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L. O. HOWARD, Entomologist and Chief of Bureau.

THE ALFALFA CATERPILLAR.

BY

V. L. WILDERMUTH,
Agent and Expert.

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[Cir. 133]

United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE ALFALFA CATERPILLAR.

(*Eurymus eurytheme* Boisd.)

By V. L. WILDERMUTH, Agent and Expert.

INTRODUCTION.

The insect under consideration in this circular is the caterpillar (fig. 1) of one of our most beautiful and common butterflies (figs. 2, 3) belonging to the group known as "the yellows," and is closely related to the well-known cabbage butterfly. The name "yellows" at once gives one an idea of the appearance of the adult, but this may be misleading, as the species is polymorphic, the coloration varying from a bright yellow (very frequently noticed), through an orange-sulphur (the most commonly noticed), to a pale white (the least often noticed).



FIG. 1.—The alfalfa caterpillar (*Eurymus eurytheme*): Larva or caterpillar stage. About twice natural size. (Original.)

For some years past the green caterpillars of this butterfly have been reported from various localities in the southwestern United States as feeding on, and in some cases doing a large amount of damage to growing alfalfa (*Medicago sativa*). It should be mentioned here that it is the caterpillar or worm stage of this species that does the damage, and not the adult butterfly. The latter feeds on the nectar of the bloom and in no way injures the plant. In fact, the writer has noticed these butterflies to all appearances springing the pollen triggers on the alfalfa blossoms while feeding, thus, should his observations prove correct, benefiting the plant for seed production.^a In the year 1906 a correspondent of the Department of Agri-

^a Though the author is quite confident of the accuracy of his observations, it is a case where misconception is exceedingly liable to occur; if correct, however, the fact is entirely new. See Dr. I. Urban, *Verhandlung des Botanischen Vereins der Provinz Brandenburg*, 1872, p. 13; Herman Muller, *The Fertilization of Flowers*, par. 93 and 94, 1873; C. V. Piper, *Report of American Breeders' Association*, 1909, *Report of Committee on Breeding Forage Crops*—F. M. WEBSTER.

culture reported the caterpillar infesting the lucern fields in Big-horn County, Wyo., and in the year 1907 another correspondent reported it as a "cutworm," damaging the alfalfa at Hanford, Cal. This caterpillar is also known to have injured alfalfa in Utah. In 1909 Mr. C. N. Ainslie, of the Bureau of Entomology, found the eggs

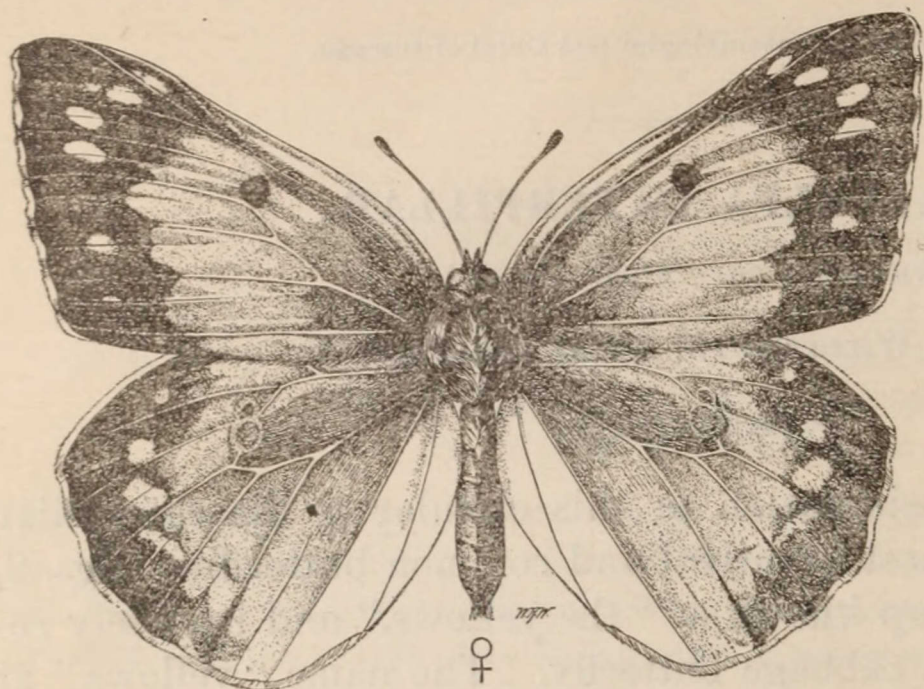


FIG. 2.—The alfalfa caterpillar (*Eurymus eurytheme*): Female in the adult or butterfly stage. One-half enlarged. (Original.)

and larvæ of this species on alfalfa at Springer, N. Mex., but doing no apparent damage. In the same year Mr. E. O. G. Kelly, also of the Bureau of Entomology, found the larvæ feeding on alfalfa at Wellington, Kans. In Arizona, in the Salt River Valley and in the Yuma Valley, farmers say that on an average

about one year in every three or four the "worms" become sufficiently numerous to cause considerable damage. In the Sacramento Valley, and in the irrigated alfalfa regions of south-central California, according to Mr. W. E. Packard, of the California Agricultural Experiment Station, the butterflies are quite numerous during certain years and cause more or less damage.

