but only 14 days in the lab (see rearing section).

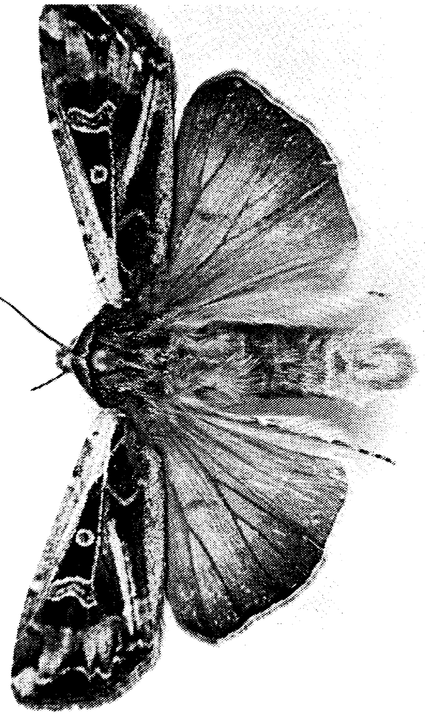
A technique for field collecting pupae which resulted in less injury to the insect was the use of a flat, wide object to scrape away the soil a little at a time. The top of the cell is then scraped away revealing the anterior end of the pupa before any contact injury occurs.

The Adults

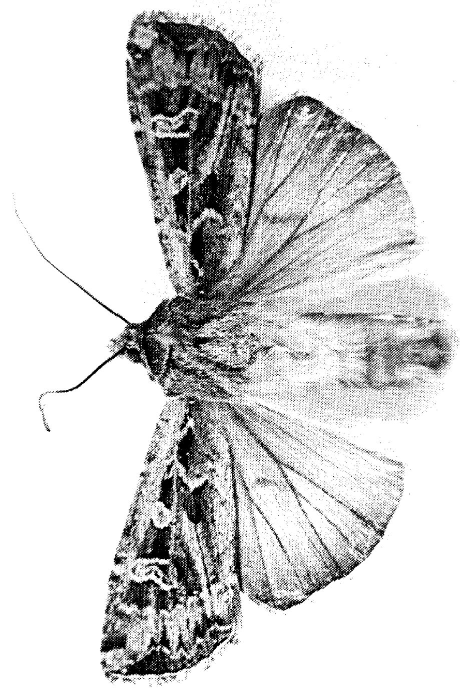
Description

Considerable variation occurs in the appearance of army cutworm moths. The extreme variation is due to the existence of at least five color forms. Strickland (1916) discussed three of these forms as variations which were first described as distinct species; *E. auxiliaris* Grote, *E. introferens* Grote, and *E. agrestis* Grote. The three forms are distinguished by two quite macular types and one (*E. agrestis)* considerably less maculate (see photo in Strickland 1916). They are obviously color forms since Wolley-Dod (1918) reared all three forms from a single species. Cook (1930b) separated the forms based on color characters and sex; he also mentioned that rearing at low temperatures altered the forms (color) as well. Cook added and described a new form, *E. montanus*, and stated that Mendelain characters are probably involved in the forms. More recently, Sutter (personal communication, G. R. Sutter, USDA, SEA-AR, Northern Grain Insects Res. Lab., Brookings, S.D.) has shown that the characters are heritable and the color forms are genetically controlled. Pruess (1967) discussed these forms in detail and added another, the melanic form. He presented a photo of all five color forms. Pruess also discussed geographic distribution of the forms and indicated that the ratio of color forms were found to be very similar throughout the insect's range and from year to year. He discussed other characters and stated that east-west clines were not found. Four of the color forms are pictured in Figure 6.

