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

PAPERS ON INSECTS AFFECTING VEGETABLES.

THE IMPORTED CABBAGE WEBWORM.

BY

F. H. CHITTENDEN, Sc. D.,

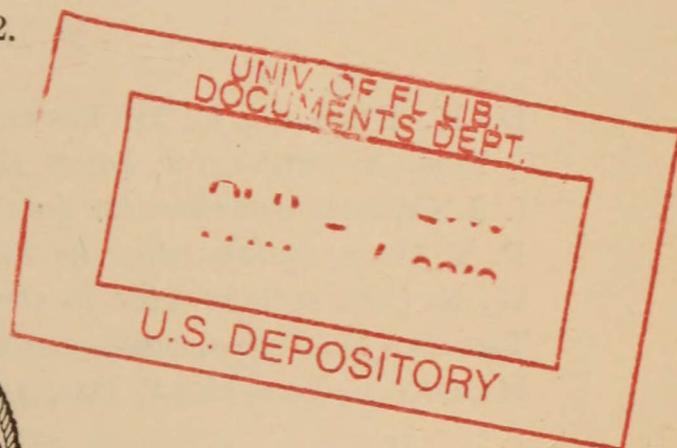
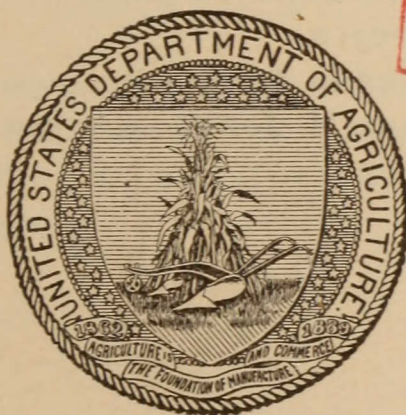
In Charge of Truck Crop and Stored Product Insect Investigations.

AND

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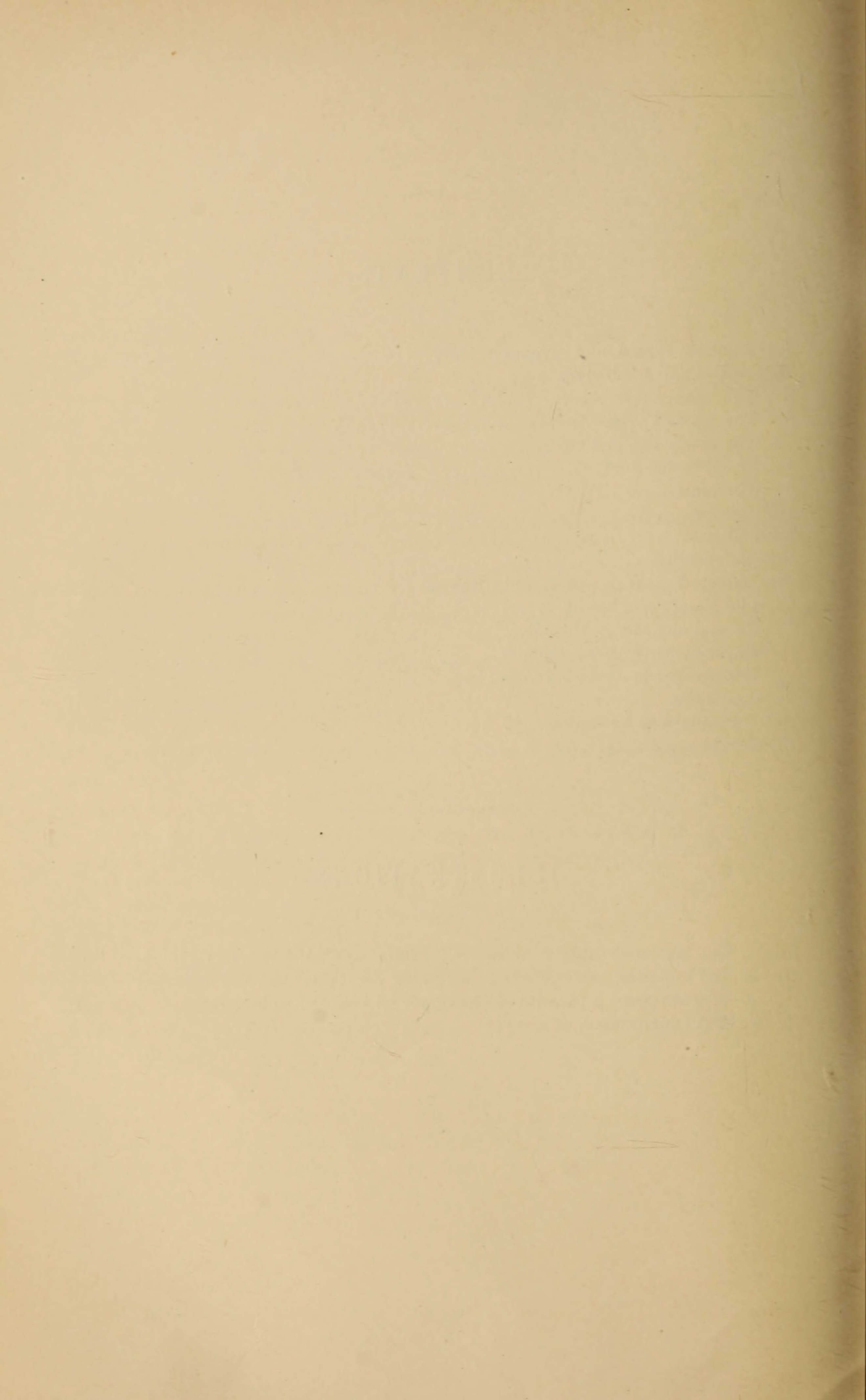
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(*Hellula undalis* Fab.)

By F. H. CHITTENDEN, Sc. D.,

In Charge of Truck Crop and Stored Product Insect Investigations,
and

H. O. MARSH, *Agent.*

INTRODUCTION, SPREAD, AND RAVAGES.

Beginning with the year 1897 the imported cabbage webworm (*Hellula undalis* Fab.) has repeatedly come under observation as a pest in new States and Territories, namely, in Florida, Mississippi, North Carolina, Texas, California, and Hawaii.

In 1907, Mr. H. M. Russell observed attack to collards at Lakeland, Fla., in June and July, to collards at Orlando, Fla., in July, and at Dade City, Fla., to cabbage in December. The species has undoubtedly been in that State for many years, since it has been known for more than a decade from South Carolina to Georgia, but this is the first record of injurious occurrence there.

In November, 1907, Prof. R. I. Smith reported injury to cabbage at West Raleigh, N. C. Whether this insect will be able to establish itself much farther north than the Carolinas is problematical. Our records show complete establishment throughout the Gulf States; in fact, the insect occupies a considerable portion of the same territory as that permanently inhabited by the harlequin cabbage bug (*Murgantia histrionica* Hahn), save that the latter, having been introduced many years earlier, is better known and occurs farther northward.