However, not until alfalfa began to be widely grown in the newly irrigated region in the Imperial Valley of southern California did the butterfly assume such proportions, and appear with such regularity each season, as to become a dread to the farmers, particularly to those confining their efforts wholly to alfalfa growing.

It was in 1909, after a season when the larvæ had taken all of one crop of hay, causing a loss of hundreds of dollars on his 320-acre ranch, as well as a similar loss to dozens of other ranchers in the valley, that Mr. J. A. Walton, of the Imperial Valley, wrote the United States Department of Agriculture asking for a remedy or a

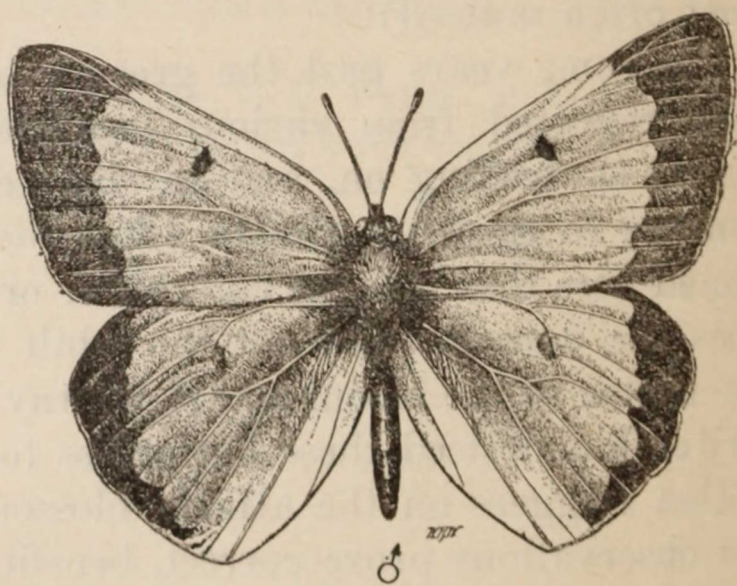


FIG. 3.—The alfalfa caterpillar (*Eurymus eurytheme*): Male in the adult or butterfly stage. One-half enlarged. (Original.)

method of dealing with the pest. As no remedy was known, plans were at once begun for investigating the outbreak and if possible working out some plans of controlling the same.

This circular is a partial report of the work done by the writer in the Imperial Valley the past season (1910), and while the investigation is still under way, another year being necessary to complete the same, it is thought desirable to give to the farmers in the alfalfa-growing section of the country the information secured, it being of such a nature as to be of great immediate benefit, if put to practical use, in controlling the pest.

DISTRIBUTION.

According to Scudder, this species is more especially a western insect, being, as a rule, much more abundant west of the Mississippi River than east of it, and although its range extends eastward it is rather rarely found east of the Allegheny Mountains. In the West it occurs from Mexico northward into the Dominion of Canada, thus covering the chief alfalfa-growing section of the United States. It is especially abundant throughout the regions where irrigation is most extensively followed.

DESCRIPTION OF THE SPECIES.

A meager description is given here of the various stages of development, in order to enable the casual observer to recognize the different forms:

The adult (figs. 2, 3).—The wings of the adults vary in color from yellow to white, being usually a sulphur-yellow above, with black outer margins, a conspicuous black spot in the center of each fore wing, and a faint yellowish spot in the center of each hind wing. The underside of the wings is of a lighter shade than the upper surface and is the side noticed when the butterfly is at rest with its wings folded above its back. The wing expanse is nearly 2 inches; in some it is a little less than this and in a few a little more.

The egg.—The eggs (fig. 4) are small, only 0.06 inch long, with from 18 to 20 slightly raised longitudinal ridges or ribs, broken by cross lines. They are elongated, white when laid, but turning reddish brown after the second day, and are deposited upright, with the basal end attached usually to the upper surface of the leaf. They are always deposited on fresh, green alfalfa, and never on dry or partially matured alfalfa.

The larva.—The full-grown larva (fig. 1) is usually 1 inch long, sometimes a little over, dark green in color, with a white stripe on

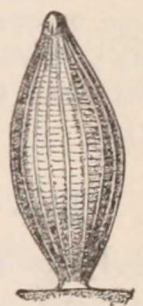


FIG. 4.—The alfalfa caterpillar: Egg. Greatly enlarged. (Redrawn from Scudder.)

each side, partially broken by black and red dots at each spiracle. There is often an intermediate, narrower, and less distinct white line just above each of the lateral lines. In some specimens a black or dark-green median dorsal line is also present.