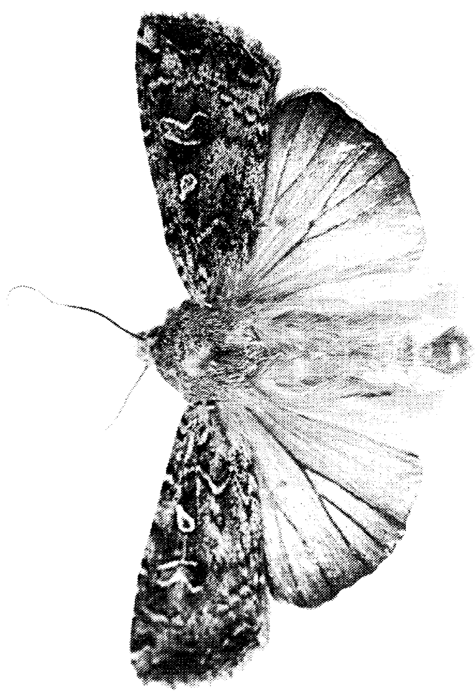
Hardwick (1970) described the adults in detail, including most of the variations.



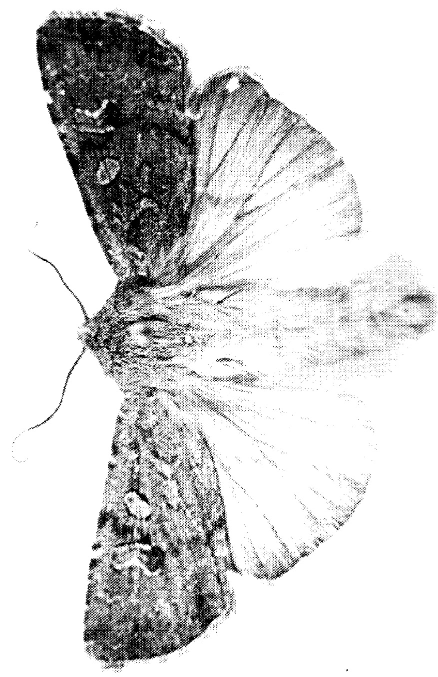
A, *auxiliaris*



B, *introferens*



C, *montanus*



D, *agrestis*

Figure 6. Color forms of the army cutworm moth, *Euxoa auxiliaris;* A, *auxiliaris;* B, *introferens;* C. *montanus;* and D, *agrestis.* See Pruess (1967) for photo of the melanic form. It is similar to *montanus* but with a layer of dark scales covering the forewings, slightly obscuring the characteristic spots. This melanism occurs in about 2-3% of the population.

Generally, the adult appearance is that found in Figure 6. The orbicular and reniform spots are well defined — even in less maculate specimens. The elongate claviform spot is usually defined with a pale streak extending outward from its apex. The wings are folded over the back when at rest. The antennae of both sexes are filiform. The sexes, however, can usually be separated since the males have more brown in their coloration than the females, which tend to be predominantly gray. We have found this character useful when sexing adults from light trap catches.

Hardwick (1970) described the male and female genitalia and external characters. The morphology of the internal reproductive system of the adult female was deftly done by Drecktrah (1978). Rings (1977) presented an illustrated field key with photos of some of the common cutworms, including the army cutworm.

Emergence and Seasonal Occurrence

Little is written about the actual process of emergence. Strickland (1916) only stated that moths emerge and come to the surface of the soil at all hours of the day and night. If actual moth flights are an indication, much of the emergence takes place within about a two-week period (Figure 3).

Since the army cutworm is a univoltine species it would appear that seasonal timing of development would be somewhat critical. Certainly the stages are locked into seasonal occurrence, although the range of development time may be somewhat broad. We know, as we shall discuss later, that the development of ova in the adult is delayed for several months but we do not know if any form of quiesence occurs in the larval, pre-pupal, or pupal stages. During a mild fall and winter larva can and do develop rapidly. Daniels (1964) stated that a few fields had been notably damaged during the previous fall, causing some reseeding. Although he did not mention size, the larvae must have attained considerable growth during this period. However, the larvae did not complete their development until spring. Soil temperature may play a large part in slowing development time. Even during mild years in Oklahoma soil, temperatures are quite cold and, of course, the immature stages spend essentially all of their time beneath the soil so that the larva becomes a cold incubator. Even so, if the adult emerges the first few days in May (Figure 3) and the eggs are not laid until September, October, and November, this could mean the adult life would span up to five months. It is possible, however, that army cutworms from the more temperate areas such as Oklahoma may play little part in the new generation. The individuals that contribute to the following year's populations may come entirely from cooler climates and those areas closer to the areas of summer estivation. These populations may emerge later in the spring, thus reducing the length of the adult life necessary for fall oviposition.

