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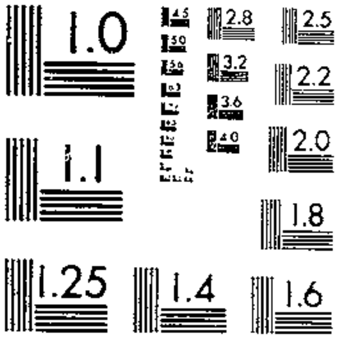

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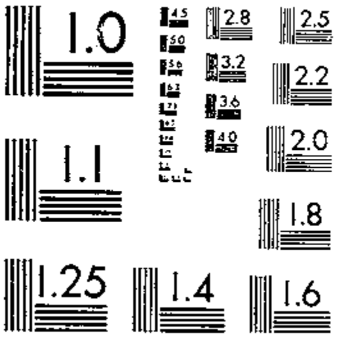

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Technical Bulletin No. 846 • Issued March 1944

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

The Cabbage Looper as a Pest of Lettuce In the Southwest[1]

By K. B. McKinney, *associate entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*[2]

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SUMMARY

Beginning in 1933, and continuing through 1938, investigations were conducted on the biology and control of the cabbage looper (*Autographa brassicae* (Riley)) as it occurred on lettuce in the Salt River Valley of Arizona.

During years and seasons of sufficient rainfall in southern and central Arizona, wild food plants, on which large numbers of loopers breed, appear over the desert areas, and apparently the adults migrate long distances between the cultivated and desert areas in adjusting themselves to the food-plant sequences.

In the Southwest two crops are grown yearly. The crop seeded in September and marketed during December and early January is known as the fall crop. The crop seeded in the latter half of October and marketed during March and early April is known as the spring crop.

The spring crop is grown during the winter when the looper activities are at their lowest, and therefore the lettuce goes on the market practically free of looper injury.

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[1] Submitted for publication May 19, 1943.

[2] The writer acknowledges the assistance rendered by O. A. Hills, V. E. Romney, and N. L. Wildermuth in helpful suggestions, by members of the Division of Insect Identification in determining various insects, and by members of the Division of Insecticide Investigations in analyzing the insecticides.

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The fall crop is grown at a time when the loopers are more abundant, and therefore it is subject to attack year after year.

The eggs of the cabbage looper are deposited singly on either side of the leaves and may hatch in from 3 to 10 days. The newly hatched larva is dusky white, but takes on a light-green color immediately after feeding begins. The feeding period may last from 10 to 50 days and there may be 4 or 5 larval stadia. The cocoons are usually attached to the under side of the lower or ground leaves. During the summer the pupal stage may last as few as 6 days, but the entire winter may be passed by some of the insects as pupae. With a wing spread of approximately 1¼ inches the adults are capable of covering long distances. As many as 200 eggs may be deposited by a single female.

All stages of the cabbage looper are attacked by parasites and predators. *Trichogramma minutum* attacks the eggs and effects an appreciable control, tachinids attack the larvae and pupae, and birds and bats attack the adults. The combined effect of the natural enemies in the summer and the practice of growing lettuce during the fall and winter allows the crops to be grown with a minimum of artificial control.

Little if any advantage was gained by removing the discarded plants from the field at the time of thinning.

It was determined from a study of plant-growth records that lettuce could be treated with poisonous insecticides up to within 35 to 40 days of harvest without leaving an objectionable residue to reach the consumer.

The data for the control of cabbage loopers on lettuce were obtained from field plots ranging from $\frac{1}{18}$ to 1 acre each. It was determined under the irrigated conditions of the Southwest that derris dusts were toxic to the cabbage looper, that cryolite or paris green could be used to control loopers on small lettuce, and that when a mixed infestation of loopers and beet armyworms occurred calcium arsenate would be more effective for controlling the combined infestation than derris, and equal to the cryolite or the paris green.

The rate of application ranged from 10 to 20 pounds per acre, depending on the size of the plants and the kind of insecticide. There was no appreciable difference in effectiveness of early-morning and late-evening applications of the various dusts.

Usually the more severe damage to lettuce from the attacks of the cabbage looper comes immediately after the thinning of the plants, and if the infestation at that time is controlled no further damage occurs. It is therefore preferable that the insecticides be applied 3 to 5 days previous to thinning to avoid a concentrated attack on the plants left standing. Insecticides applied before thinning will not be present on the product that reaches the consumer.

INTRODUCTION

It has been known for many years that the cabbage looper (*Autographa brassicae* (Riley)) was not only an important pest of crop plants of the cabbage family but that the species also attacked several other crops, including lettuce, beet, pea, celery, parsley, potato, cotton, tomato, and some flowering plants, in addition to many species of wild plants. Although lettuce has been mentioned by numerous writers as a host plant of the cabbage looper, very little has been published dealing directly with the biology and control of the loopers on lettuce. During the 5-year period immediately prior to 1933, apparenty affected by the availability of large acreages of lettuce and an abundance of other cultivated and wild host plants, plus favorable climatic conditions, the cabbage looper caused serious damage to lettuce grown under irrigation in the Salt River Valley of Arizona.

Preliminary investigations in 1933 disclosed that the lettuce growers were combating the loopers with some degree of success by the application of insecticides containing arsenicals, but that the use of these materials late in the development of the crop very often resulted in the presence of harmful residues on the marketed lettuce.

This bulletin reports the results of investigations during the period from 1933 to 1938, inclusive, on the biology, seasonal occurrence, and control of the cabbage looper on lettuce in the Salt River Valley of Arizona.

SEASONAL OCCURRENCE, ABUNDANCE, AND HOST-PLANT RELATIONSHIPS OF THE CABBAGE LOOPER IN ARIZONA

During the early spring, summer, and early fall of 1935, observations were made on the seasonal occurrence, abundance, and food-plant relations of the cabbage looper as found throughout the cultivated and desert areas of south-central Arizona.

The rainfall for the winter 1934–35 was more than twice the normal (fig. 1). During December 1934 and January, February, and March 1935, 7.23 inches of rainfall were recorded at Phoenix. The increased amount of moisture caused rank growth of plants (fig. 2) over the entire desert areas, and the loopers bred readily on a number of these wild plants.

No systematic counts of the numbers of cabbage loopers were made during the early spring of 1935, but it was recorded that loopers were easily found on several species of the desert plants.

During the latter half of April the plants dried rapidly, and at that time the adult moths were emerging and migrating to plants that were still flowering in the higher elevations. On the 5th of May looper adults were too numerous to be counted as they fed on a wild desert composite, *Encelia farinosa* Gray, which was in full flower along the foothills adjacent to the cultivated areas in the Salt River Valley.

Throughout May and June loopers were scarce. A few could be found on several species of plants, but considering the large number of adults present a short time earlier it seemed that all host plants would have been heavily infested. The light larval infestation seemed to indicate that the adults migrated for oviposition to points more distant from the cultivated areas of the Salt River Valley.

During August the loopers were more numerous than at any time since the early spring. The summer rains had produced sufficient vegetation again over the desert areas for widespread breeding to occur.

Loopers were readily found as far as 15 to 35 miles from cultivated areas in the Harqua Hala Basin, where population counts were taken during August from *Pectis papposa* A. Gray. These records were made at random by the sweep-net method in 6 localities, and larvae were taken in 5 of them about the basin, 15 larvae being taken in 650 strokes of the net. The insect nets used were from 12 to 15 inches in diameter, with handles 2½ feet long. The net swept the top portions of the plants for a distance of one-fifth to one-fourth of a circle, or a strip approximately 6 feet long by 1 foot wide.

The total looper population on the plants covered with the net was not obtained, but the numbers taken from the different localities were

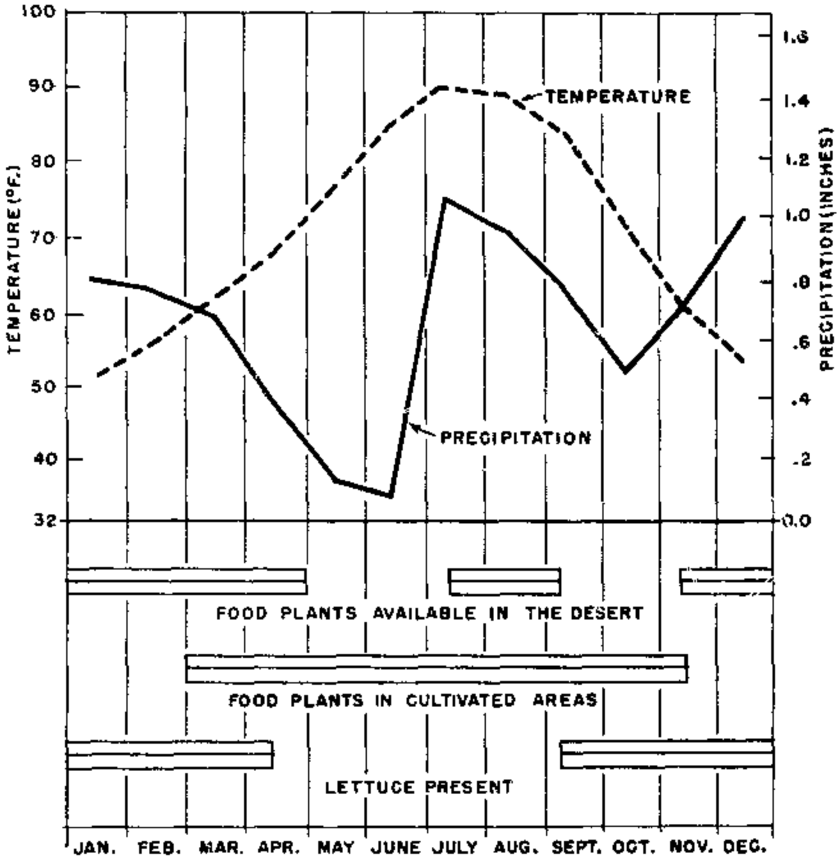

FIGURE 1.—Average temperature (broken line) and precipitation (solid line) throughout the year at Phoenix, Ariz., and periods when the spring and fall crops of lettuce are being produced, when other food plants are abundant in the cultivated (irrigated) areas, and when wild hosts are available in the desert.