A review of the distribution of this species shows that it first came under notice as a pest in 1897, when it was destructive to crucifers about Augusta, Ga. Here it did great injury during that and the succeeding year. In after years it was observed in various other localities in Georgia, at Auburn, Ala., and at Charleston and Beech Island, S. C. Later it was noticed as a pest in Texas.

The list, which will be furnished under the heading of distribution, simply includes the localities reported to this bureau and is doubtless

far from being complete. The mere occurrence of this insect at Los Angeles, Cal., was observed as early as 1891 or 1892, but nothing further was heard of the insect in the Pacific States until 1907, when it was reported by Messrs. Ball and Titus, working on sugar beets in that same region.

In 1908 the species came under the observation of the junior author on several occasions in Orange County, Cal. In October it was found attacking horse-radish and cabbage at Santa Ana in the customary manner, namely, feeding in the heart, webbing the leaves, and eating out the tissues. At Garden Grove, Cal., it was attacking cabbage and mustard.

During June, 1908, Mr. D. K. McMillan observed this species on radish, cabbage, and kale at Brownsville, Tex., the plants being considerably damaged. The larvæ in most cases had destroyed the "buds" or had bored down into the center of the plants. They seemed to attack only the midrib of kale and most cabbage plants, feeding in a groove on the upper surface, which they cover with a web, varying this by eating a small cavity extending along the interior from one-fourth of an inch to an inch in some cases. Larvæ were observed on rape at Mission, Hidalgo County, and at Santa Maria, Cameron County, Tex. At Brownsville they were found in November on mustard cultivated for table use. At this time many were found with tachina eggs placed in the usual location near the head. Turnip tops were also affected, the work on turnip and mustard being similar to that observed on rape and radish. The larvæ concealed themselves along the midrib, boring down into it as well as along the groove, with a covering of silk under which they are fairly well protected.

From finding the insect in many localities, in several cases not in destructive numbers, Mr. McMillan expressed the opinion that the species in southern Texas is evidently largely controlled by parasites and other natural enemies, as most individuals observed, even in June, were parasitized. It is probable that the species is well distributed throughout nearly the entire State of Texas, and, although held in check during most seasons by natural enemies, there is always the likelihood that at any time it may crop out as a serious pest.

October 17, Mr. Charles M. Jones, Stallo, Miss., reported injury to turnip and collard. The larvæ were not so active when the weather was cool and appeared to work at all times of the day. An entire crop of collards was destroyed.

In Mississippi, also, Mr. M. M. High found larvæ September 9, 1909, in large numbers on cabbage and turnip near Columbia. He described them as beginning work by first spinning a web in which to retreat. They then eat out the ends of young plants and check their growth, besides causing the death of some of them. They did much damage, cutting out the "buds" of young cabbage, in addi-

tion to devouring the remaining leaflets and spinning their small but conspicuous webs over the plant. A grower here stated that the damage seemed greater that season than heretofore, and that he should have been marketing cabbage, but had none that had small heads, all having been destroyed by this larva.

He had tried to poison the larvæ with Paris green applied dry, but with little success. The webs prevent the poison in powdered form from reaching the caterpillar in its protected feeding quarters.

The insect infests the turnips to about the same extent as cabbage, while it seems to be not quite so serious with turnips.

September 16, 1909, the larvæ did considerable damage to cabbage and turnips at Kosciusko, Miss. When first hatched they are difficult to find, because of their habit of concealing themselves in the crotch of a stalk and turning the edges of the leaflet back, forming a domicile into which they retreat when not feeding.

September 24, this pest was seen in large numbers on turnips at Crystal Springs, Miss. Many had already transformed to adult, as many cocoons were found containing empty pupal cases. This pest had destroyed about 16 per cent of the turnips upon the plat and many dead leaflets were found among the remaining green ones, due to its ravages. Hundreds of moths were flying over the patch, alighting upon turnips and upon the ground. It was thought that the insect was destined to do greater damage before the season was over, as many larvæ were still spinning their webs and devouring the leaves.

The part of the plat most seriously affected by the pest was not nearly so well fertilized as the remaining portion. The portion where most damage was done was upon high dry land, while the remaining portion was upon damp rich soil. This same species was observed cutting buds from late cabbage at Columbus, Ridgeland, Starkville, and Gulfport, Miss. Mr. High wrote:

The moth undoubtedly deposits her eggs near the "bud," where they hatch, the young larvæ devouring the bud, spinning webs, tying the larger leaves together, one to three larvæ going to each leaflet, curling the edge of the leaf and forming an individual web, and, later, spinning a cocoon to transform into the pupal stage. The larvæ come out of these webs to feed and then retreat when their hunger has been satisfied. This is one of the most serious pests of the truck grower about Crystal Springs, Miss.

It is evident that this remark may apply to practically the entire State of Mississippi, and that similar conditions obtain in Georgia and South Carolina.

February 3, 1909, Dr. W. E. Hinds, entomologist to the Alabama Experiment Station, Auburn, Ala., wrote that he had received this species from Phoenix City and Montgomery, besides Auburn.

October 2, Mr. High reported that he had again found this pest at Gulfport, Miss., both upon late cabbage and turnips. Injury was

more serious on young cabbage, because the "buds" were being devoured and small webs filled with excrement were left in their stead. There was only a small plat of cabbage where, on the other hand, there were acres of turnips. The webs were distributed also over the turnips, some of them being empty, the larva having transformed to the moth. This pest was doing great damage to the two truck crops. Some other pests were associated with it and were doing some injury, such as the flea-beetle (*Phyllotreta bipustulata* Fab.) and the cabbage looper (*Autographa brassicæ* Riley).

During the fall of 1909 the late F. C. Pratt reported this webworm as a pest to cruciferous crops at Sabinal, Tex. About the middle of January, 1910, the junior author visited Sabinal and in company with Mr. Pratt examined the gardens where injury had occurred. The characteristic work of the larva was observed on radish and cabbage, which remained as crop remnants, but none of the insects was found. Mr. Pratt said he had taken an adult, out of doors, late in November and expressed the opinion that the insect might winter in the adult condition in that locality.

October 22 the larva was observed in large numbers at Columbus, Miss., upon cabbage, turnips, and collards grown by Mr. J. E. Slaughter. The larvæ bore into the stems of the cabbage and turnips for some little distance or eat out small crevices in the edges of the stems, enough to bury their bodies, and then, spinning a cocoon, they transform into pupæ.

November 2, 1909, the larva was found by Mr. M. M. High in large numbers at Starkville, Miss., upon turnips. The larva was observed in the crotch of every other plant, boring and hiding from the light. From one to three were found in the "buds." Fully 50 per cent of the turnip crop under consideration had the buds destroyed by this imported webworm. The plants attacked had small roots and looked stunted or checked in their growth.