Three years of light trap data (Walkden and Whelan 1942) showed that in the same location (Garden City, Kansas) emergence only varied by about two weeks from year to year and coincided with moth flight dates in Figure 3. The effect of latitude and altitude on climate probably has some effect on flight dates. The following are recorded dates of adult appearance at different locations:

Canada	June-July	Strickland (1916)
Montana	July	Cooley (1916)
Montana	July	Cook (1927b)
Minnesota	May-June	Knutson (1944)
Colorado	April-May	Corkins (1921)
Kansas	April-May	Smith (1934)
Kansas	May-June	Walkden and Whelan (1942)
Oklahoma	May	Fig. 3.
Texas	March-April-May	Crumb (1929)

As noted from the Kansas dates, yearly climate factors probably also affect dates.

The army cutworm can be a nuisance as an adult. During the large spring flights that occur during outbreak years, the moths seek temporary shelter during daylight hours. They hide under and in almost anything. They seem to have an uncanny ability for squeezing through the smallest openings and invasions of homes by large numbers is not uncommon. Strickland (1916) took 700 moths/night from a light trap in the attic of one home. Complaints were common in 1976 from home owners in Oklahoma.

Adult Feeding and Digestion

Considering that the moths of the army cutworm must fly for considerable distances and survive an extensive summer period of two months or more, feeding must surely play an important role in survival and is probably critical. Through the years, observations by various workers have labeled the moth as an active feeder. Cook (1927b) concluded from his observations that the two flight maxima of this insect coincided with the blooming period of two important adult food plants; the spring flight with the flowering of sunflowers (*Helianthus* spp) and the fall flight with that of rabbit bush (*Chrysothamnus* spp). He collected large numbers of moths feeding at these flowers. Cook (1930a) commented that army cutworm moths feed on flowers for two or three weeks, after which they estivate until about the first of September, when they again feed, mate, and lay their eggs. Other observers have found, however, that the moths probably actively feed throughout the summer. Walkden (1950) saw thousands feeding on flowers of various shrubs during June at a high elevation in Nevada. Chapman et al. (1955) reported moths flying about alpine flowers during July in Montana. Pepper (1932a) collected moths that were feeding on rabbit bush during September and October. Feeding at flowers on the short grass plains of Colorado was recorded by Lavigne (1976).

The most amazing aspect of adult feeding was shown by Pruess (1967). In taking moth weights in Nebraska he found the mean abdomen weight for moths collected in the spring was less than the mean weight for fall collected moths. Also, that 70% of the moths collected during the fall were heavier than any moth collected during the spring. Therefore, the depletion of body reserves that would be expected during a long migration-estivation does not occur but instead the moths actually accumulate fat reserves while in the mountains during the summer. Pruess concluded that the moths do not have an inactive estivation period during the summer at the higher elevations.

In the laboratory, food for the adults has been shown: to be necessary for subsistence (Jacobson and Blakeley 1959); to increase the longevity of both sexes (Pruess 1963); to delay oviposition and extend the egg laying period (Pruess 1963), and to increase their flight potential (Koerwitz and Pruess 1964).

Koerwitz and Pruess (1964) indicated that fat reserves carried over from the pupal stage can be utilized to only a limited extent for flight; that feeding would appear essential during any extensive migration; and that because flight potential was excellent, migration would depend only on periodic availability of additional food. They also showed that a nectar meal increased the longevity of moths over those fed honey solution when both were flown to exhaustion.