The pupa.—The pupa (fig. 5) is yellowish green, has no cocoon, and is found head end up, attached by two threads, one of them forming a swing, to an alfalfa stalk.

INVESTIGATIONS IN THE IMPERIAL VALLEY OF SOUTHERN CALIFORNIA.

The investigations were begun by the author about the middle of March, 1910, and carried on through the summer until late in the fall of the same year. The writer was at first located on the J. A. Walton ranch, in the extreme southeastern part of the valley, and later at El Centro, where the work was carried on in cooperation with Mr.

Walter E. Packard, an agent of the California Agricultural Experiment Station, to whom a great amount of credit is due for the assistance and timely suggestions offered.

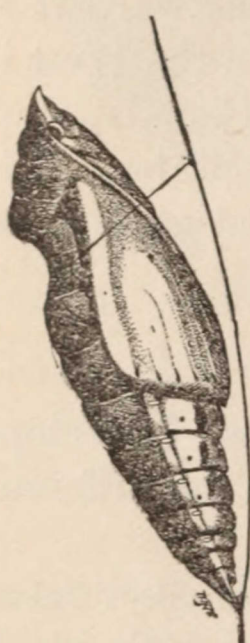


FIG. 5.—The alfalfa caterpillar (*Eurythmus eurytheme*): Pupa or chrysalis stage. Twice natural size. (Original.)

The Imperial Valley is a place unique in location and altitude. It is an irrigated region entirely surrounded by mountains and desert. The major part of the valley lies below sea level—some of it, in fact, as much as 250 feet below. The weather is warm most of the year and hot the rest of the year. It hardly ever rains, and the humidity is usually very low. The growing season extends over practically the entire year, there being an entire lack of freezing weather during some winters. On the average there is not during the year more than one month of weather that could be called winter weather.

The conditions just referred to serve to explain the immense numbers of these butterflies in the valley. The period over which the butterflies are able to continue breeding without being molested is very long, being from March to December. Then, too, owing to the very low humidity there is usually insufficient moisture to permit the development of what appeared to be a contagious disease, resembling in effect *flacherie* of the silkworm. This disease was found to be largely responsible for keeping this butterfly in check in other parts of the State of California and in southern Arizona.

SEASONAL HISTORY IN THE IMPERIAL VALLEY.

On the 15th of March, 1910, several adult individuals, possibly adults that had issued from hibernating pupæ, were caught in the act of flying over alfalfa fields and placed in a large mosquito-bar

cage which covered an alfalfa plant. These immediately deposited eggs. It can be said, therefore, that the hibernating forms issue between March 1 and March 20. The season of 1909-10 was exceedingly cold in the valley, while that of 1910-11 was, up to the middle of February, precisely the reverse, and up to the 8th of this month larvæ had been found present in limited numbers in the fields. It seems, therefore, probable that during some winters the species may breed throughout the entire season, as sometimes there is hardly a frost. Either the larval or pupal stage, or both stages, would during such winters be merely lengthened, for that is really what happens in the spring or fall of the year, and thus the insect could hardly be said to hibernate. However, eggs were being laid on March 15, and possibly a few days earlier, and these gave rise to the first or spring generation. This generation was very slow in developing, requiring about 44 days, the egg stage being 6 days, the larval stage 30 days, and the pupal stage 8 days. As the weather became warmer each of these periods gradually lessened until in the third generation only 22 days were required for complete development, the egg stage in this case being 4 days, the larval stage 12 days, and the pupal stage 5 days. These were the periods of development for individuals confined in cages; in the field a few days longer, often as many as four or five, seemed to be required for development from egg to adult.

The first generation covered the period from March 15 to April 30; the second generation from May 1 to May 28; the third generation from May 28 to June 20; and the fourth generation from June 20 to July 15. There were thus four distinct generations, the last being less distinct than the others. Later in the year the generations became so largely confused that it was impossible to separate them. Just as the fourth generation was beginning to pupate, the supposedly contagious disease before mentioned killed a large majority of the larvæ present at the time, and thus observations along life-history lines were checked. From this time on, scattering individuals produced eggs and gradually increased in numbers up to October, after which time quite a few worms were present in some fields, and often considerable damage was noted. In fields that had been green during August, when the water supply was short in the valley, there were always more of these caterpillars noticed than there were in fields that had not been green during the month stated. This was due to the fact that the worms were able to feed in these green fields, and therefore in the fall there remained quite a number of adults. By the middle of October, as the nights became cool, the larvæ and pupæ did not develop as rapidly as during the summer months, and the species just held its own in numbers up to December 28, 1910, when all were in the hibernating stage.