comparable, and established the fact that loopers were breeding in large numbers. The loopers taken were in the first and second larval stadia, showing that a generation had been begun on *Pectis papposa*, which covered large areas. Previous to the summer rains only the perennial desert brush had been growing there, and loopers had not been observed feeding on these plants.

The desert areas had been practically bare from late April to August, and as the perennial brush is not a food plant, one is led to believe that the adults migrate comparatively long distances in search of plants suitable for food and for oviposition.

During September 1935, similar counts were made in the desert areas in the Queen Creek Basin to the east of the cultivated areas of the Salt River Valley, the Harqua Hala Basin to the west, and the Wickenburg, Marinette, and Paradise Valley areas to the north. The larvae present at this time were full grown, which indicated that a generation had developed and that adults would be emerging a few weeks later to deposit eggs on the lettuce that would be seeded between September 10 and 25. At this time summer annuals on the desert were drying, and it was too early for the fall and winter annuals to appear (fig. 1). This food plant condition forced the adults to migrate to the cultivated areas to obtain suitable hosts for egg deposition.

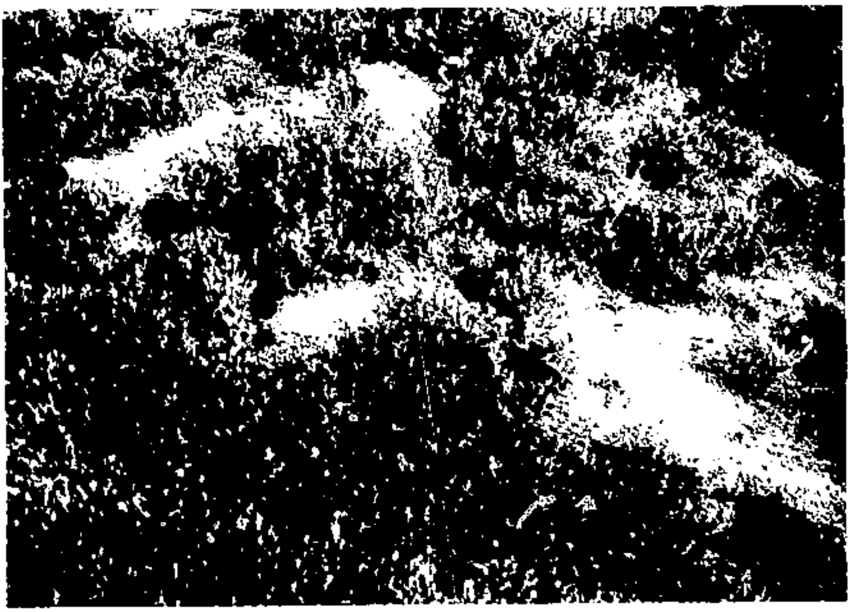

FIGURE 2.—A close-up view of an excellent stand of host plants of the cabbage looper on the desert.

The food plant sequence and seasonal distribution of the loopers are practically the same year after year, with only such slight modifications as are caused by variations in rainfall and other climatic conditions. Breeding in the cultivated areas usually proceeds at an even rate, but when conditions on the desert are favorable for breeding, infestation of the lettuce is usually increased.

ECONOMIC IMPORTANCE

A definite method of rating the actual economic damage sustained by the lettuce growers from the attacks of loopers has not been established. The nature of the crop, price fluctuations, and the time element in marketing defeat attempts to set a monetary loss. The loss in stand, as gathered from the opinions expressed by several growers, has been placed at from 5 to 30 percent during seasons of heavy infestation. Plants that have been weakened and that do not produce normal heads were not considered in these estimates.

In the fall of 1935 approximately 10,000 acres were seeded to lettuce in the Salt River Valley, of which 9,200 to 9,500 acres were sprayed or dusted. A part of this acreage received two applications. It is estimated that at $2.50 per acre per treatment these insecticide applications cost approximately $25,000.

The appearance of loopers on the small plants is a danger signal, and spraying and dusting are begun at once. The more cautious growers dust or spray the small lettuce whether the loopers are present or not. Such control practices are considered a necessary insurance against a possible loss

FOOD PLANTS

The cultivated food plants of the cabbage looper upon which it has been found feeding in the Salt River Valley are cabbage, cauliflower, broccoli, lettuce, mustard, turnip, radish, tomato, pea, squash, cantaloupe, watermelon, cucumber, potato, sweet pea, hollyhock, and snapdragon. The common wild food plants that occur on the desert and along water courses in the valley under favorable conditions include *Nicotiana trigonophylla* Dunal; *N. glauca* Graham (tree tobacco), wild mustards (at least five species), mallow (several species), *Eschscholtzia californica* Cham. (California poppy), *Erodium cicutarium* (L.) L'Her., redstem filaree or alfileria, *Chaenactis stevioides* Hook. and Arn. (morning bride), *Pectis papposa* A. Gray (chinchweed), *Lactuca* spp. (wild lettuce), and a few unknown species. The looper has been recorded as feeding on a number of other plants, among which are cotton, beet, celery, and spinach.

With this wide variety of cultivated and wild plants to breed on, the food-plant sequence is so strongly interwoven that each succeeding generation of loopers may find sufficient food to maintain an infestation that might become of outbreak proportions at any time.

LETTUCE-PRODUCING AREAS AND CROP SEASONS IN THE SOUTHWEST

In the principal lettuce-growing districts of the Southwest two crops of lettuce are produced yearly. These areas include the Salt River Valley and the Yuma Valley in Arizona and the Imperial Valley in California (fig. 3).

The spring crop of lettuce, growing through the winter when the looper activities are at their lowest, is comparatively free of looper injury. An occasional larva may be found at all times, but the crop is harvested in March or early in April before the spring infestation reaches the point of causing damage.

In 1935 a series of examinations to determine the winter infestations on the spring crop was begun on January 17 and continued through February 26. During this period 17 examinations were made of 50 plants each. Lots of 5 plants taken in 10 different places about each field constituted a sample. Only 20 eggs and 32 larvae were found. This was a very light infestation that merely shows that the loopers were present and remained active during the winter.

The fall crop, however, is grown at a time when the loopers are approaching the peak of abundance and therefore is subject to more or

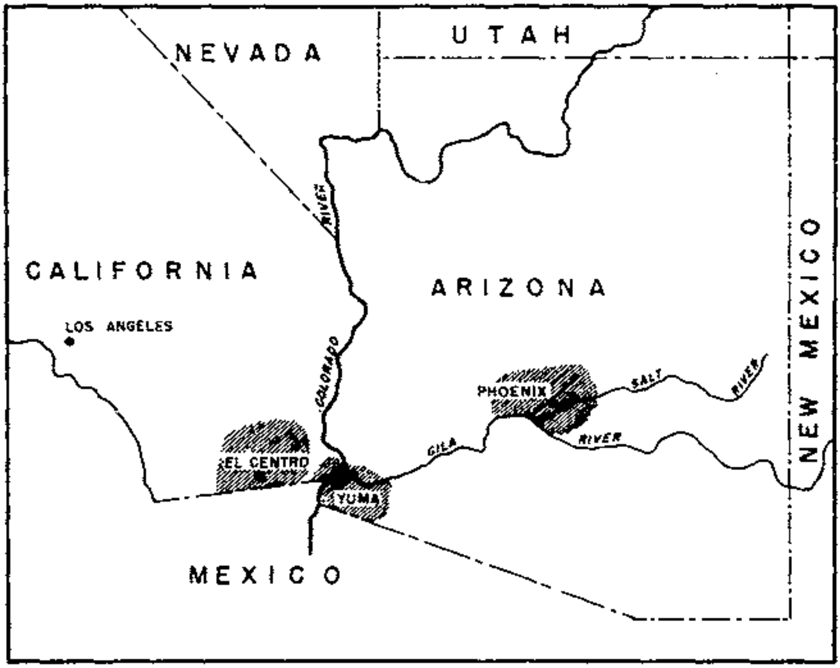

FIGURE 3.—Map showing the lettuce-growing districts of the Southwest.

less severe attacks from year to year during the early stages of plant growth. This crop for the December and January market is usually seeded between September 10 and 25, and germination takes place within 48 to 72 hours. The small plants may become infested soon after they appear above the ground (fig. 4, *A* and *B*).