The examination of digestive carbohydrases in the adult's ventriculus and salivary gland have shown that the insect would certainly be capable of hydrolyzing a large number of different sugars. The following data gives some insight into the ability of the moth to digest certain sugars that might be found in nectar (Our methods have been previously published [Burton 1975]).

Carbohydrate	Salivary Gland*	Ventriculus*
Sucrose	++++	++++
Raffinose	-	+++
Trehalose	++	++++
Melezitose	-	++++
Starch	-	-
Glycogen	-	-
Maltose	-	+
Melibiose	-	+
Methyl glucoside	-	+
Inulin	No test	-
Lactose	No test	-
Cellulose	No test	-
Cellobiose	No test	-

*The number of "+'s" indicates the relative activity on a test material whereas a "-" indicates no activity.

Sucrose is usually the most common and most abundant sugar in nectar; so the activity exhibited for this sugar by both organs is as expected. The high activity level of the ventriculus for raffinose, trehalose, and melezitose, however, is surprisingly high when compared to the activity found for each in the adult corn earworm, *Heliothis zea* (Boddie) (Burton 1975). Raffinose is also a common sugar in nectar. In addition, the extended longevity afforded by the nectar meal (Koerwitz and Pruess 1964) could indicate the presence and utilization of additional nutrients other than just the sugars required as an energy source.

Seasonal Migration of Adults

Army cutworm moths migrate to the Rocky Mountain area in the spring and return to the plains in the fall. This habit allows the adults to escape the high summer temperatures experienced on the plains, thus extending their longevity. Many observations of large concentrations of army cutworm adults at higher elevations have been reported (Gillette 1904, Walkden 1950, Chapman et al 1955, Pruess 1967). We have not observed such concentrations but have trapped large numbers of moths at a 9000 ft. elevation during August in Wyoming. The most amazing aspect of the trapping was that up to 100 moths/night were caught even though night time temperatures dropped to 40°F and below. Cooley (1916) reported oviposition at very cool temperatures and observed that moths flew at temperatures below 40°F when disturbed. We have observed in the lab that adults will feed at near freezing temperatures. Such adaptibility to cold should seem contradictory, since the adult lives during the summer months; but, since much of the time is spent at higher elevations where temperatures are lower perhaps it seems reasonable. It has been shown that temperature does affect longevity (Jacobson and Blakeley 1959, and Jacobson 1960). We have also found that moths can be kept for several months at low temperatures (4°C) in the laboratory. Pruess (1967), in discussing summer populations in the Rocky Mountains, stated that in most years there is an upslope movement during the summer. He said that this is possibly a response to changing nectar sources but followed by saying that when the years are cool and wet, moths can be found at lower altitudes. Hence, there might be a temperature response; that is, as the temperature increases, upslope movement increases.

The army cutworm has always been known to have two flights/year, an abundant flight in the spring and a reduced one in the fall. All workers found that the eggs were never developed in the ovaries during the spring flight but were always fully developed during the fall flight. These facts, plus the absence of the insect during the summer months, caused Cooley (1916) and Strickland (1916) to conclude that the species was single brooded. Strickland (1916) believed that the adults estivated by spending the summers hiding under straw piles and in attics. However, Cooley (1916) got only a few to survive at Great Plains temperatures in cages during the summer and other workers got none (Pepper 1932b and Pruess 1967).