TWO CLASSES OF RANCHES—PASTURE RANCHES AND HAY RANCHES.

The alfalfa ranches in the Imperial Valley, Cal., can all be divided into two classes: (1) Pasture ranches, or those devoted entirely to the fattening or pasturing of cattle and hogs, and (2) hay ranches, or those on which the crop is utilized for hay. For convenience we can look at these separately.

Pasture ranches.—It was noticed early in the summer, and the writer's attention was called to the fact by a number of farmers, that ranches devoted to the raising of stock, either cattle or hogs, were rarely, if ever, seriously affected by the pest. On some dozen such ranches visited and inspected very few worms could be found, and the butterflies flying over the fields were never numerous. At first this was considered entirely due to the fact that there was hardly ever any bloom present for the adults to feed upon and that the greater part of the fields was kept grazed quite closely, making the condition in pastured fields less favorable for the laying and development of the eggs. Under such conditions the number of eggs deposited is greatly reduced. Many of the eggs laid on the young growth under such conditions are destroyed by the grazing of the stock, and the percentage that develops is kept to a minimum. Later in the season it was noted that on the stock ranches visited the disease previously mentioned, which is common to lepidopterous larvæ, was more prevalent than on hay ranches. All the factors determining this difference have not been ascertained, but the fact itself is quite significant.

On some of the ranches coming under the writer's observation the alfalfa was allowed to grow for some four weeks, or until it reached the height of about 20 to 24 inches. Cattle were then turned into the field, and within a few days the alfalfa became trampled. The ground and the alfalfa were very moist, there being more or less dew present every morning, and droppings from the cattle and hogs naturally brought about a foul condition in the field, assisting in the retention of moisture. Whether as a result of these conditions or as a coincidence, the contagious disease appeared to the writer to be much more prevalent in these fields than elsewhere.

Hay ranches.—It is on ranches and fields from which successive crops of hay are taken that the height of the damage is reached. In such fields the conditions for the development of the species are as nearly ideal as possible, and here the worms are ordinarily unmolested in their feeding and growth. The period elapsing from the time that one crop is cut until another is ready to harvest so nearly coincides with the length of the period necessary for the development of any one generation of the butterfly that the cutting of the hay, as ordinarily carried on, does not reduce their numbers or disturb their work, since the worm will likely be in the advanced stage

or, perhaps, have passed into the pupal stage before the crop is cut off.

Many fields observed by the writer were attacked in strips or patches. Sometimes one border would be almost totally devoured, while an adjoining plot would not be molested. Again, in other fields irregular patches would be attacked and the rest of the field not materially injured. In cases where whole borders of alfalfa were injured, the time and amount of water applied in irrigating produced an uneven growth, and as the generation of butterflies, on issuing, chose for egg-laying the strip that was the greenest and freshest, this strip would be the one damaged. It seems possible to account for the irregular patches in the same way—that is, considering that these patches were ones that were held back because of the condition of the soil. The soil conditions in one part of the field may be quite different from those in another part of the same field, and thus a varying growth of the crop results, which would be attacked in patches.

FOOD PLANTS.

Besides alfalfa the larva is known to feed upon the two buffalo clovers, *Trifolium reflexum* and *T. stoloniferum*, which probably constitute its original native food plants. It also feeds upon white clover (*T. repens*), and in California on *T. tridentatum*, but is said not to attack red clover (*T. pratense*). Other food plants noted by Scudder are *Hosackia*, ground plum (*Astragalus caryocarpus*), and *A. crotalariae*. The butterfly is known to oviposit on *Medicago hispida*, and at Indio, Cal., on July 1 the writer found larvæ feeding on sweet clover (*Melilotus alba*), which strangely enough they seemed to prefer to a patch of alfalfa growing close by. Eggs were also observed to be very numerous upon the leaves of the sweet clover at the same time.

INSECT ENEMIES.

The white eggs of tachinid flies were always in evidence wherever any larvæ were to be found, and the young of these destroy quite a large number of worms. In one instance it was noted that as many as 15 per cent of the worms had tachinid eggs on them. Because of the supposedly contagious disease, as shown in a following paragraph, little success resulted from rearing these parasitic flies. Five specimens were reared from the larvæ of *Eurymus*. These were all of the species *Euphorocera claripennis* Macq. (fig. 6). One specimen, determined by Mr. D. W. Coquillett, of this bureau, as *Masicera* sp., was reared from the pupa of *Eurymus*.