A moderate infestation before the plants are thinned usually causes no appreciable loss, as even more plants are taken out in the thinning operation than are destroyed by the looper, whereas plants destroyed after the lettuce has been thinned cannot be replaced and therefore are a total loss.

INSECT INJURY TO LETTUCE

During the early stage of plant development lettuce may be attacked and severely damaged by insects at any time. There are two critical periods, however, during which the injury may become more serious than at other times. The first critical period comes soon after the plants appear above the ground, when they are subject to the attacks of grasshoppers, crickets, saltmarsh caterpillars, and cutworms. The damage from these insects may result in a complete loss.

The second critical period comes immediately after thinning, when the cabbage loopers that were infesting the plants that were discarded find their way to and congregate on the plants left standing (fig. 4, *C*).

At this stage of plant development the infestation is at or is approaching its maximum capacity for causing damage. One larva in the last instar may destroy several plants in a short time. When the plants have become well established after thinning, the looper attacks do not usually cause any appreciable loss. The plants soon become

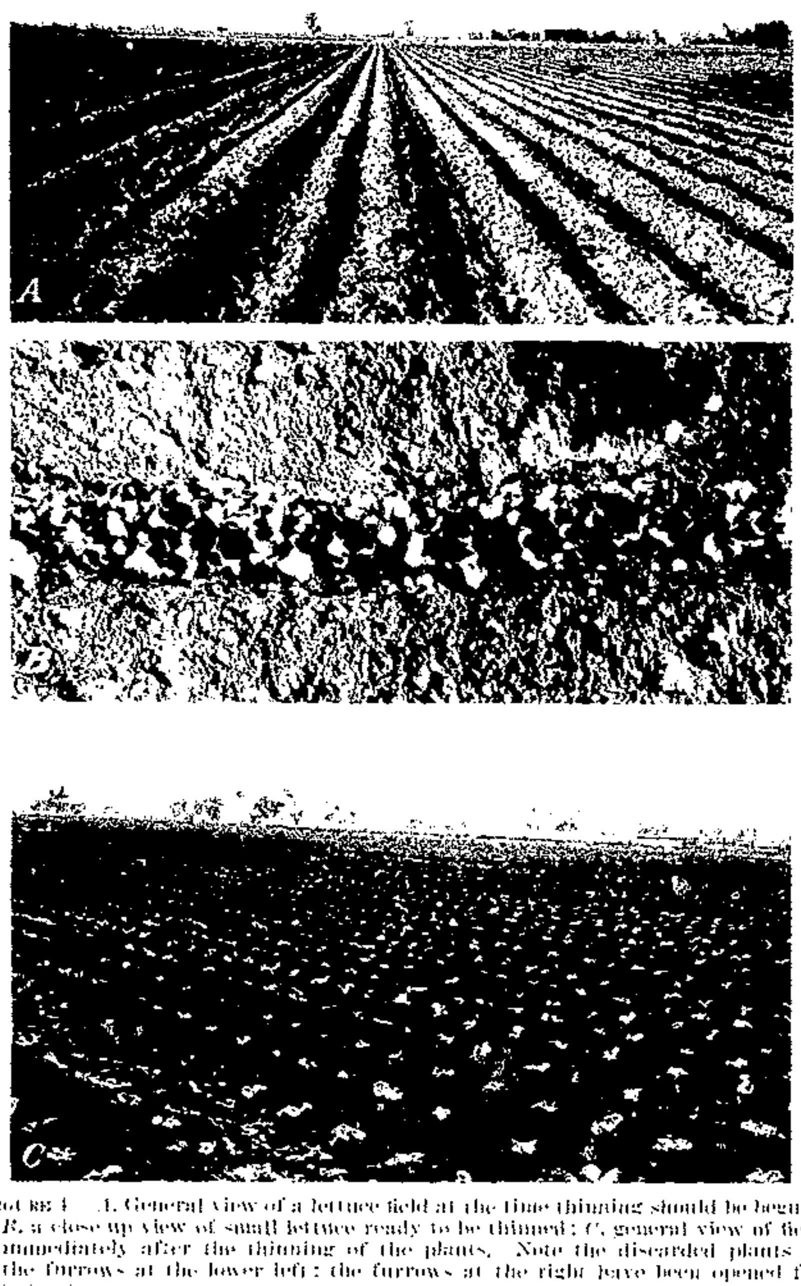

FIGURE 4.—*A*, General view of a lettuce field at the time thinning should be begun; *B*, a close-up view of small lettuce ready to be thinned; *C*, general view of field immediately after the thinning of the plants. Note the discarded plants in the furrows at the lower left; the furrows at the right have been opened for irrigation.

FIGURE 5.—General view of a lettuce field about 15 days before harvest.

established and outgrow the subsequent infestations (fig. 5). As a rule the lettuce crop goes on the market showing very little or no looper injury.

Cabbage loopers destroy or injure lettuce by consuming the leaves or vegetable growth. When the plants are small they may be completely eaten, or the terminal bud may be destroyed or injured, which causes the plant to develop axillary buds that usually do not produce

FIGURE 6.—The lettuce plant on the left will not produce a normal marketable head on account of injury or destruction of the terminal bud by cabbage loopers during the early stages of plant growth. Note the development of axillary buds. The lettuce plant on the right, with the same cultural history but not injured by cabbage loopers, will produce a marketable head.

marketable heads (fig. 6), or the plants turn vegetative and develop thick, leathery leaves with no tendency to produce heads.

As the plants become more mature, the outer edges of the older leaves seem to be preferred by the loopers. Several larvae may feed on the outer leaves of a rapidly developing plant and cause no appreciable loss, whereas one larva boring into the head would destroy it. Loopers seldom bore into and riddle the heads (fig. 7, *A* and *B*).

FIGURE 7.—*A*, Mature head of lettuce showing severe damage to the outer leaves by cabbage loopers; *B*, the same head split open showing that the larvae did not bore into the head but confined their feeding to the outer leaves.

A characteristic feeding habit of the larvae is to perforate a portion of the leaf near the edge. The perforation is usually arc-shaped and the area outlined is governed by the size of the larva that made it. The arc-shaped cut is made by the larva partly cutting out the leaf tissues as far as it may reach from a more or less stationary point. The segment outlined is not always immediately consumed, and several such areas may be found on one leaf. No satisfactory explanation can be offered for this type of feeding.

A loss that occasionally occurs at harvesttime is produced by excrement falling into the wrapper leaves and soiling the head. This damage is usually caused by a few larvae that are feeding on the outer leaves, and the actual loss from the plant material consumed is negligible. Control measures are rarely undertaken against the larvae at this time.

LIFE HISTORY AND HABITS

The Egg Stage

The hemispherical eggs are finely engraved with longitudinal ridges or ribs crossed with fine transverse lines (fig. 8, *A*). They are pearly white when first deposited, but as the larvae develop they turn a few shades darker. A short time before hatching, the black head and thoracic shield of the larva may be plainly seen as blackened areas, and the prominent setae appear as dark broken lines.

The eggs are usually deposited singly on either side of a leaf, but more often they are found on the under side and near the margin. Eggs may be deposited at any time during the year, and the incubation period may last from 3 to 10 days, depending on the temperature.

The Larval Stage

The newly hatched larva is dusky white with black head and thoracic shield. The setae are long and conspicuous but become less noticeable in the later instars. Soon after the larvae begin to feed they take on a light-green color and retain it throughout the larval and the first part of the pupal period. There are thin, longitudinal, white lines along the sides that become less noticeable in the last instar (fig. 8, *B*).

Owing to the fact that two out of four abdominal prolegs are missing, the larva crawls in a looping manner, from which it derives the name "looper." The larva has the habit of curling into a ball-shaped mass and dropping from the plant on being disturbed. The large larva is a strong crawler and may cover comparatively long distances in search of food. The larva passes through four or five stadia and completes the feeding period in from 10 to 50 days, depending on the seasonal temperature. When full grown the larvae are from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long, and the last two instars are voracious feeders and consume large quantities of plant tissues.

The Pupal Stage

When the feeding period has been completed the larva spins a white, thin, fragile cocoon in which it transforms to a pupa which is easily seen inside (fig. 8, *C* and *D*). The newly formed pupa is light green,

FIGURE 8.—Life stages of the cabbage looper: *A*, Eggs in natural position on leaf, × 8; *B*, full-grown larva, × 2; *C*, cocoons; *D*, pupae (note the light color of the newly formed one on the left); *E*, adults at rest with wings in natural positions. *C*, *D*, and *E* slightly enlarged.

but darkens gradually until a short time before the moth emerges, when it takes on a dark brown or almost black appearance.