This insect seems to do the greater damage to cabbage and turnips, although injury to collards is by no means slight, especially while the latter are young. The larva seems to prefer turnips in the row to those sown broadcast. There was not a plant, either cabbage or turnip, but that contained from two to many of these larvæ.

December 3, 1909, Mr. High found webworms of this species in large numbers in the crotch and stems of turnips at Hattiesburg, Miss., where they concealed themselves beneath their webs, destroying the most vital portion of the plant. One grower stated that this insect was a perfect nuisance to older plants and a menace to young ones. He said:

The little striped worm enters the bud of both cabbage and turnip when the plants are quite young and devours them, thus forcing the plant to grow a new bud and start or begin new growth—my first crop of cabbage in the spring being almost totally destroyed from the work of this striped worm.

The cabbage plat now appears to be unmolested by this larva, while nearly every turnip in the plat adjoining cabbage has one or more of the larvæ somewhere near the base of the stems or leaves.

A few mature larvæ were found at Brownsville, Tex., November 5, 1910, boring in stems of mustard and crowns of young cabbage plants. Evidence of past injury was common and indicated that the larvæ were more numerous in early October. Several cabbage growers stated that worms, which from their description were evidently this species, caused considerable damage in seed beds. One grower lost fully 50 per cent of his plants, which had the bud destroyed and were worthless for planting.

The following synonymy is recognized:

Hellula undalis Fab., Ent. Syst., vol. 3, 2, p. 226; Herrich-Schäffer, Eur. Schmett., vol. 4, pl. 8, f. 54.

Scopariaalconalis Walker, Catalogue, vol. 19, p. 827.

Leucinodes exemptalis Walker, Catalogue, vol. 34, p. 1313.

Botys rogatalis Hulst, Trans. Amer. Ent. Soc., vol. 13, p. 149.

The wing venation, head, and antenna are shown in figure 5.

THE EGG AND OVIPOSITION.

A pair of moths newly reared was placed in a vial July 24, and next morning the female was found to have deposited singly, doubly, and in masses of from 3 or 4 to 20, a total of 235 eggs. The following day 24 were laid; on the 27th, 37 were found, or 296 in all. Afterwards the moth died, having laid no more. A few eggs were found upon dissection, making the probable number usually deposited between 300 and 350.

Most of the moths die in confinement within a week.

The egg.—The egg is of sufficiently large size, about four one-hundredths of an inch in length, as to be readily discernible to the naked eye. It is of

FIG. 4.—The imported cabbage webworm (*Hellula undalis*): a, Moth; b, larva, lateral view; c, larva, dorsal view; d, pupa. All three times natural size. (From Chittenden.)

oval form and rather variable in contour, being usually more or less flattened upon the surface of deposit, and there is often a distinct nipple at one extremity. Its greatest width is about three-fifths its length. The color when first laid is light gray, and under a strong hand lens the surface appears to be rugose and strongly iridescent. Under a higher power the surface is found to be made up of depressed irregular areas, mostly hexagonal and pentagonal in outline.

Length, about 0.5 mm.; greatest width, 0.3 to 0.35 mm.

A day after deposition the eggs begin to take on a pinkish hue, due to light reddish spots below the surface. On the second day the embryo can be detected, the head showing as a blackish dot near one end and on the lower surface of the egg or the side of attachment.

Experiments conducted in the latter days of July, in a temperature officially rated by the Weather Bureau of this department as mod-

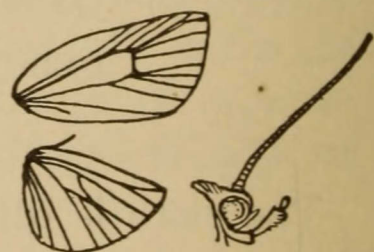


FIG. 5.—The imported cabbage webworm: Wing venation, head, and antenna. All enlarged. (After Hampson.)

erate (indoor 80° to 84° F.), showed that the eggs hatched three days after deposition, a rather remarkably short period for the eggs of a moth with a wing expanse of nearly three-fourths of an inch.

THE NEWLY HATCHED LARVA.

The larva when just hatched measures about a millimeter in length and about a twelfth that in diameter across the abdomen. The head, as is usual with young larvæ, is prominent, wider than the body, and dusky in color. The thoracic plate is also dusky and of somewhat similar subcrescentic form to the more mature stage. The body is very pale yellowish gray, nearly white, and the surface is moderately clothed with long, fine hairs.

Very soon after hatching the larva shows the characteristic striæ of the more mature form. Thus larvæ 2 mm. in length are so little different in general appearance from the full-grown ones as to be readily recognized as of the same species.

THE FULL-GROWN LARVA.

The full-grown larva, shown at *b* and *c* of figure 4, measures a little upward of half an inch in length, being about six times as long as wide.

The form is subcylindrical, tapering toward each extremity, widest near the middle—the third, fourth, and fifth abdominal segments being nearly equal. The general color is dull opaque grayish-yellow or yellowish-gray, striped with broad, somewhat irregular, brownish-purple, longitudinal bands, which extend from the second thoracic to the terminal or anal segment. These are bright and conspicuous on the dorsal and more feebly indicated on the ventral surface. The dorsal stripes are five—a moderately wide medial one, a broader medio-lateral on each side, and a dorso-lateral one, of about equal width with the median one, also on each side. On each side below are two lateral lines, faint, and interrupted toward the ends of each segment; a similar ventro-lateral line; and a much fainter interrupted median line.

The head is black and shining, the V-mark well indicated, the cervical or thoracic shield is shining, light, somewhat purplish-gray, and is rather variably marked with brown, which forms, each side of the median stripe of the second thoracic segment, two irregular longitudinal dark brown patches, darkest and widest toward the posterior margin. On each side above the spiracle of that joint is a shorter dark patch. Near this there are sometimes two or three small dark rounded spots. The spiracle of this segment is dark brown, the remainder being concolorous with the body. The thoracic legs are more or less infuscated, and the prolegs are nearly concolorous with the venter. The entire surface of the body is sparsely covered with moderately long yellow and light brown hairs, proceeding from small and shining piliferous tubercles.

The anal shield bears from 10 to 12 round purplish spots, the most posterior one the largest and standing alone, the remainder forming a subcrescentic pattern.

The length when in natural position at rest is about 13 mm. and when extended 15 mm., the width being a trifle more than 2 mm. at the widest part.

THE PUPA.

The pupa is moderately shining, light yellowish brown in color and the surface is covered with a light pruinose bloom. The eyes are dark brown, varying

to black, and the dorsum is marked by a median stripe. The contracted antepenultimate segment is noticeable. The anal segment terminates in two pairs of straight brown hairs. It is of rather robust cylindrical form, measuring about three-tenths of an inch (7.5 mm.) in length and one-twelfth (2 mm.) in width.

The somewhat peculiar outline of the abdominal segments is shown at *d* of figure 4.

Transformation to pupa and thence to imago takes place in a rather compact cocoon composed of webbed-up grains of earth, which the larvæ form after burrowing into the soil. Those before the writer measure about three-eighths of an inch (9 mm.) long and a little less than half that in width.