Two species of hymenopterous parasites were reared. From the *Eurymus* larvæ several specimens of *Limnerium* sp.—all females, how-

ever—were reared, while one specimen of *Chalcis ovata* Say (fig. 7) was reared from a pupa of *Eurymus*. It seems from this that the

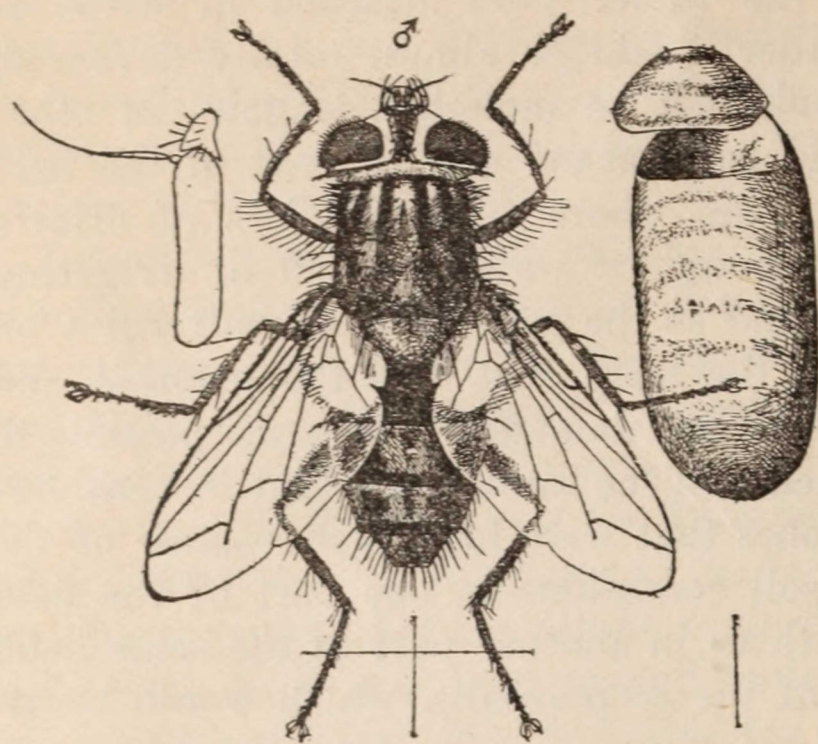


FIG. 6.—*Euphorocera claripennis*, a parasite of the alfalfa caterpillar: Adult and enlarged antenna of same; puparium. Enlarged. (From Howard.)

hymenopterous parasites are much in evidence, although if the material had not been affected by the supposedly contagious disease many more might have been secured.

The cotton bollworm mistaken for an alfalfa caterpillar.—A large green caterpillar known as the bollworm, *Heliothis obsoleta* Fab. (fig. 8), that can be distinguished from the *Eurymus* because it is of a lighter green color, about one-

fourth larger, and hairy and rough in appearance rather than smooth, with three black lines traversing its body lengthwise, is quite prevalent in the Imperial Valley, and is often mistaken for the

alfalfa caterpillar by many farmers. Mr. E. O. G. Kelly and Mr. T. H. Parks, agents of the Bureau of Entomology, working at Wellington, Kans., in the summer of 1909 also noted this species and reported it as being of a predaceous habit.^a As noted in the valley, it was found to do very