The cocoons may be attached to any object, but more often they are found on the under side in the folds of the lower or ground leaves of the host plants, or they may be attached to clods or other objects on the soil near the plants.

The pupal period may be passed in as few as 6 days during the summer, or the winter may be passed in this stage.

The Adult Stage

The adult is a grayish-brown moth with a wing spread of approximately 1¼ inches, and an irregular, characteristic marking in the front wing (fig. 8, *E*).

The adults are seminocturnal and usually avoid strong sunlight. They usually feed and deposit eggs about dusk, but in cloudy weather and in the fall when the evenings become cool they may be found active throughout the day. They are strong, active fliers and are apparently capable of covering long distances.

In cages the adults may live 2 weeks if given sufficient moisture and food, and during that time a single female may deposit from 50 to 200 eggs.

The time required for the complete life cycle depends on the temperature, but it is possible to complete the cycle, from the time the eggs are deposited until adults are formed and ready to deposit eggs, within a period of 20 days.

SEASONAL HISTORY

Under the climatic conditions prevailing in the Salt River Valley all stages of the cabbage looper may be found at any time. The continuous breeding throughout the winter, though greatly retarded by the cold weather, begins to build up populations that reach their maximum numbers early in the fall (October 15 to November 15). The number of generations produced has not been determined, but it is believed that as many as five to seven may occur.

Hibernation in the true sense does not take place for the species as a whole. Some pupae remain as such throughout the winter, which extends from approximately December 15 to February 1, but others produce adults that feed and deposit eggs during the warmer periods throughout the winter. Eggs hatch and the larvae are present during the winter, but the normal functions and rate of development are greatly retarded.

NATURAL CONTROL

The cabbage looper is readily attacked by parasites and predators. The eggs are deposited on the leaves with no protective covering. The larvae feed on the outer leaves of the plants in exposed locations. The cocoons are fragile and none too well hidden. The adults may be attacked by birds, bats, and other predators. The prevalence of parasites and predators to take advantage of these opportuntities allows lettuce to be successfully grown with a minimum of artificial control during certain years.

Diseases of the looper occur in Arizona to a certain extent, but do not appear to afford an appreciable degree of control except possibly during periods of excessive rainfall.

Parasites and Predators of the Eggs

The egg parasite *Trichogramma minutum* Riley becomes prevalent during the summer and fall, but varies in abundance in different fields. During October and November 1933, 365 looper eggs were collected and the parasitization ranged from 2.7 percent in one field to 38.4 in another in a different locality. During October and November 1934, parasitization ranged from zero to 47.1 percent in 965 eggs, and during October 1937 from zero to 23.6 percent in 446 eggs.

During the fall, when there is an overlapping of generations of the cabbage looper, an appreciable degree of control may be obtained when the larger larvae destroy the eggs while feeding, as most of the eggs are deposited on the parts of the plant where the larvae feed.

The remains of eggs that had been fed on by some predaceous form have been observed, but no particular insect has been found at this work.

Parasites and Predators of the Larvae

The larvae are subject to attacks from several parasitic forms, the predominating species being the tachinid *Voria ruralis* (Fall.). These parasites exercise an appreciable amount of control during the late summer and fall. During November and December 1934, out of 312 larvae collected from the fields the parasitization ranged from 81.1 to 100 percent, and during November 1937 the parasitization in 268 larvae ranged from 65 percent in one field to 81.3 percent in another. The larval parasites seem to be more uniformly distributed from field to field than do the egg parasites and exercise a more effective control against the looper.

One lot of looper larvae collected in December 1934 showed a parasitization of 96.6 percent. At that time host larvae were comparatively scarce and the tachinid adults were so numerous that looper larvae too small to develop parasites normally were attacked, and consequently 17.2 percent of the parasitic larvae died for lack of sufficient food. Larvae collected the following April, however, showed a parasitization of only 19.8 percent.

During the course of examining looper larvae for parasites it was not uncommon to find as many as five, six, seven, and eight parasites per host larva. The average for all the looper larvae collected in January 1933 was 3.19 parasites per host larva, and for all those collected in November, December, and January 1934 was three parasites per host larva.

The following hymenopterous parasites have been reared from looper larvae: *Euplectrus comstockii* Howard, *Microplitis brassicae* Vier., *Rogas rufocoxalis* Gahan, *Sagaritis websteri* (Vier.), and *Copidosoma truncatellum* (Dalm.). A few of these forms may be found from time to time, but they do not usually become sufficiently numerous to effect any appreciable control.

A predaceous ground beetle, *Calosoma peregrinator* Guér., and possibly others readily feed on the loopers. These beetles have been observed climbing the plants and devouring the larvae. The larger larvae seem to be more readily attacked by the beetles, whereas the smaller larvae are attacked by spiders that inhabit the lettuce plants.

Parasites and Predators of the Pupae

The pupae are not subject to the attacks of parasites to any appreciable extent. An undetermined tachinid has been reared that carries over from the larval stage and emerges after the pupae have been formed. This parasite enters the body of the host in the form of eggs or newly hatched larvae which are present on the food. Loopers reared in the laboratory from eggs deposited in cages may become parasitized by ingesting eggs or larvae of this species present on food taken from the fields.

Cocoons are often found that have been opened and the pupae destroyed, apparently by beetles, mice, or birds.

Enemies of the Adults

The adults are attacked to some extent by birds, but bats exercise a greater degree of control. The moths are usually more active during the evening when the bats are feeding than when the birds are awake. Large numbers of wings of *Autographa brassicae* are observed from time to time floating on the surface of the lakes in the early mornings, and these are believed to be from moths taken by bats.

CULTURAL CONTROL

Disposal of Lettuce Plants Discarded in the Thinning

It had been observed during the course of the work in 1933 and 1934 that a large part of the damage to lettuce from looper attacks came at or immediately following thinning. This was especially so if the plants had been allowed to grow to a height of from 2 to 4 inches or more before they were thinned. The larvae infesting the discarded plants found their way to the remaining plants and established a concentrated infestation. The removal from the field of the discarded plants with the larvae infesting them was attempted, but the habit of the larvae of dropping from the plants upon being disturbed served to hasten their establishment on the plants desired for the permanent stand.

Two plots of approximately 1 acre each were selected for conducting the plant-removal experiment. In one of the plots the discarded plants were immediately raked up, put into bags, and taken from the field. In the other plot the discarded plants were left in the furrows—the usual practice when lettuce is thinned.

Three days and again 11 days after the removal of the plants the larval counts were made in each plot on a sample of 50 plants. Each sample was divided into 10 subsamples taken at random and each subsample consisted of 5 consecutive plants.

In the plots where the plants were removed from the fields by laborers following immediately after the thinners, an average of 0.66 larva per plant was found 3 days after the plants had been removed, and an average of 0.78 larva per plant 11 days after the plants had been removed. In the plot where the plants were allowed to remain in the furrows an average of 0.61 larva per plant was found 3 days after thinning, and 0.60 per plant 11 days after thinning. It was noted at the time the plants were being removed that the larvae were dropping to the ground and crawling about in search of food.

Approximately 20 days after thinning there were 307 plants that would not produce marketable heads owing to looper injury on the acre plot from which the discarded plants had been removed, as compared with 382 plants on the acre where the discarded plants were allowed to remain in the furrows. The margin of 75 plants saved per acre seems too small for the practice to become of economic value.

Destroying the discarded plants at the time of thinning by plowing them under could not be successfully accomplished. The system of planting two rows of lettuce on a bed does not allow for sufficient soil to cover the discarded plants without uprooting those left on the side of the beds, and the furrows must be kept open for carrying the irrigation water.

INSECTICIDAL CONTROL

Allowable Time for Spraying or Dusting

Studies were made with the idea of establishing a definite time or period in the development of the lettuce plant at which spraying or dusting might be done without leaving an objectionable residue on the heads. The natural growth and development of the head of lettuce is from the inside, and the outer leaves so overlap that those underneath are protected. It naturally follows that it would be safe to use poisonous insecticides if all the outer leaves were stripped off when the lettuce was packed, but in order to protect the heads while in transit close stripping is not practiced.

A number of leaves, however, are stripped from the plants during commercial packing operations. For example, on one occasion an average of 10 leaves per plant were stripped from 69 plants during these operations. On this basis it would be safe to have remaining on the plants after harvest, but before stripping, not more than 10 leaves that were exposed to applications of poisonous insecticides. The number of such leaves were determined for a limited number of plants by recording at intervals during the growing period the leaves that were exposed and those that died or were left in the field at harvest. The resulting data as summarized in table 1 indicate that insecticides applied to these plants 35 to 40 days prior to harvest would not remain on the marketed product.

This period is a conservative one and is sufficient to cover plants that develop slowly. During seasons of maximum growing conditions the period of 35 to 40 days previous to harvest during which spraying or dusting should not be done may be safely reduced to 25 to 30 days and still leave no residue to reach the market.