The notes which appear above, on the life history of the species, were made by the senior writer at Washington, D. C., where the temperature and other conditions are not materially different from those of the Eastern Gulf States.

DISTRIBUTION.

In previous articles it was stated that this species would probably not spread beyond certain natural boundaries, i. e., not much above the Lower Austral life zone. Thus far this prediction has been verified.

The following is the known distribution as recorded in this branch of the bureau: West Raleigh, N. C.; Charleston and Beech Island, S. C.; Auburn, Phoenix City, and Montgomery, Ala.; Augusta, Waycross, Tifton, Athens, Griffin, Montreal, Albany, Marshallville, Macon, Fort Valley, Meansville, and Leesburg, Ga.; Lakeland, Dade City, and Orlando, Fla.; Stallo, Columbia, Kosciusko, Crystal Springs, Columbus, Ridgeland, Starkville, Gulfport, and Hattiesburg, Miss.; Corpus Christi, Brownsville, Beeville, Mission, Santa Maria, and Sabinal, Tex.; Los Angeles, Orange County, Santa Ana, and Garden Grove, Cal.; and Honolulu and Wahiawa, Hawaiian Islands.

The foreign localities need not be repeated.

FOOD PLANTS.

The first record of injury by this species was to cabbage, turnips, and beets. October 14, 1897, Mr. N. L. Willett, a reliable correspondent of this department, estimated that the cost to the grower of these plants and collards in the county of Richmond, Ga., alone would amount to \$15,000 to \$20,000 during that year, while Mr. W. M. Scott, at that time State entomologist of Georgia, estimated, November 26, 1897, a loss to that county of \$50,000.

Besides cabbage, turnips and beets, collards, cauliflower, kale, rutabaga, radish, kohl-rabi, mustard, rape, horse-radish, and some other

cultivated plants, such as "Japanese radish," are subject to attack and injury. Among weeds and wild food plants are the common shepherd's purse (*Bursa* [*Capsella*] *bursa-pastoris*) and "pussley" or "cutter's grass," otherwise purslane (*Portulaca oleracea*).

NATURAL ENEMIES.

Natural enemies of cruciferous insect pests are of great value in keeping their hosts in check, and some dependence must be placed upon these agencies in restraining the undue multiplication of this webworm. Indeed, there is evidence that they do hold it in check in many regions, although they have not prevented its natural spread.

In spite of the short time that we have known of its occurrence in this country as a pest—since about 1899—we are already certain that at least five natural enemies, and probably more, are at work in decimating its numbers.

Exorista pyste Walk. (fig. 6), a tachina fly, has been repeatedly reared from the caterpillar of *Hellula undalis* from July 27 to as late as October 27.

Limnerium tibiator Cress., a very abundant parasite reared with this species, is an ichneumonid. It was reared from the latter part of October until the last week of December. It has not been positively ascertained to prey upon this larva, as it is a well-known enemy of the diamond-backed moth (*Plutella cruciferarum* Curt.), which was also present in smaller numbers, but as it is also known to attack the cabbage looper (*Autographa brassicae* Riley) and *Mineola indiginella*, it seems probable that it is in reality an enemy of this webworm.

Plagiprospherysa sp., a tachinid fly parasite, was reared June 12 and 17, 1908, from its host from Brownsville, Tex. The identification was made by Mr. C. H. T. Townsend.

Two other hymenopterous parasites of this webworm, reared in 1899, were identified by the late Dr. William H. Ashmead as *Meteorus vulgaris* Cress. and *Temelucha* (*Porizon*) *macer* Cress., female. The

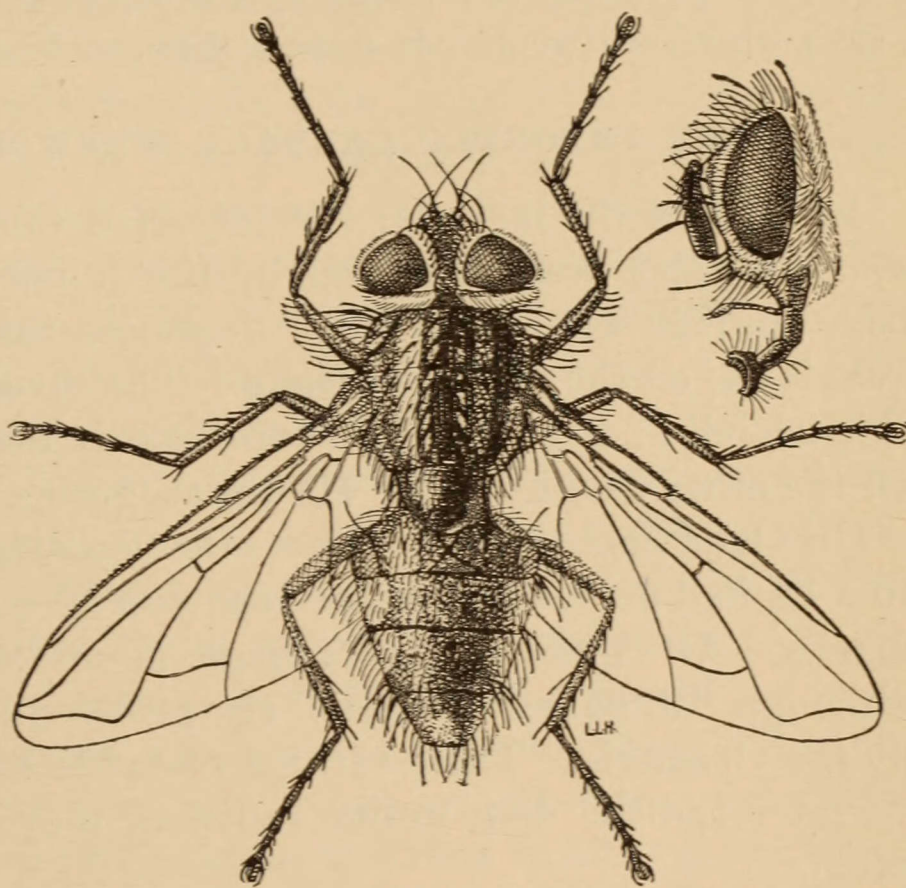


FIG. 6.—*Exorista pyste*, a parasite of the imported cabbage webworm (after Titus).

former, an ichneumonid, was reared in September from material received from Auburn, Ala.; the latter, a braconid, issued during the latter days of July from larvæ received from Charleston, S. C.

November 12, 1908, Prof. R. I. Smith, West Raleigh, N. C., stated that in attempting to rear larvæ of this species several were killed by mites, which bred in great numbers in a single night. Samples of the mites were forwarded to this office, for identification by Mr. Nathan Banks, who reported as follows:

The mite is *Tyroglyphus americanus* Bks., a species common in the Eastern States and feeding on a great variety of substances. These mites have a migratory stage which is attached to many insects, and so they gain access to places where one would not suspect them.