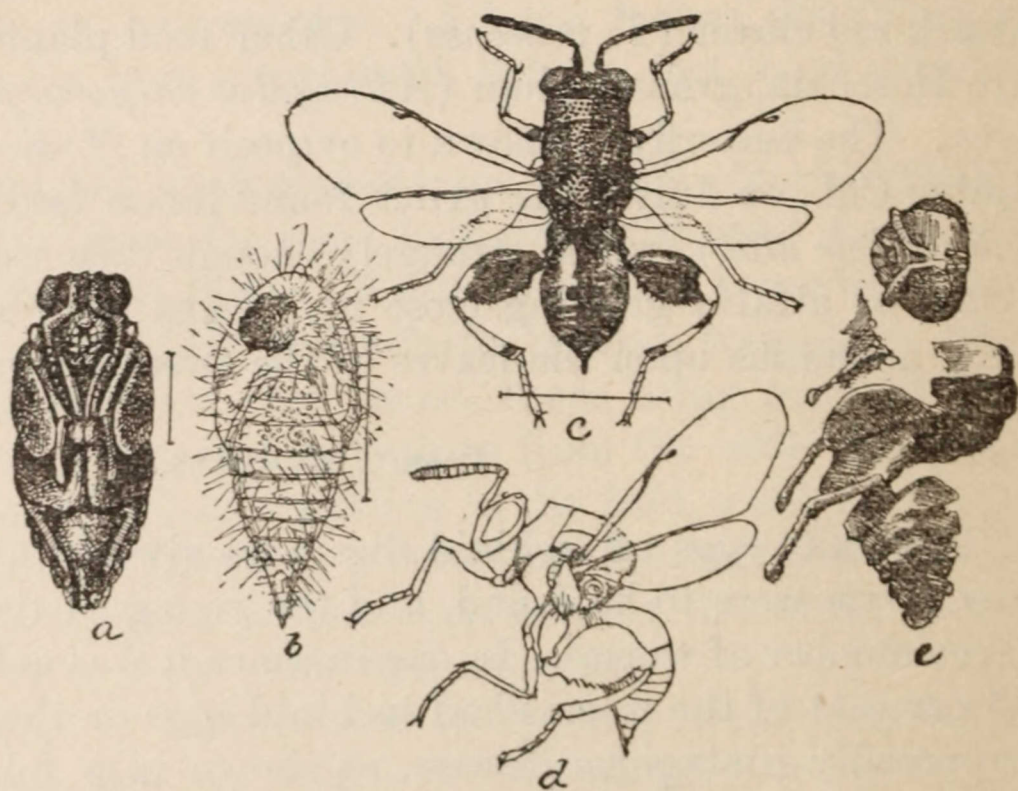


FIG. 7.—*Chalcis ovata*, a parasite of the alfalfa caterpillar: a, Pupa; b, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); c, adult; d, same in profile; e, pupal exuvium. Enlarged. (From Howard.)

little damage to alfalfa, but to be a ravenous enemy of the alfalfa

^a This cannibalistic habit has also been observed in Texas by Quaintance and Brues. Bul. 50, Bur. Ent., U. S. Dept. Agr., pp. 79-80, 1905.

caterpillar, never eating alfalfa as long as it could find the larvæ or pupæ of *Eurymus* around.

One of these larvæ ate 5 larvæ of the *Eurymus* during a single day, and on May 25 the writer counted many dozens of pupal cases in the field that had the contents eaten out. Each case had an irregular opening eaten into it; sometimes the end of the abdomen would be eaten away, and again the opening would be on the side, often the entire side being destroyed. Upon further search the larvæ of *Heliothis* were found in the act of devouring the pupæ and were thus responsible for the damage.

OTHER NATURAL ENEMIES.

Larval disease.—The most common natural enemy observed was a supposedly contagious disease which there has not yet been an opportunity to carefully study. This was prevalent all over the valley and is present at all seasons. It destroys both the pupa and larva, but more often the larva. The worms when attacked by the disease turn a lighter green, become sluggish, and in a day or two are nothing but a soft, decayed mass, usually found hanging to the alfalfa stalks. The development of the disease apparently depends upon moisture, as it is more often noticed in moist fields. The fact that it does not

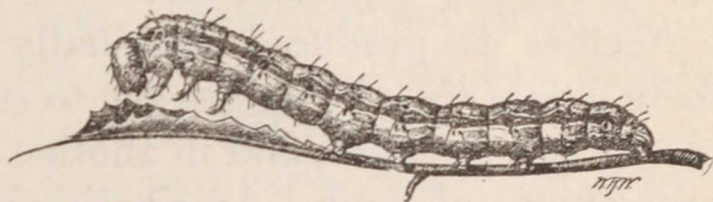


FIG. 8.—Bollworm (*Heliothis obsoleta*), an enemy of the alfalfa caterpillar. Twice natural size. (Original.)

at all times keep the worms in suppression is without a doubt due to the fact that the climate of the Imperial Valley is very dry. Larvæ brought to the laboratory for rearing of insect parasites and for life-history studies in a large percentage of cases died of the disease as soon as confined. A quantity of worms sent to Berkeley, Cal., by Mr. Wilsie, of the Imperial Valley horticultural commission, for experimental rearing of parasites, all died of the disease, either before reaching their destination or the day after. During the first week of July the humidity was exceptionally high for the Imperial Valley, and at the time about 95 per cent of the larvæ in the valley succumbed to disease, thus saving a hay crop for a great many of the farmers, but stopping experiments almost completely. It is probable that this disease has occurred in years past, and it may occur in future years, at some time during the summer season, in such abundance as to destroy a brood, as it did in the past year (1910).

It seems to be partly due to this disease that the alfalfa caterpillar does not appear in such large numbers in other regions of the Southwest, notably in alfalfa regions in Arizona. Here there seems to be greater humidity and more moisture, and the disease is able to keep the number of worms reduced to a minimum.

It is the intention of the Bureau of Entomology to repeat these observations and experiments in the Southwest during the summer of 1911, and in order to do so the bureau would be glad to cooperate with any farmers who wish to put their farms or ranches under a rigid system of control. The greater the number of farmers following this plan the greater the beneficial results that may be expected.

METHODS OF CONTROL.

INSECTICIDES.

In dealing with insect pests affecting cereal and forage crops it has proved possible in only a few instances to control them by the use of any of the various insecticides or poisons. The reason for this lack of success lies largely in the fact that such crops are distributed over a wide area and the expense of application of any insecticide as a control measure is necessarily high, while a lack of thoroughness is likely to arise when one tries to keep the expense of treatment down to an economical basis.