TABLE 1.—*Number of lettuce leaves on harvested plants before and after being stripped for packing, classified by the length of the time prior to harvest that they were exposed or unprotected by overlapping leaves. Phoenix, Ariz., 1934*

Group No.	Plants in group	Minimum period leaves were exposed[1]	Leaves per plant exposed throughout period	
			On plant before stripping	On plant after stripping
	Number	*Days*	*Number*	*Number*
1	6	57 39 29 22	2 8 10 13	0 0 0 3
2	8	54 36 26 19	1 8 10 12	0 0 0 2
3	12	54 40 29 21	0.3 6 10 12	0 0 0 2
4	22	48 34 23 15	1 7 8 10	0 0 0 0

INSECTICIDE APPLICATIONS

During the course of the experimental work no special effort was made to apply a specific weight of dust to a given plot or plots. The rate of application shown for the various insecticides used was obtained by putting a given weight in the duster, treating a plot or plots, and then weighing that which was left. The thoroughness of each application was judged from the appearance of the flow of the dust or the density of the dust cloud.

A rotary-type hand duster was used in applying the insecticides. A Y-shaped nozzle spreader arrangement (fig. 9) was used so that both rows on a bed of lettuce could be dusted at the same time. During 1936 and 1937 one set of plots was sprayed each year. A constant-pressure hand sprayer was employed in these tests. The insecticides were applied when there was no wind, and the operator so guided the duster or nozzle that each plant received a uniformly thorough coverage.

Unless otherwise stated, the proportions of each of the ingredients of the dust mixtures appearing in the following tables are expressed in terms of the commercial grade of the insecticide used, and of the diluent, by weight.

A wide range in the rate at which the different insecticides were applied will be noted. The density of the various mixtures seemed to have had a direct bearing on this point. It was noted at the time of application that the heavier dust mixtures, such as paris green and lime, cryolite, and sulfur, and mixtures containing talc, flowed or were dusted more readily than did the mixtures of lighter densities, such as derris and clay, derris and pyrethrum, and calcium arsenate. In most of the experiments the tendency when the heavy dusts were used seems to have been for a greater amount of the insecticides to be applied than was desired, and when the dust mixtures of the lighter densities were applied, too little of the insecticides for a satisfactory control.

FIGURE 9.—The Y-shaped spreader of a hand-operated duster applying the insecticide to both rows on a bed.

APPLICATIONS AFTER THE LETTUCE HAD BEEN THINNED

The experimental control measures and the results for each year will be presented and discussed separately. The same general procedure was followed each year, but because of some variations the experiments do not lend themselves to direct comparisons in some instances.

The data relative to the value of applying various insecticides as control measures against the cabbage looper attacking lettuce will show for the most part (1) the percentage of plants free from infestation during the different examinations in the treated and untreated check plots, (2) the average number of larvae per plant at the time of the different examinations in the plots for the various insecticides and the untreated checks, and (3) the change in the percentage of infestation from that of the original population at subsequent examinations in the treated and untreated check plots.

EXPERIMENTS IN 1933

A portion of an 80-acre field of lettuce was selected for the experimental control work in 1933 on account of its high potential infestation. On September 27 there was an infestation of 169 eggs and 20 larvae per 100 plants, which on October 4 had increased to 514 eggs and 197 larvae per 100 plants, or a potential infestation of 7.1 larvae per plant.

Insecticides were applied to single large-sized field plots. During the course of the experiments frequent rains interfered with the efficiency of the various insecticides, and the larval populations became so low that a second application was unnecessary. The results obtained from these experiments are considered as of a preliminary nature.

The frequent rains during the experimental period altered the results to such an extent that definite conclusions could not be drawn.

but the decrease in the infestation of the treated plots when compared with the untreated plots showed that any of the insecticides used may control the cabbage looper to some degree.

Undiluted barium fluosilicate applied at the rate of 14 pounds per acre indicated excellent control, whereas barium fluosilicate, 1 part, to lime, 2 parts, applied at the rate of 7 pounds per acre showed no appreciable control. The derris-tobacco dust (1.66 percent of rotenone) gave good control, and the results on these plots and on those where undiluted derris dust (5 percent of rotenone) was used show clearly that rotenone is very toxic to the cabbage looper. The paris green, 1 part, to lime, 5 parts, applied at the rate of 7½ pounds per acre showed an appreciable degree of control, but it was also indicated that the rate of application was too low. The degree of control appeared to depend to a great extent on the rate of application and the proportion of the active ingredients in the various mixtures.

EXPERIMENTS IN 1934

During 1934 the experiments were conducted on small-sized field plots which included 16 treated and 8 untreated check plots of 1/16 acre each. The plots were 8 beds, or 16 rows, wide by approximately 100 feet long, and each treatment consisted of 2 replicates.

The population of the loopers was ascertained by examining a sample of 25 plants in each plot. Each sample was made up of 5 subsamples taken at random, and each subsample consisted of 5 consecutive plants. During the examinations the live and dead larvae and the number of eggs on each individual plant were recorded separately so as to make an individual infestation record for each plant.

At the time the insecticides were applied the looper populations were determined on the plots to be treated. The plots used as checks were not examined until later.

From a study of the data for 1934 presented in table 2 it is evident that a distinct degree of control was obtained by the use of each of the insecticides. This control was shown in the difference obtained (1) in the percentage of plants free of infestation in the treated plots when compared with those in the checks, (2) in the average number of larvae per plant for the treated plots when compared with those found in the untreated check plots, and (3) in the reduction of infestation from the original population.

Table 2.—*Cabbage looper infestation on lettuce following the application of insecticides to plants after thinning, Phoenix, Ariz.*

EXPERIMENTS OF 1934

Insecticides and diluents	Time of application	Rate per acre	Plants free of larvae after 6 to 13 days	Larvae per plant after 6 to 13 days	Reduction of larval population [1]
		Pounds	*Percent*	*Number*	*Percent*
Derris-clay (0.5 percent rotenone)	Morning	12	62	0.62	48.4
Derris-talc (0.5 percent rotenone)	do	9	46	.70	35.2
Derris-clay (0.75 percent rotenone)	do	14	64	.48	45.5
Derris-talc (0.75 percent rotenone)	do	18	70	.38	56.9
Cryolite [2] and clay (1-2)	Evening	7	60	.46	42.5
Pyrethrum flowers-clay (1-1)	do	20	72	.34	52.5
Derris-clay (1.0 percent rotenone)	Morning	19	68	.42	65.6
Derris-clay (1.0 percent rotenone)	Evening	19	72	.44	52.2
Untreated checks			35	1.29	

[1] Percent reduction during period between application of insecticide and the last examination, based on the infestation at the time of application.

[2] Imported synthetic cryolite containing approximately 98 to 99 percent of sodium fluoaluminate.

TABLE 2.—*Cabbage looper infestation on lettuce following the application of insecticides to plants after thinning, Phoenix, Ariz.*—Continued

EXPERIMENTS OF 1937

Insecticides and diluents	Time of application	Rate per acre	Plants free of larvae after—		Larvae per plant after—		Reduction of larval population
			3 days	7 days	3 days	7 days	
		Pounds	*Percent*	*Percent*	*Number*	*Number*	*Percent*
Derris-clay (0.95 percent rotenone)	Evening	9	82	60	.18	.60	−11.1
Derris-clay (0.95 percent rotenone)	Morning	9	82	62	.22	.50	24.3
Derris-sulfur (0.95 percent rotenone)	Evening	25	92	60	.08	.42	63.2
Derris-sulfur (0.95 percent rotenone)	Morning	25	90	76	.12	.26	73.0
Pyrethrum-sulfur-derris (0.17 percent rotenone)[3]	Evening	22	90	70	.12	.32	66.0
		Gallons					
Derris spray (0.01282 percent rotenone) with spreader 1-400.[4]	Morning	22	68	66	.54	.44	46.1
Untreated checks		------	40	26	1.14	1.32	−37.1

[3] Pyrethrum dust containing 0.95 percent of total pyrethrins, diluted with 2 parts sulfur, by weight, with sufficient ground derris to make 0.17 percent of rotenone.
[4] A commercially prepared alkylphenylbenzenesulfonic acid.

A distinct control trend is shown in the decrease in the percentage from the original infestation in the treated plots. At the same time there appeared to be an increase in infestation in the untreated check plots. The degree of control as indicated in the treated plots was higher than that actually shown. The elapsed period between the time that the insecticides were applied and the final examinations of the plants were made allowed eggs to hatch and larvae to feed on new plant growth that carried no poison, and the percentages as given included this increased infestation. A substantial degree of control, however, was obtained with each treatment. The 1 percent and 0.75 percent rotenone mixtures and the pyrethrum dust showed approximately the same degree of control, the 0.5 percent rotenone ranked second, and the cryolite third.

It is concluded from these data that any of these insecticides when applied in sufficient quantity may effect a control of the cabbage looper on small lettuce.