THE IMPORTED CABBAGE WEBWORM IN HAWAII.

In Hawaii the larvæ of the imported cabbage webworm (*Hellula undalis* Fab.) were observed by the junior author¹ attacking cabbage, radish, kohl-rabi, and "Japanese turnips," at Honolulu and Wahiawa, on the island of Oahu. The investigation was confined to this island, and it was not determined if the species occurs as a pest on the other islands of the Hawaiian group.

On Oahu cabbage and a few other cruciferous crops are produced to a limited extent throughout the year, for consumption in the local market. Of these crops cabbage is probably the most valuable, although "Japanese turnips" are grown and used quite extensively by the Orientals. These turnips resemble what we in the States call "winter radish," but, unlike radishes, they are cooked before being eaten.

Most of the cabbage is grown during the cooler months, from November until April. According to the oriental gardeners, the other months of the year are "too hot," and the plants seemingly do not thrive. Ordinarily only a few acres are grown annually, and the production is so limited that it becomes necessary to import considerable quantities of this vegetable from the mainland to supply the demand at Honolulu and other towns. Cabbage grown during the cooler months is usually of good quality and is said to be a profitable crop. Under the circumstances it doubtless seems odd to one unacquainted with the conditions that this crop is not produced in sufficient quantities to supply the local demand. The failure to grow cabbage more extensively is due in part to the fact that this crop is preyed upon by a horde of insects. Although most of these pests can be easily controlled, the Chinese and Japanese gardeners are,

¹ The notes on the occurrence of the imported cabbage webworm in Hawaii were made by the junior author while engaged as assistant Territorial entomologist and as a collaborator of the Bureau of Entomology. Thanks are due Mr. E. M. Ehrhorn for the courtesy of allowing Mr. Marsh to retain these notes. The junior author is not responsible for any statements made in other portions of this paper.—F. H. C.

almost without exception, ignorant of methods of control, and as a result much of the crop is injured and the growers become discouraged and plant other crops which are less damaged by insects.

Among these insects are the common cabbage worm (*Pontia rapæ* L.), the imported cabbage webworm (*Hellula undalis* Fab.), cutworms (*Agrostis crinigera* Butl.), a looper (*Autographa precatationis* Guen.), the diamond-back moth (*Plutella maculipennis* Curtis), the beet army worm (*Caradrina exigua* Hübn.), the cabbage aphid (*Aphis brassicæ* L.), the spinach aphid (*Rhopalosiphum dianthi* Schrank), and a number of minor pests. Among the latter is a leaf-miner (*Agromyza diminuta* Walk.), an unidentified species of thrips, and the melon fly (*Dacus cucurbitæ* Coq.). The larvæ of the melon fly work in cabbage which has previously been injured by the larvæ of *Hellula undalis*. This fruit fly is an exceedingly destructive enemy of cucurbits, and its occurrence in cabbage is rather uncommon.

The operations in Hawaii occupied a period of about seven months (July, 1910, until February, 1911), and during this time the insects affecting cabbage were kept under fairly constant observation. During this period the imported cabbage webworm apparently caused more damage to cabbage than any other insect. The growers claim, however, that from January to April the common cabbage worm (*Pontia rapæ* L.) is the most troublesome pest. During the period of actual observation, however, the webworm appeared to outrank the other species in destructiveness; in fact, at least a few of the webworms could be found whenever a search was made for them, although cabbage and turnips were the only crops which were noticeably damaged. The most serious infestation observed in 1910 occurred at Wahiawa, Oahu. On October 10, in company with Mr. E. M. Ehrhorn, a visit was made to a grower at Wahiawa, who planned to grow about 7 acres of cabbage that season. At this time he had three seed beds containing thousands of small cabbage plants. In one bed many plants had been killed, and of those which remained fully 75 per cent were infested by webworms and were worthless. In the other two beds in another field, at a distance of about 200 yards from the first, about 10 per cent of the plants were infested. The larvæ in the seed beds were all small. On large cabbage plants in a garden, a mile or more from the seed beds, full-grown larvæ were found in moderate numbers. One moth was observed, but no eggs were seen. In small garden patches at this place the Japanese killed occasional larvæ which lived in folded leaves or between two leaves, by crushing them with the fingers. Apparently only larvæ of conspicuous size were found, and as the majority of the webworms mined into the plants, beyond the reach of hand-picking, this method of control seemed of doubtful value.

The seed beds were again visited October 17. The conditions had not materially changed, except that some larvæ had reached maturity and left the plants. On November 2, 3,000 plants were taken from the three beds and transplanted to a field fully $2\frac{1}{2}$ miles from the seed beds. The plants were carefully examined and only those free from larvæ were transplanted. Unfortunately, small patches of old cabbage and Japanese turnips occurred but a short distance from the transplanted plants. The old cabbage was not badly infested, but the webworms were abundant in the turnips, and a portion, about one-fifth of an acre, of one patch was nearly destroyed. It will thus be seen that, although the young plants were free from larvæ when transplanted, they were placed in a badly infested and dangerous neighborhood. When these plants were examined November 18 nearly every one in the entire patch was found infested with from 1 to 10 webworms. These were mostly small—very few more than a week old—and many were not more than 4 days old. They had burrowed into or between the tender, curled leaves at the “bud” and were so well protected that they were apparently beyond the reach of a spray. Even at this early stage the plants showed plainly the results of infestation. It was obviously a hopeless case, and the man in charge, a Japanese, was advised to pull up the plants and burn them, but this he refused to do. At the next visit, December 8, little remained of these plants but stunted, worthless stumps. Larvæ were still abundant in them, although many had reached maturity and burrowed into the soil. About 700 plants which had been set out shortly after the middle of November in an adjoining patch were also generally infested and were rapidly becoming worthless.

In summing up these observations it will be seen that nearly 4,000 transplanted plants were destroyed by webworms, while at the same time the plants in seed beds were so generally infested that it was almost impossible to procure stock for replanting.

One of the most obvious factors making possible this loss was the almost utter indifference with which the necessity of clean culture was regarded. Old cabbage stumps and abandoned seed beds were not promptly destroyed, but were allowed to serve for months as breeding centers. An essential lesson that these growers have to learn is the absolute necessity of promptly destroying remnants of the crop by burning or some other equally effective method.

LIFE HISTORY AND HABITS.

Under normal conditions the eggs, when deposited on cabbage, are placed about the “bud” at the axils of the terminal leaves or on the leaves. From 1 to 12 eggs may be deposited on a single small plant.