Since the alfalfa hay is fed to stock, it is not possible to use any of the arsenical poisons against the caterpillar of the alfalfa butterfly. A few experiments were tried by using pyrethrum or "buhach." As this is not a poison, and since its fatal effect upon the larvæ of butterflies is produced externally through their breathing pores, there would thus be no danger to stock. Pyrethrum was used in one case at full strength, and in another instance it was diluted with equal proportions of flour. An application was made by dusting this substance from a cheesecloth sack, following the primitive method of applying Paris green to potato vines, at the rate of 3 pounds of pyrethrum to the half acre, which in the case of diluted material would make $1\frac{1}{2}$ pounds of pyrethrum to the half acre. This first test was tried on July 8, and no results were obtained, because of the fact that just two days later practically all of the worms in the field where the test was being made were destroyed by the malady before mentioned. The same experiment was repeated, however, on September 22, and in this case also the results were negative, not a caterpillar being killed. It would seem, therefore, that the application was not sufficiently heavy to kill the worms, and that to have increased the amount of pyrethrum applied might have resulted in the eradication of the pest; but as the cost of pyrethrum at the rate of 3 pounds to the acre is already nearly \$2, without considering the expense of application by hand, this would be out of consideration from an economic point of view. However, the excellent results obtained through the use of pyrethrum in the case of other insects will justify further experimentation along this line, and it may be possible to use it in the smaller fields.

SYSTEM OF CROP CULTURE.

For the reasons just given the control problem, in dealing with this alfalfa pest, resolves itself to one of the method of handling the crop. Not long after the Bureau of Entomology began observations in the Imperial Valley the writer was informed by well-to-do ranchers that not all alfalfa fields or even all ranches were affected by the caterpillars, there being apparently certain conditions regulating the devastation. One cause for this, as noted earlier in this paper, was the presence of stock in certain fields, but even in hay ranches there was a variation in the numbers of the caterpillars. Accordingly there was outlined a series of experiments in which, in certain fields under observation, definite methods of management were tested to see whether some of them would not reduce or perhaps entirely eliminate the damage. Before describing the conditions existing in these fields it would be well to consider, first, the conditions existing in certain other alfalfa fields not under the direction of the agents of the bureau which suffered greatly because of the pest, the owners often losing an entire crop. The first fact noted was that the caterpillar damage in such fields seemed to be correlated with the condition of the soil. A field seriously damaged often revealed a poor soil; at least, a soil not well adapted to alfalfa culture, and consequently producing a slow-growing crop. Of course, not all the fields damaged were of such poor soil, for some of the very best alfalfa fields were seriously ravaged, but in these latter cases this was attributable to other factors, such as time and careless manner of cutting and time of irrigation. The sandy loams or light soils are the best for alfalfa production, and consequently least damaged. A heavy soil can be greatly improved and the growth of the alfalfa increased by deep plowing and thoroughly preparing the seed bed at time of seeding the crop and then renovating the alfalfa yearly by disking or by the use of an alfalfa renovator.

The worst conditions noted were those in which the attack of the caterpillar was due to delayed cutting of the hay crop and due quite often to the fact that many of the ranchers were trying to cultivate more land than it is possible for one man to farm successfully. With such ranchers some of the following defects are observable in their treatment of the hay crop: First, there is often insufficient water used to provide for the prompt development of the alfalfa crop. An abundance of water is very necessary, as it enables the alfalfa to make faster growth, and thus the farmer can reap his crop sooner and before the caterpillars have effected much damage. Second, the crop is not cut early enough in the majority of cases—about 90 per cent—that is, the alfalfa is too far advanced in bloom when cut, and this delayed cutting enables the caterpillars to mature successfully. The

alfalfa should be cut just when it is beginning to bloom. Other noticeable factors which tended to hamper control measures were that at haying time the crop was cut high, the turning corners were left ragged, and the ditch banks and borders poorly mowed, if at all, and thus the caterpillars that were present and had not gone through to the adult stage had a large amount of material upon which to develop, and soon did so, so that the butterflies from these were ready for the next crop. These places would also afford bloom which would naturally attract the butterflies.

For fields in which good cultural conditions were to be created and in which methods were to be inaugurated that would not further the development of the caterpillars, 10 locations were selected and used as a basis of work. From what was said in the previous paragraph it will be readily seen that the thing to be done in these fields was to put them under a system that would remedy all or part of the defects noted in other fields.