EXPERIMENTS IN 1935

The experiments of 1935 were carried out on field plots similar to those employed in 1934. The infestation at the time the insecticides were applied was approximately 0.5 larva per plant. The subsequent examinations revealed a general decrease in the infestation at the first-day, fifth-day, and tenth-day examinations. The decrease, being somewhat greater in the treated plots than in the checks, indicated a control trend for the insecticides, but owing to the light initial infestation and the general decrease over all the plots the tabulated data for 1935 are not presented.

EXPERIMENTS IN 1936

The fall lettuce crop of 1936 was seeded between September 10 and 25. Growing conditions were favorable, and the looper damage was considerably below that usually occurring. A survey of five fields in representative localities in the Salt River Valley was made and an average of 0.16 to 0.44 larva per plant was found during October 9 to 21. This infestation was very light, but the experimental control was conducted as had been done in previous years. Twelve plots were treated with the various insecticides and four plots were left untreated as checks.

The examinations to determine looper populations at the time the insecticides were applied on October 26 showed an average of 0.2 larva per plant. This infestation was rather low for evaluating the merits of the various insecticides, but a control trend was shown when the results of the population counts in the treated and check plots were compared. Since the infestation was so light, the tabulated data for 1936 are not presented.

EXPERIMENTS IN 1937

The procedure in conducting the experimental work during 1937 followed closely that for previous years. The experiment consisted of 14 treated and 2 untreated check plots. The lettuce was thinned on October 13 and the insecticides were applied on October 14 to 15. Weather was favorable during the experimental period. Temperatures ranged slightly above normal and there was no rainfall. An outbreak of the yellow-striped armyworm (*Prodenia ornithogalli* Guen.) caused some loss to the stand when the lettuce was small.

From the data presented in the 1937 block of table 2 the general control trend of the treated plots over the untreated checks was shown to parallel very closely the trends shown in 1934. The percentage of plants free of infestation, the average number of larvae per plant, and the decrease in the percentage of infestation from the original population count, with some exceptions, show a decided advantage in the insecticide-treated plots as compared with the untreated checks.

The comparative degree of control of one treatment over another cannot be shown, since the rates of the insecticide application were not comparable, but the better control indicated in the plots where dusting sulfur was used as the diluent was probably due in large part to the difference in the rates at which the insecticides were applied.

In the plots where the derris-sulfur mixtures were used 0.2357 pound of rotenone per acre was applied, and on the plots where the derris-clay mixtures were used 0.0855 pound of rotenone was applied, or more than 2½ times as much rotenone was used on one set of plots as on the other. It was recognized, however, that sulfur influenced the control to a greater extent than did the clay.

The relatively good control as shown from the use of ground pyrethrum-sulfur-ground derris was due to the liberal application of 0.1034 pound of rotenone added to the ground pyrethrum, with whatever advantage sulfur might add.

The degree of control as indicated from the use of the derris spray was too inconsistent to permit any definite conclusions to be drawn, but the 0.0334 pound of rotenone applied per acre seemed to give a slow rate of kill of the looper larvae. It was noted during the examination made 3 days after the spray was applied that the looper larvae had ceased feeding and that some had dropped from the plants although still alive. The examinations made 7 days after the spray was applied indicated that the larvae did not recover but died.

This same examination indicated that eggs may hatch and the small larvae feed on new plant growth that carries no poison. The count of the total larval infestation showed an increase in the average number of larvae per plant on the seventh day over the count made the third day after the insecticides were applied, and the percentage of plants free of infestation showed a decrease for the same period. When, however, consideration was given only to the larvae that were present on the plants at the time the insecticides were applied (fourth and fifth instars), the average number of larvae per plant showed a decided decrease, and the percentage of plants free of infestation by the large larvae showed a decided increase.

The data gathered from the experiments of 1937 show that good control was obtained. The decrease in the percentage of infestation in the treated plots and the decided increase in the percentage of infestation in the check plots clearly show that these insecticides were effective, and that when properly applied they may control the cabbage looper attacking small lettuce.

EXPERIMENTS IN 1938

The same general procedure was followed in conducting the experiments in 1938 as had been used during previous years. Three insecticidal treatments and one check were each replicated four times in a systematic square arrangement of plots. The lettuce was thinned on October 24, and the insecticides were applied on October 26.

The data presented in table 3 show a decided reduction in the infestation following the use of the different insecticides. The degree of control is shown by comparing the difference in the infestation at the time the insecticides were applied and the infestation 5 days later, and by comparing the infestation of the untreated checks with the infestation of the treated plots covering the same period.

TABLE 3.—*Cabbage looper infestation on lettuce following the application of insecticides to plants after thinning, Phoenix, Ariz., 1938*

Insecticides and diluents	Rate per acre	Average per plant: At time of treatment: Large[1] larvae	Average per plant: At time of treatment: Small[1] larvae	Average per plant: 5 days after treatment: Large[1] larvae	Average per plant: 5 days after treatment: Small[1] larvae	Reduction in infestation: Large[1] larvae	Reduction in infestation: Small[1] larvae	Reduction in infestation: All larvae	Plants free of infestation: At time of treatment	Plants free of infestation: 5 days after treatment
	Pounds	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Derris-clay (1.0 percent rotenone)	9	0.49	0.76	0.06	0.09	87.7	88.2	88.0	50.0	85.0
Cryolite-clay [2] (1:2)	8	.39	.68	.02	.12	94.9	82.4	80.9	51.0	88.0
Calcium arsenate [3] (undiluted)	9	.46	.67	.12	.24	73.9	64.2	68.1	48.0	73.0
Untreated checks		.43	.65	.80	.40	−86.0	38.5	−11.1	47.0	39.0

[1] The term "large" refers to the third, fourth, and fifth larval instars, and "small" to first and second larval instars.
[2] Imported synthetic cryolite containing approximately 98 to 99 percent of sodium fluoaluminate.
[3] Containing arsenic equivalent to 70 percent of tricalcium arsenate $Ca_3(AsO_4)_2$.

At the time the insecticides were applied, approximately 50 percent of the plants were free of infestation. Five days later the percentage of plants free of infestation had materially increased in the treated plots and had materially decreased in the untreated checks.

Data were collected which showed that after the treatment the plants having three or more larvae per plant were rare in treated plots, but the percentage of plants with an infestation of three or more larvae each in the untreated check plots remained practically the same as in the original infestation—and usually it is in this group of highly infested plants that the more severe losses occur.

It is concluded from these data that derris-clay and cryolite-clay may give satisfactory control of the cabbage looper, but the degree of control obtained with calcium arsenate was so low as to indicate that a higher rate of application per acre would be necessary.

During the course of the experimental work late-evening and early-morning dustings were made to determine which might be more effective, but there was no appreciable difference in the degree of control shown. Since there is here usually little or no dew to cause the dusts to adhere to the plants, the dusts should be applied at the time of day when very little or no wind is blowing.

APPLICATIONS PREVIOUS TO THINNING

During the course of the experimental work conducted in 1936, 1937, and 1938 a series of tests were made each year in an effort to establish the value of applying insecticides to small lettuce a few days previous to thinning.

In 1936 and 1937 the work was planned in such a manner that the insecticides might be applied from 3 to 5 days before thinning, but each year 7 to 10 days elapsed between the time the applications were made and the time the plants were thinned. This increased interval minimized the value of the resulting data.

In the fall of 1936 the insecticides were applied on October 12, the lettuce was thinned on October 19, the first infestation record was made on October 22, and the second on October 27. At the time the applications were made the lettuce had from 3 to 6 leaves, and the plants were from 1½ to 3 inches in diameter and overlapped one another in the row.

Since before the lettuce was thinned there was no method of determining the population of the loopers that could be adequately compared with one taken after thinning, the degree of control was determined by comparing the population of the treated and untreated plots at intervals of 7 and 15 days after the insecticides had been applied, and by computing the percentage of plants injured by loopers that would not produce marketable heads.

The experimental plots were 8 beds wide by 300 feet long and contained approximately 3/16 of an acre each. There were two replicates of each treatment. The records on the looper populations were made by following the same plan that has been described previously for the experiments in which the insecticides were applied after the lettuce had been thinned.

The elapsed time of 7 days between the date the insecticides were applied and the first record of infestation was too great for obtaining data that would show the maximum degree of control. The general trends, however, when the results of the treated plots are compared with those from the untreated check plots, as given in table 4, show that some control had been obtained.