At Honolulu eggs have been observed to hatch in from two to three days. Within a very short time after hatching the larvæ endeavor to conceal themselves. When very small cabbage plants in seed beds are infested the larvæ conceal themselves by folding a tender leaf and fastening the edges together with a web. Rarely is more than one larva found on a single leaf. With somewhat larger plants the larvæ mine into or crawl between the curled, terminal leaves at the "bud," and, as they increase in size, burrow deeper into the main stalk. When a plant is thus infested it is rendered worthless. With large plants which are beginning to head the larvæ mine into the mid-ribs or live in burrows between two leaves. The chief damage is caused by the larvæ destroying the "buds" of the small to medium-sized plants. When the "buds" of small plants in the seed bed are attacked the plants may be killed outright. With larger plants the destruction of the "bud" effectually prevents further normal development. Rain falling into the burrows hastens decay, thus completing the injury begun by the larvæ. On Oahu the larvæ are called "center worms," from their habit of mining into the center or "bud" of cabbage plants.

The larvæ usually reach maturity in from 13 to 15 days. They then leave the plants, burrow slightly beneath the surface of the soil, and form rather frail cocoons of webbed-together grains of earth, within which they pupate within 2 days. During the progress of these studies thousands of larvæ were under close observation, and they invariably burrowed into the soil and made cocoons of webbed-together grains of earth. The adults usually issue in from 6 to 12 days after pupation. They fly easily, but are shy and are rarely noticed by the casual observer.

It is probable that this species breeds throughout the year in Hawaii. Judging, however, from the reports of gardeners, it is evident that reproduction is at a low ebb during the cooler months. This idea is borne out by the fact that the larvæ were noticeably less abundant at Wahiawa in late December and at Honolulu in January than earlier in the season.

Four generations of this webworm were reared in an insectary at Honolulu. The record for the first generation is incomplete.

FIRST GENERATION.

September 2, 1910, several mature larvæ were collected from cabbage in a garden at Honolulu and confined in a cage. They burrowed into the soil September 3 and pupated September 5. The first moths, 4 in number, issued September 12, and the following day 8 more issued. The 12 moths were then put in another cage, containing a

living cabbage plant, and were supplied with diluted molasses as food. The following is a summary of the three succeeding generations:

SECOND GENERATION.

September 12-13	Twelve adults issued.
September 14	First eggs deposited.
September 16	The eggs hatched.
September 29	First larvæ reached maturity.
October 1	First larvæ pupated.
October 7	First adults issued.
October 8	More adults issued.

From the above record the stages are as follows:

	Days.
Egg stage	2
Larva stage	15
Pupa stage	6
Total	23

THIRD GENERATION.

October 7-8	Adults issued.
October 9	First eggs deposited.
October 12	The eggs hatched.
October 26	First larvæ reached maturity.
October 28	First larvæ pupated.
November 6	First adults issued.
November 7	More adults issued.

From the above record the stages are as follows:

	Days.
Egg stage	3
Larva stage	16
Pupa stage	9
Total	28

FOURTH GENERATION.

November 6-7	Adults issued.
November 9	First eggs deposited.
November 12	The eggs hatched.
November 27	First larvæ reached maturity.
November 29	First larvæ pupated.
December 11	First adults issued.

From the above record the stages are as follows:

	Days.
Egg stage	3
Larva stage	17
Pupa stage	12
Total	32

The moths which issued December 11 deposited eggs for a succeeding generation. Unfortunately, it was necessary to abandon the work at this point and records of further development were not obtained.

EGG-LAYING RECORDS.

On October 11 a pair of moths, which had issued that day, were observed mating. These moths, while still together, were put into a separate cage and the following record obtained:

	Eggs deposited.
October 13.....	79
October 14.....	49
October 15.....	31
October 16.....	32
October 17.....	13
October 18.....	15
October 19.....	5
October 20.....	11
Total	235

The female died October 21 and the male died the following day. The female lived 10 days and deposited 235 eggs. The male lived 11 days.

With another mating pair, which were likewise confined during October, the female lived 14 days and deposited 237 eggs. The male lived 17 days.

The life-history records were obtained in an open-air insectary in which open wire cages were used. Food was supplied the moths by putting in wads of absorbent cotton which had been saturated with molasses and water. They fed on the diluted molasses eagerly. The moths were docile and easily handled, and mating pairs were readily obtained during the daytime. In all cases, cabbage was used as food for the larvæ. Usually young, tender plants from seed beds were supplied.

Following is the temperature record at Honolulu during the time the species was reared:

Month.	Minimum tempera- ture.	Maximum tempera- ture.	Average mean tem- perature for entire month.
1910.	° F.	° F.	° F.
September.....	69	85	77.0
October.....	65	84	75.3
November.....	66	84	74.6
December.....	62	80	71.2

NATURAL ENEMIES IN HAWAII.

Many larvæ were collected at various dates from cabbage and other cruciferous plants in the gardens in Honolulu and Wahiawa

and confined in cages. No parasites were obtained, nor were predaceous enemies observed in the field. In one or two so-called stock cages in the insectary, which were crowded with surplus webworms and neglected, a disease or "wilt" developed which killed many larvæ. This "wilt" did not occur in the regular cages and was not observed in the field. Apparently, as far as Hawaii is concerned, this webworm seems to be remarkably free from natural enemies.