Cook (1923) guessed that moths "must have flown at least 300 miles from the place where they emerged." However, Pepper (1932b) was the first to propose that moths probably migrate and spend the summers at higher elevations. He based the conclusion on his summer cage test and on observations of a unidirection flight of moths. Chapman and his co-workers (1955) also showed evidence and proposed migration. Koerwitz and Pruess (1964) first showed that the moth was capable of long extended flights. Then, in 1967, Pruess showed evidence that proved beyond any reasonable doubt that migration does happen and that no inactive estivation of the moth occurs. His evidence was based on many factors: the flight period in Nebraska and Wyoming showed that in the eastern portion of the range, activity of moths in the spring coincided with known emergence; the flight occurred progressively later as you went west; percent of moths possessing meconium (an indication of age) declined to the west; spring flights appeared unidirectional also (he and a co-worker showed this fact letter, [Pruess and Pruess 1971]; few or no moths were able to survive the summer on the Great Plains (cage studies); activity in the mountains coincided with inactivity on the plains; neither food nor temperature requirements were limiting factors in the mountains; moths collected on the plains during the fall had larger fat reserves than spring-collected moths; such an accumulation of fat could not occur during an inactive estivation but would have to occur for survival on the plains; moths occurring in the mountains during the summer showed the same type accumulation of fat reserves; fall populations on the plains were directly correlated to size of the oversummering populations in the Rocky Mountains; and females which have mated or contain mature eggs have never been collected anywhere before late August, so no summer reproduction occurs in the mountains or elsewhere. Pruess states, "Only the hypothesis that moths migrate satisfactorily explains the observed phenomena. My conclusion is that the army cutworm oviposits only on the Great Plains in the fall, that moths migrate to the Rocky Mountains following emergence the next spring, and that the same individuals return to the plains again in the fall."

The seasonal migration of the army cutworm adults is not totally unique. Many insects are known to migrate (Johnson 1969) and in lepidoptera, many types of moths and butterflies have some form of migration. Johnson (1969) classified the different types of migration in insects. He describes the type exhibited by the army cutworm as Class IIIb; that is, the emigration to hibernation or estivation sites and return by the same individuals after an imaginal diapause. Several moth species other than the army cutworm also belong to this category. In Australia, mass migrations and summer moth assemblages in several mountain ranges by the bogong moth, *Agrotis infusa* (Boisd.), have been documented by Common (1952, 1954). In India, Kapur (1955) presented evidence for the mass migration of the greasy cutworm, *Agrotis ypsilon* Rott., in the Himalayas. Another moth with similar habitats is *Euxoa sibirica* Boisduval. Mass migrations and estivation of this insect at high altitudes in the Tohoku District of Japan were reported by Oku et al (1972).

Laboratory Rearing

Since research first began on the army cutworm, workers have brought the insects from the fields to their greenhouses and laboratories for rearing. This permitted first hand study of the insect. Initially the larval stages were placed on natural food plants until development was completed. Cooley (1916) was unsuccessful with larvae in large cages but his results were good when the caterpillars were confined individually in tin boxes. Pupae were also collected from the field and allowed to emerge in cages in the laboratory (Cooley 1916). Adults from light trap collections (Pepper 1932a, Jacobson 1960, and Sutter and Miller 1972) have also been used for starting new colonies.

Adults

In our laboratory adults were caged in 1 gal. ice cream cartons for oviposition. Food was always provided. It has been determined that adults require food for subsistence, oviposition, and increased longevity of both sexes (Pruess 1963). Most workers have fed their laboratory colony adults a 10% solution of honey and water but Sutter and Miller (1972) fed a mixture of beer, sucrose, and ascorbic acid (12 oz., 25 g., and 1.25 g., respectively). Research is needed on the effects of adult diets on oviposition, particularly for this long-lived species.