TABLE 4.—*Cabbage looper infestation on lettuce following the application of insecticides to plants previous to thinning, Phoenix, Ariz.*

EXPERIMENTS OF 1936

Insecticides and diluents	Rate per acre	Average larvae per plant		Plants free of larvae		Plants injured that did not head
		7 days after treatment	15 days after treatment	7 days after treatment	15 days after treatment	
	Pounds	*Number*	*Number*	*Percent*	*Percent*	*Percent*
Derris-clay (1.17 percent rotenone)	19	0.06	0.12	94	88	0.7
Cryolite [1] and clay (1-2)	12	.10	.24	90	80	.6
Paris green [2] and lime (1-6)	12	.10	.08	92	94	.7
Untreated checks		.36	.40	68	72	1.0
EXPERIMENTS OF 1937						
		14 days after treatment	18 days after treatment	14 days after treatment	18 days after treatment	
Derris-clay (0.05 percent rotenone)	14	0.04	0	96	100	0.35
Cryolite [1] and clay (1-2)	7	.14	.10	88	90	.20
Paris green [2] and lime (1-6)	5	.02	.08	98	92	.23
Calcium arsenate [3] (undiluted)	7	.20	.10	85	90	.32
Untreated checks		.20	.24	80	82	.40

[1] Imported synthetic cryolite containing approximately 98 to 99 percent of sodium fluoaluminate.
[2] Containing more than 50 percent of arsenious trioxide, and not less than 3.5 percent of this in the "free" (uncombined) state.
[3] Containing arsenic equivalent to 70 percent of tricalcium arsenate, $Ca_3(AsO_4)_2$.

The examination made 15 days after the insecticides were applied showed an increase in the infestation over the 7-day examination. This indicated that the period of effectiveness of the insecticides had passed, owing largely to the rapid growth of the plants.

In 1937 the same general procedure was followed. The plots, however, contained one-eighth of an acre each, and the plants ranged from 1 to 3 inches in diameter and had from three to five leaves at the time the insecticides were applied. The plants were standing thick and overlapped in the row. The insecticides were applied on October 2, and the lettuce was thinned on October 12. The infestation records were made on October 16 and 20.

The data presented in the lower half of table 4 do not show any appreciable advantage of one insecticide over another, but a control trend was indicated when the results of the treated plots as a whole were compared with the results of the untreated checks. The first examination was made 14 days after the insecticides had been applied, and during that time the plants had increased several diameters in size. During this 14-day interval many looper eggs were deposited and hatched, and many of the resulting larvae fed on the unpoisoned plant growth that had developed since the insecticides were applied. Therefore, in judging the control values only the fourth and fifth instars should be considered, since the small larvae were not exposed to the insecticides, and to consider them would not give a true index of the degree of control obtained.

The difference between the looper populations in the treated plots as a whole and those in the untreated check plots was not great, and there were individual reversals within the treated plots that showed higher infestations than in the untreated checks. One of the cryolite-clay plots and the calcium arsenate plots showed high looper populations, but the general trend showed an appreciable degree of control in favor of the insecticide treatments.

The same general procedure was followed in 1938 as had been employed in the previous years. Conditions developed, however, that allowed two series or groups of experiments to be carried on. Group-1 experiments consisted of 25 plots arranged in a systematic square of 4 insecticide plots and an untreated check, each of which was in 5 replicates. Group-2 experiments were similar to those of group 1 except that 1 of the insecticides was omitted, which allowed a 16-plot arrangement with the 3 insecticides and an untreated check, each of 4 replicates. The presentation and discussion of the data from the 2 groups of experiments will be taken up separately since there was a great difference in the infestations in the 2 fields.

In the group-1 experiments the insecticides were applied on October 6, when the plants were from 1 to 3 inches high and were well overlapping in the row. The lettuce was thinned on October 9, thus allowing an interval of 3 days between the time the insecticides were applied and the time the lettuce was thinned. The infestation records were made on October 11 and 19.

The looper infestation was low in these plots at the time the insecticides were applied. Table 5 shows the mean infestation for the replicates of group 1 recorded 5 and 13 days after the insecticides were applied and the percentage of plants injured that did not make heads. The infestation 5 days after the insecticides were applied was low, but a considerable increase in the infestation of small larvae was shown by the examination made 13 days after the insecticides were applied. The low infestation of the large larvae at the 13-day examination indicated that the various insecticides had effectively controlled the infestation present at the time the applications were made.

TABLE 5.—*Cabbage looper infestation on lettuce following the application of insecticides to plants previous to thinning, Phoenix, Ariz., 1938*

Insecticides and diluents	Group 1						Group 2			
	Rate per acre	Average per plant				Plants injured that did not head	Rate per acre	Average larvae per plant 7 days after treatment	Plants free of larvae 7 days after treatment	Plants injured that did not head
		5 days after treatment		13 days after treatment						
		Large [1] larvae	Small [1] larvae	Large [1] larvae	Small [1] larvae					
	Pounds	*Number*	*Number*	*Number*	*Number*	*Percent*	*Pounds*	*Number*	*Percent*	*Percent*
Derris-clay (1.0 percent rotenone)	31	0.024	0.088	0.016	0.360	1.62	9	0.25	77.0	1.28
Cryolite [2] and clay (1-2)	10	.032	.072	.024	.472	1.16	8	.32	80.0	1.02
Calcium arsenate [3] (undiluted)	17	.048	.096	.024	.367	.50	9	.63	63.0	1.73
Paris green [4] and lime (1-6)	7	.072	.096	.048	.504	.92				
Untreated checks		.160	.248	.160	.328	3.95		1.81	31.0	11.46

[1] The term "large" refers to the third, fourth, and fifth instars, and "small" to first and second instars.
[2] Imported synthetic cryolite containing approximately 98 to 99 percent of sodium fluoaluminate.
[3] Containing arsenic equivalent to 70 percent of tricalcium arsenate, $Ca_3(AsO_4)_2$.
[4] Contents more than 50 percent of arsenious trioxide, and less than 3.5 percent of this in the "free" (uncombined) state.

The percentage of plants injured that did not make heads was comparatively low following the use of calcium arsenate, paris green-lime, and cryolite-clay, but rather high following the use of the derris-clay. This was due to an infestation containing not only cabbage loopers but also beet armyworms, and it has been determined that the beet armyworm cannot be readily killed with derris.

In the group-2 experiments for 1938 the insecticides were applied on October 26, the lettuce was thinned on October 31, and the only infestation count was made on November 2.

The looper infestation in these plots was higher than in those in group 1, and table 5 shows that the untreated plots had an infestation of 1.81 larvae per plant 7 days after the insecticides were applied; and when the untreated check-plot infestation is used as a basis for calculating the degree of control obtained following the use of the insecticides it will be seen that the derris dust containing 1 percent of rotenone in clay applied at the rate of 9 pounds per acre produced 86.2 percent decrease in the infestation, the cryolite and clay applied at the rate of 8 pounds per acre gave 82.3 percent decrease, and the calcium arsenate applied at the rate of 9 pounds per acre 65.2 percent decrease.

The percentage of plants free of infestation and the percentage injured that did not head show the same general control trend as was shown by the infestation count.

No appreciable difference in the degree of control is evident between the derris dust mixture and the cryolite mixture, but the control shown for the calcium arsenate seems to indicate that it may be less toxic to loopers and therefore may require a heavier rate of application to give a satisfactory control of cabbage loopers on small lettuce.

EFFECT ON LOSS IN MARKETABLE STAND

The percentage of plants missing, as shown from the data gathered from the various plots employed for testing the insecticides and thsoe used as untreated checks, may be the result of a number of influences, such as poor germination, improper cultural methods, disease, and attacks from various insects. There was no way of separating the causes of these different losses, but it was known that an important part was due to the attacks of the cabbage looper.

The loss attributable to cabbage loopers because of plants that did not produce marketable heads was low, as the difference from this cause between the loss in the treated plots and that in the untreated checks was not great. No data were collected or estimates made of the loss sustained because injured plants were delayed in their development, although they later produced marketable heads, but the combined losses from the above-mentioned sources were more severe than was apparent from the data presented.

Experiments conducted to determine the degree of loss to the lettuce crop due to the attacks of loopers when the insecticides were applied after the lettuce was thinned, and others to determine the loss when the insecticides were applied before the lettuce was thinned, have been discussed. When further damage was unlikely, examinations were made in the experimental plots 15 to 20 days after the application of the insecticides, to determine the percentage of plants missing and the percentage of looper-damaged plants that did not produce marketable heads. The data were collected from each treated and each check plot used during the different years and are presented in table 6.