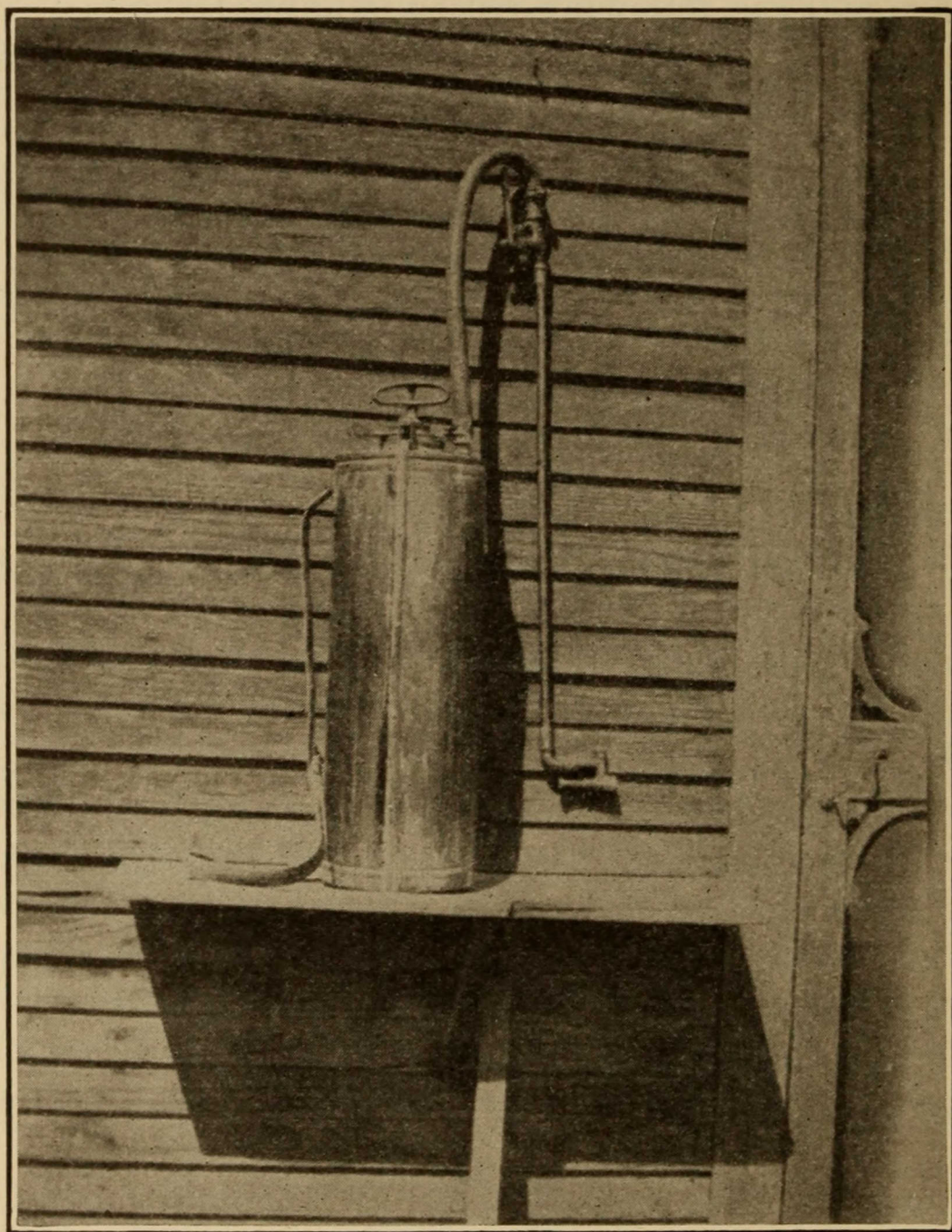


FIG. 7.—Small compressed-air sprayer, fitted with extension rod, elbow, and Vermorel type nozzle. (Original.)

EXPERIMENTS WITH INSECTICIDES.

During the fall of 1910 some experiments were made against this webworm. All experiments with insecticides were conducted on infested cabbage in a garden at Honolulu. In all cases the insecticides were applied with a small compressed-air sprayer (fig. 7), which was fitted with a short extension rod, elbow, and a small nozzle of the Vermorel type. The experiments were as follows:

Experiment No. 1.—Paris green, 2 pounds, and whale-oil soap, 8 pounds, in 100 gallons of water.

September 7 the plants in two seed beds and 495 older plants were sprayed. One seed bed contained plants from 1 to 3 inches in height, many of which were infested by small webworms. They had not entered the bud, but were working in folded leaves.

The second bed contained larger plants ready to transplant and only slightly infested. The few larvæ present were mostly in small folded leaves or occasionally in a bud. The 495 plants had been transplanted for some time and varied from small plants, which had made little growth, to a few which had just begun to head. In fully one-fifth of these plants the bud had been destroyed by webworms, making the plants worthless.

In this experiment the plants were simply wet from above. In the seed beds the entire upper surface of the plants was wet, but with the larger plants only the leaves at the center were reached. The mixture adhered very well. At the time of the application all the larvæ were concealed in the folded leaves or buds. The weather was hot and clear.

In the seed bed containing the small plants a few larvæ were dead the following day (September 8). They were found clinging and exposed on the surface of the leaves.

The plants sprayed in the second seed bed had been removed and transplanted. The infested ones were discarded, and as a result the effects of the treatment could not be determined.

In the large plants the larvæ were buried beyond the reach of the poison and none were killed.

September 9 it was noted that a few additional larvæ had died in the first seed bed. Some of the leaves were slightly burned by the arsenical. On the old plants no effect was apparent, either upon the larvæ or upon the foliage.

A heavy rain occurred September 10 which washed the poison from the plants, and the experiment was closed on that date.

As a result of this treatment only a moderate number of larvæ, in the folded leaves on the young plants, were killed. With the large plants no larvæ were killed. All things considered this experiment must be rated as a failure.

Experiment No. 2.—Paris green, 5 pounds; lime, 5 pounds; and whale-oil soap, 10 pounds, in 100 gallons of water.

September 12 a seed bed of small, well-infested plants was sprayed. The larvæ were practically all in folded leaves and only one was found entering the bud. The spray mixture adhered perfectly and the surface of the leaves was thoroughly coated with the poison. The weather was cloudy and sultry.

A shower occurred the following day, but the poison was not washed from the leaves. No dead larvæ could be found at this time. Some of the leaves were slightly burned.

September 15 the application was repeated. The older leaves were still well coated with the poison from the first dose, but many new leaves had been put out and these were unprotected. All were completely coated by the second spraying. At this date there were occasional dead larvæ, but they were not common.

September 16 it was noted that some of the larvæ were actually entering the bud and that very few of them had been killed.

Heavy showers occurred September 18, 19, and 20, but the coat of poison remained fairly good. At this latter date, most of the larvæ were in flourishing condition, and the experiment was considered a failure. The plants were slightly burned, but no serious damage resulted. One interesting point brought out by this experiment is that the mixture was remarkably adhesive and not readily washed from the foliage by rains.

Experiment No. 3.—Arsenate of lead, 5 pounds, and whale-oil soap, 10 pounds, in 100 gallons of water.

October 12, 418 good-sized cabbage plants were sprayed. The larvæ were moderately common. All were deeply buried and obviously beyond the reach of the poison. The mixture adhered well and the plants were completely coated. These plants were examined daily until October 19, but not a dead larva was found, and at that date the experiment was abandoned as a complete failure. The mixture did not burn the foliage.

Experiment No. 4.—Paris green, 2 pounds, whale-oil soap, 8 pounds, and nicotine sulphate, 25 ounces, in 100 gallons of water.

November 10, 410 good-sized moderately infested plants were sprayed. These plants were kept under almost daily observation until November 23, but not a dead larva was found. This mixture did not burn the plants, and it completely wiped out plant-lice (aphides) and several species of lepidopterous larvæ which were exposed on the leaves. It was, however, ineffective against the well-protected *Hellula* larvæ.

The experiments with insecticides may be summarized as follows:

Experi- ment No.	Date.	Insecticide used.	Effect on larvæ.	Injury to foliage.	Remarks.
1.....	1910. Sept. 7	Paris green, 2 pounds, and whale-oil soap, 8 pounds, in 100 gallons of water.	Ineffective..	Not worth mention- ing.	A few larvæ, in folded leaves, on small cabbage plants were killed. None were killed on large plants.
2.....	Sept. 12	Paris green, 5 pounds, lime, 5 pounds, and whale-oil soap, 10 pounds, in 100 gallons of water.	do.....	do.....	A few larvæ, in folded leaves, on small cabbage plants were killed.
3.....	Oct. 12	Arsenate of lead, 5 pounds, and whale-oil soap, 10 pounds, in 100 gallons of water.	do.....	None.....	Applied to large cabbage plants. No larvæ were killed.
4.....	Nov. 10	Paris green, 2 pounds, whale- oil soap, 8 pounds, and nicotine sulphate, 25 ounces, in 100 gallons of water.	do.....	do.....	Do.