As has been mentioned before in this paper, four generations of caterpillars were observed in the Imperial Valley the past year (1910). A large part of the damage was due to the caterpillars of the third and fourth generations, the first and second not being numerous enough to assume any serious aspect. The task, then, was to keep their numbers below the point at which they could do any considerable damage. The time to start this control work was naturally with the earlier generations. The ten fields mentioned (no two of which had had the same conditions of culture previous to that year, and which had all suffered more or less damage the year before, namely, in 1909) were given what might be termed clean culture, or careful management. Just as soon as possible after removing a crop of hay, using the methods to be described later, the field was irrigated thoroughly, thus starting the growth quickly. The field was again irrigated as soon as the dry condition of the crop required, and thus the growth was forced and not allowed to be checked. It takes about 28 days to produce a hay crop in the Imperial Valley, a little longer than this in the spring and fall, and a few days less in warmer weather. It also takes just as many days as has been shown under "seasonal history" for the butterflies to develop from egg to adult. Now if the crop of hay be forced by frequent watering, or because of good soil conditions, the worms will not have gone into the resting stage at time of cutting, but, instead, will still be feeding on the green alfalfa, and when the hay is cut and removed conditions are rendered unfavorable for their development and their food supply will be correspondingly reduced. Therefore, the hay should be cut just as it is coming into bloom, which is a few days sooner than it is generally thought advisable to cut it, as a generation of worms will take a whole field in a short time. Thus not only will the hay

be saved, but the major portion of the larvæ, finding a lack of the food necessary for their complete development, will ultimately perish. To bring about this condition, however, it is necessary to mow the field carefully, leaving no high stubble. The turnrows, borders, and ditch banks should also be closely mown, as this will not only reduce the supply of food for the larvæ but also that of the butterflies, as such plants will afford considerable bloom. In two cases in the writer's experiments it became necessary to remove the fields at a cost of from 30 to 50 cents per acre, and then in all cases to irrigate promptly. As a result of this procedure a large percentage of the caterpillars failed to develop to the imago or butterfly stage. Deducting these, together with the larger number that failed to reach the pupal stage, it will be seen that there were many hundred less worms to attack the next crop, as each butterfly developing from them would have deposited at least 100 eggs. In some fields, instead of irrigating immediately after the hay was removed, the experiment was tried of letting the field go dry for several days, and thus starving the worms. While this gave good results it was not as satisfactory as the method of immediate irrigation, for there was always enough moisture in the field to start the new crop going and thus provide a little food for the caterpillars.

The complete success of these methods is dependent on cooperation among the farmers, for the larger the percentage of those who inaugurate a good cultural system the greater will be the benefit derived therefrom. The butterflies, however, do not fly very long distances, and as long as the conditions are favorable for their existence on one field or on one ranch they will remain there. They may, however, fly considerable distances when forced to do so for want of food or for fresh green alfalfa on which to deposit eggs or when driven by the wind, and thus it is that one farmer can secure, by his individual efforts, such remarkable results as are reported below.

RESULTS OBTAINED.

Of the ten fields cultivated according to these methods only one was damaged by the caterpillars up to July 10, the date on which so large a number of them were killed by the disease previously mentioned. This one field was damaged because irrigation had been delayed for nearly two weeks after the cutting of the second crop, owing to a new ditch which was under construction. Being a thrifty field naturally, the alfalfa had made a start, assisted by the moisture still present in the ground, and butterflies coming in from an outside field deposited eggs on this new growth, thus enabling the worms to destroy the best of the crop after it was finally irrigated. As a result almost an entire crop was lost. A field adjoining on the south, which had been

irrigated immediately after cutting, was not in the least damaged. This was a lesson in itself, as it indicated the necessity for prompt work.

PROTECTIVE MEASURES ADVISED.

Thus from a comparison of observations made in the two classes of fields it is possible to derive the following rules for handling the crop:

Do not abandon a field because the caterpillars are beginning to damage a hay crop. If the caterpillars threaten the destruction of a crop of alfalfa before the hay can possibly mature, mow it at once, cutting it low and clean, and in so doing starve a large majority of this generation of worms, thereby protecting the next crop as well as saving a part of the one already affected.

Get the ranch in the best possible cultural condition. Irrigate often and thoroughly and as soon after cutting as the crop of hay can be gotten off the ground.

Cut close to the ground and clean, especially along the ditch banks, borders, and turnrows, as well as in the main part of the field.

Cut the crop early. When just coming in bloom is the proper time. Watch for caterpillars in the early spring crop, and if many are observed about grown cut the hay a few days before it is in bloom, and thus save the next crop.

Pasture alfalfa whenever possible, as a minimum amount of damage occurs in such fields.

Use the methods just mentioned on early spring crops, no matter whether any worms are noticeable or not, and thus avoid any risk of having overlooked them. The satisfactory results must come from an application to an early crop.

Renovate every winter, either by disking or by the use of an alfalfa renovator, thus disturbing any pupæ that may be wintering over, and putting the land and alfalfa in condition for good growth the following spring.

These methods, while they will probably be of value in other sections, have been tried only in the Imperial Valley of California, and they are not specifically recommended for sections where climatic and other conditions differ from those found in this valley.

Approved.

JAMES WILSON,

Secretary of Agriculture.

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