Oviposition

In the field it has been shown that oviposition only occurs after a long period, which some call estivation. Because of this, under laboratory rearing culture, there seems to be a special requirement for conditioning before ova will develop. Blakeley et al. (1958) incubated adults at 15°C for 30 days and then placed them at a temperature of 25°C. Egg production was good. Jacobson and Blakeley (1959) did not mention a low temperature pre-incubation of adults but experienced good oviposition at 10°, 15°, 20°, and 25°C. Photoperiod may play a part in oviposition, particularly on the duration of the pre-oviposition period. Sutter and Miller (1972) maintained their adults, with success, at a constant temperature of 24°C with 12-hr. photophase. On the other hand, Lutz and Pruess (1959) recommended mild refrigeration of adults to induce them to mate in captivity. While these workers seemed to have no difficulty with egg production we have only been successful in obtaining oviposition in our laboratory under special conditions. Only when adults were preincubated at a low temperature (10°C) and then maintained at 16°C in darkness were they induced to lay eggs. Moths maintained at room temperature (25°C) in spite of pre-incubation at low temperature (10°C) and the several photoperiods tried, showed no egg development upon dissection. Hinks and Byers (1976) appeared to have similar problems when moths failed to produce eggs under a 16-hr. photoperiod after several months. Struble (1977), on the other hand, stored females for at least 44 days at 10° in the dark, followed by 7 days at room temperature with 14 to 16 hr. of light and they responded with a better sex pheromone extract than with other regimes tested. However, he did not mention egg production which, it seems to us, requires holding adults at something less than room temperature. Fall collected wild adults require no conditioning for good oviposition.

Eggs

Workers generally provide small dishes of soil as oviposition sites. It has been shown by Pruess (1961b) that females respond ovipositionally to differences in soil color, texture, and depth; and that a light-colored sand fulfilled all requirements and was preferred over soil. From his study, the ideal ovipositional container might be ⅛ in. of fine white sand in a shallow petri plate. A slot, the size of the petri plate, in the side of the cage permits removal without disturbing the adults. Eggs are laid singly and in groups in the soil or sand and are collected by most workers on a 50 or 60 mesh screen from presifted soil or sand. Sutter and Miller (1972) surface sterilized their eggs. This they accomplished by submersing eggs in 10% formaldehyde for 30 min., rinsing with distilled water, and air drying on a Buchner funnel. Eggs are kept on moist filter paper in the laboratory since moisture promotes hatching as reported by Jacobson and Blakeley (1959). Jacobson and Blakeley also found that fully incubated eggs would hatch when temperatures were only slightly above O°C. Most eggs hatch in about 5 days at room temperature. According to Blakeley et al. (1958) fully incubated eggs (about 5 days at 25°C) can be stored at 0°C for up to 30 days.

Larval Diets

Natural food has been used frequently to rear army cutworm larvae. Blakeley et al. (1958) tried wheat and barley sprouts, and leaves of lettuce, dandelion, and alfalfa. Dandelion, supplied fresh daily, proved to be superior in producing large larvae of uniform size. Jacobson and Blakeley (1959) compared alfalfa and dandelion as larval diets. Dandelion was again superior, producing only six larval instars compared to seven for alfalfa. Alfalfa also extended the larval period, produced lighter pupae, and the resulting moths laid fewer eggs. Struble (1977) started with fresh dandelion leaves and fed wheat sprouts to second generation larvae. Although the types of natural food that have been tried in the lab have been limited, it seems that many other types would be suitable, perhaps even superior, judging from the long list of host plants discussed previously. Cooley (1908), perhaps for lack of other green material, reared "to full size a large number of the caterpillars in our greenhouse in the winter of 1906-7 by placing in their cages pieces of green lawn sod (blue grass) from over steam pipes passing from one building to the next."

Sutter and Miller (1972) developed an artificial diet to replace natural food for feeding larvae. For rearing large numbers, the technique is much more convenient and efficient, saving labor and space. The diet closely resembles the wheat germ-casein diet used in rearing many types of lepidoptera but with the addition of raw linseed oil (1 g/4 l.) and several new formulation techniques. Five to eight larvae are reared together in 1 oz. cups for 14 days, then separated to fresh diet cups. Larval feeding lasted 30 days on the diet with seven instars. The survival and adult recovery was excellent.

In our lab, we have tried two additional diets, a modified bean diet (Burton 1969) and a bean-casein-wheat germ combination used for other cutworms at the Ohio Agriculture Research and Development Center, Wooster (T. Archer, personal communication). Both diets were successful in producing healthy appearing adults. Development times were essentially the same as mentioned above: eggs, 5 days; larval stage, 30 days; and pupal stage, 14 days. We have chosen to use the modified bean diet because it is easier and quicker to formulate.

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