EXPERIMENT IN SCREENING A SEED BED.

On October 18 two cabbage seed beds were planted at Wahiawa. The beds were about 11 yards in length and nearly 1 yard wide. They were separated by a path about 12 inches in width. One bed was screened and the other was left uncovered in the usual manner.

The screen was made by placing 12-inch boards on edge around the sides and ends of the bed, and over this a strip of cotton cheesecloth was tacked. This strip of cloth was a yard wide and a little more than 11 yards in length. It cost 5 cents per yard. It was originally intended to make the cover of the fine-meshed, cotton mosquito netting, but as this netting was not obtainable at the time cheesecloth was used instead.

These beds were examined November 8. At that date the plants in the exposed bed were well infested by *Hellula* larvæ. The plants in the screened bed were free from insect pests and were larger and in better condition than those in the exposed bed. Their condition was accounted for by the fact that the screen prevented rapid evaporation, as well as insect attack, and the abundant moisture and freedom from insects favored a thrifty growth.

November 18 fully 75 per cent of the plants in the exposed bed were ruined or injured by webworms. The plants in the screened bed were free from webworms and other insect pests and were of sufficient size to transplant. Owing to the protection they had received and their rapid growth, these plants were quite tender, and it was necessary to remove the cover and expose them to the sun to harden them. After being exposed a little more than a week the plants were well hardened, and several thousand were successfully transplanted.

A final examination of the transplanted cabbages was made December 23. At that date most of them were growing vigorously and only a few were infested by webworms.

On the whole this experiment was a success, although it is very evident that a mistake was made in using cheesecloth for the cover. This material shaded the plants from the sun and their growth was too rapid. Undoubtedly mosquito netting would have been an ideal cover.

CONCLUSION.

The observations on this webworm have been made under normal field conditions in several localities in Texas, California, and the Hawaiian Islands. Basing an opinion on the studies and experiments made in these places, arsenicals can not be depended on to control this species on cabbage. This belief is strengthened by the experience of Mr. M. M. High, who reports, as mentioned on another page of this article, that dry Paris green was unsuccessfully used against this pest on cabbage in Mississippi during 1909.

After the larvæ have crawled between the terminal leaves or mined into any portion of the plant they are beyond the reach of a stomach poison. The period between the hatching of the eggs and the concealment of the larvæ is so brief that it appears to be a practical impossibility to reach them under field conditions.

In the light of our present knowledge, the best methods of controlling this webworm consist of clean culture, the screening of seed beds, and thorough cultivation.

The necessity of prompt destruction of crop remnants and the employment of other clean cultural methods can not be too strongly emphasized. It is a disgraceful condition to allow worthless plants to serve as breeding centers for pests which will infest later planting.

By screening the seed beds it is possible to prevent infestation until the time of transplanting. When this method is followed it is advisable to leave a few plants exposed near the screened beds. These exposed plants will attract the moths, and eggs will be deposited on them. As soon as the eggs have hatched and the work of the larvæ becomes apparent these plants should be promptly burned.

Inasmuch as the larvæ of this species pupate in frail cocoons near the surface of the soil, it is possible that thorough cultivation would crush some of the pupæ and at the same time induce a more vigorous growth of the plants.

RECOMMENDATIONS FOR CONTROL.

While the limited stay on the part of the junior writer in Hawaii did not permit of experiments with other remedies than those which have been considered on previous pages, nevertheless it is believed by the senior writer that in the occurrence of this insect in the southern United States and in California it may be possible to successfully treat it on cabbage and other cruciferous plants by means of some form of spray, particularly if applied at the outset of attack. This point can never be too strongly emphasized, that if we expect to meet with success in combating this as well as so many other insects, work must be begun upon the first appearance of the insects each season, since if the pests can be destroyed then, it should materially decrease the injury for the entire year. If the first generation is missed, the second and third should be treated.

It should be stated that Mr. H. M. Simons, Charleston, S. C., one of the first to report this species as a pest in America, found that a mixture of kerosene oil and soap sprayed upon infested plants served as a deterrent against the larvæ of this moth, but that the larvæ returned as soon as the odor of the kerosene had become exhausted. Kerosene-soap emulsion and nicotine solutions and whale-oil soap should be given thorough tests as deterrents and insecticides, both alone and mixed with arsenicals.

Another method was tested by Mr. Simons. He captured many of the moths with the aid of a barrel having all but four of the staves sawed out, leaving 4 inches from the bottom to form a tub in which to hold water. From the top of this a light was suspended which attracted the moths. In this way he caught a great many insects in two seasons. The light barrels, as he terms them, were placed on seed beds of cabbage.

A thin scum of kerosene was used in this experiment, but it is suggested that this be eliminated in order not to destroy the predaceous insects, such as ground beetles and parasites, which are practically certain to be attracted. This suggestion is made in view of the fact that the destruction of one beneficial ground beetle or parasite is equivalent to the destruction of, perhaps, from 20 to 100 injurious insects. The predaceous and larger parasitic insects can be easily picked from the water, and though they may be apparently dead, it will soon be seen that they recover and crawl away. The moths are not apt to recover.

There can be little doubt that Bordeaux mixture sprayed on the plants when they are first set out, or when they first appear above ground, and continued at intervals of a week or two, should act as a deterrent of attack. It is advisable, therefore, in using an arsenical, to employ Bordeaux mixture as a deterrent. Where cabbage and similar plants, liable to infestation by this insect, are set out from sash or cold frames, dipping the plants in a solution of arsenate of lead, prepared at the rate of about 4 pounds of the arsenical to 50 gallons of water, should be useful.

Among other remedies which may be suggested for employment, at least on a small scale, are the following:

Planting an excess of seed with the aim of afterwards destroying the plants which are injured by the webworm beyond redemption.

Fall plowing, a standard remedy for many insects.

Clean culture, or the maintenance of the cabbage or other fields throughout the season free from weeds, especially cruciferous weeds, and prompt destruction of dead or dying plants during the season and the removal of all cabbage heads, stalks, and other refuse. All cruciferous crops should be treated in a similar manner.

The refuse material, including hopelessly injured cabbage heads and other crucifers, should be gathered in piles and promptly burned. The addition of straw or similar dry material will aid in ignition.

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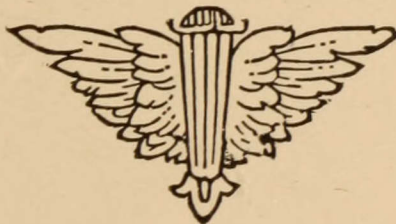
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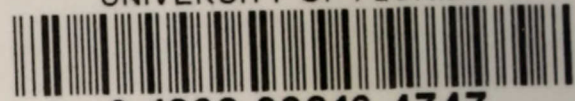
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