TABLE 6.—*Lettuce plants missing at harvesttime and those with damage caused by loopers to the marketed portion following the application of insecticides, Phoenix, Ariz.*

Insecticides and diluents	Time of application	Rate per acre	Plants missing	Plants damaged by loopers
APPLICATION MADE AFTER THINNING, 1935				
		Pounds	*Percent*	*Percent*
Cryolite [1]-clay (1-2)	Evening	16	11.0	1.1
Derris-talc (0.8 percent rotenone)	Morning	25	9.2	1.1
Derris-talc (0.8 percent rotenone)	Evening	30	9.8	1.3
Derris-tobacco dust (1.6 percent rotenone)	Morning	12	10.3	1.2
Derris-clay (0.4 percent rotenone)	do	15	5.7	1.2
Derris-clay (0.8 percent rotenone)	Evening	14	7.0	1.3
Cryolite-sulfur (1-2)	do	34	8.3	1.3
Derris-clay (0.8 percent rotenone)	Morning	15	9.6	1.4
Derris-talc (0.4 percent rotenone)	do	15	8.1	1.9
Untreated checks			7.1	1.9
APPLICATION MADE AFTER THINNING, 1936				
		Gallons	*Percent*	*Percent*
Derris-spray (0.0225 percent rotenone with spreader 1-400 [2]).		16	15.9	0.8
		Pounds		
Derris-sulfur (1.17 percent rotenone)	Evening	23	15.9	.9
Derris-clay (1.17 percent rotenone)	do	20	14.5	.9
Derris-clay (1.17 percent rotenone)	Morning	27	18.1	1.0
Derris-sulfur (1.17 percent rotenone)	do	17	20.0	1.2
Pyrethrum [3]-sulfur-derris (0.58 percent rotenone)		17	15.8	1.4
Untreated checks			18.6	1.0
APPLICATION MADE BEFORE THINNING, 1936				
		Pounds	*Percent*	*Percent*
Cryolite-clay (1-2)		12	6.8	0.6
Derris-clay (1.17 percent rotenone)		19	8.9	.7
Paris green [4]-lime (1-6)		12	8.4	.7
Untreated checks			10.7	1.0
APPLICATION MADE AFTER THINNING, 1937				
		Pounds	*Percent*	*Percent*
Derris-sulfur (0.95 percent rotenone)	Evening	25	17.0	0.30
		Gallons		
Derris-spray (0.0182 percent rotenone with spreader 1-400).	Morning	22	20.3	.34
		Pounds		
Derris-clay (0.95 percent rotenone)	Evening	9	24.2	.41
Pyrethrum-sulfur-derris (0.47 percent rotenone)	do	22	18.1	.40
Derris-sulfur (0.95 percent rotenone)	Morning	25	19.2	.51
Derris-clay (0.95 percent rotenone)	do	9	27.4	.65
Untreated checks			19.7	.67
APPLICATION MADE BEFORE THINNING, 1937				
		Pounds	*Percent*	*Percent*
Paris green-lime (1-6)		5	21.6	0.23
Cryolite-clay (1-2)		7	36.2	.20
Calcium arsenate [5] (undiluted)		7	30.6	.32
Derris-clay (0.95 percent rotenone)		14	40.9	.35
Untreated checks			33.5	.40

[1] Imported synthetic cryolite containing approximately 98 to 99 percent of sodium fluoaluminate.
[2] A commercially prepared alkylphenylbenzenesulfonic acid.
[3] Pyrethrum dust containing 0.95 percent of total pyrethrins, diluted with 2 parts sulfur, by weight, with sufficient derris added to make 0.58 percent of rotenone.
[4] Contains more than 50 percent of arsenious trioxide, and not less than 3.5 percent of this in the "free" (uncombined) state.
[5] Containing arsenic equivalent to 70.0 percent of tricalcium arsenate, $Ca_3(AsO_4)_2$.

TABLE 6.—*Lettuce plants missing at harvesttime and those with damage caused by loopers to the marketed portion following the application of insecticides, Phoenix, Ariz.*—Continued

APPLICATION MADE BEFORE THINNING, 1938

Insecticides and diluents	Time of application	Rate per acre	Plants missing	Plants damaged by loopers
		Pounds	*Percent*	*Percent*
Calcium arsenate (undiluted)	Evening	17	6.3	0.55
Paris green-lime (1-6)	do	7	0.7	.86
Cryolite-clay (1-2)	Morning	10	8.4	1.05
Derris-clay (1.0 percent rotenone)	do	11	6.6	1.51
Untreated checks			11.2	3.50

The percentage of loss, as indicated when the difference between the treated plots and the untreated check plots was compared, was very low, both for the percentage of plants missing and for the percentage of injured plants that did not produce marketable heads. In 1935 and 1938 the percentage of injured plants that did not produce marketable heads in all the plots was much higher than for the other years, whereas the percentage of plants missing was greater during 1936 and 1937 than for either 1935 or 1938.

Further than noting a slight general control trend in favor of the treated plots over the untreated check plots, the data presented in table 6 seem to indicate that little direct loss to lettuce in these particular fields could be attributed to looper attacks during 1935, 1936, and 1937, but during 1938, with a heavier infestation, there seemed to be a distinct loss that should be attributed to looper attacks, both in the percentage of plants missing and in the percentage injured that did not produce marketable heads.

In 1938 the plots treated with the derris-clay dust containing 1.0 percent of rotenone show a greater loss than those plots treated with the dust containing cryolite 1 part to clay 2 parts, or the plots treated with calcium arsenate, or those treated with paris green 1 part to lime 6 parts. This greater loss was due, as has been said, to a mixed infestation of loopers and beet armyworms in this field in 1938, and no way of differentiating between the losses caused by each of these insects has been established.

RELATIVE VALUE OF APPLICATIONS BEFORE AND AFTER THINNING

In 1938 two series of experiments furnished data from which the results of insecticide applications made previous to thinning the lettuce and after the lettuce had been thinned could be compared. The same insecticides were applied at identical rates in the respective plots in each group of experiments. The lettuce in one group was dusted 5 days previous to thinning of the lettuce, and in the other group the lettuce was dusted 2 days after the lettuce had been thinned.

The data presented in table 7 permit comparison of the infestations following the two times of applying the insecticides. The looper infestation was higher 5 and 6 days after the insecticides were applied in the plots that were treated 5 days previous to thinning than it was 5 days after the insecticides were applied in the plots on which the treatments were made 2 days after the lettuce had been thinned.

TABLE 7.—*A comparison of the cabbage looper infestation and damage to lettuce when the insecticides were applied before and after thinning, Phoenix, Ariz., 1938*

Insecticides and diluents	Rate per acre	Insecticides applied— 5 days before thinning: Larvae per plant 5 and 6 days after application	5 days before thinning: Plants: Destroyed	5 days before thinning: Plants: Unmarketable	5 days before thinning: Plants: Total loss	2 days after thinning: Larvae per plant 5 days after application	2 days after thinning: Plants: Destroyed	2 days after thinning: Plants: Unmarketable	2 days after thinning: Plants: Total loss
	Pounds	*Number*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*
Derris-clay (1.0 percent rotenone)	9	0.25	0.2	1.2	1.4	0.15	5.0	1.0	6.0
Cryolite [1] and clay (1-2)	8	.32	.7	1.0	1.7	.14	3.6	1.0	4.6
Calcium arsenate [2] (undiluted)	9	.63	.5	1.7	2.2	.36	4.3	.8	5.1
Untreated checks		1.81	1.9	11.4	13.3	1.20	6.3	3.3	9.6

[1] Imported synthetic cryolite containing approximately 98 to 99 percent of sodium fluoaluminate.
[2] Containing arsenic equivalent to 70.0 percent of tricalcium arsenate, $Ca_3(AsO_4)_2$.

The better control of the loopers obtained when the insecticides were applied after the lettuce had been thinned was due largely to the more uniform application and coverage on the individual plants after thinning than could have been obtained before the plants were thinned when they stood thick and overlapping in the row.

Even though the looper larvae were more readily killed when the insecticides were applied after the lettuce had been thinned, it does not necessarily follow that such insecticides produce a more economical control. The larvae from the discarded plants congregate on the plants left standing, and though the plants have been poisoned a certain quantity of plant tissues will have to be consumed before a lethal amount of poison has been ingested, and in the meantime the small plants will have been injured or destroyed.

The data presented in that part of table 7 which compares the percentages of plants destroyed and the percentages of plants injured that did not produce marketable heads show that the losses thus sustained were much greater when the insecticides were applied after the lettuce had been thinned than when they were applied previous to thinning.

DISCUSSION OF METHODS OF CONTROL

The experimental data presented in this bulletin indicate that when infestations of the cabbage looper occur on lettuce plants when they are small and the foliage present will drop or be removed before the lettuce heads reach market, a satisfactory control can be obtained by applying a dust mixture containing 1 part of cryolite to 2 parts of talc or similar diluent at the rate of 10 to 20 pounds per acre. At this time satisfactory control can also be obtained by the application of a dust mixture containing 1 part of paris green to 6 parts of lime at the rate of 10 to 15 pounds per acre, or of undiluted calcium arsenate at the rate of 10 to 15 pounds per acre.

When insecticide applications are required within 4 or 5 weeks prior to harvest or so near the time of harvest that residues will remain on the marketed product, the above-mentioned materials should not be used. Cabbage loopers may be effectively controlled at this time by dusting the lettuce with a mixture containing 1 percent of rotenone prepared by diluting ground derris with talc or sulfur or by applying a mixture of equal parts of pyrethrum flowers and talc at the rate of 15 to 20 pounds per acre. Indications are that fairly good control can be obtained with dust mixtures containing as little as 0.5 percent of rotenone.

Usually the more severe damage to lettuce from the attacks of the cabbage looper comes immediately after the thinning of the plants, and if the infestation at that time is controlled no further damage usually occurs. It is therefore preferable that the insecticides be applied 3 to 5 days previous to the thinning to avoid a concentrated attack on the plants left standing. If this is done, no objectionable residue from any insecticide applied at that stage of plant development will remain to reach the consumer.

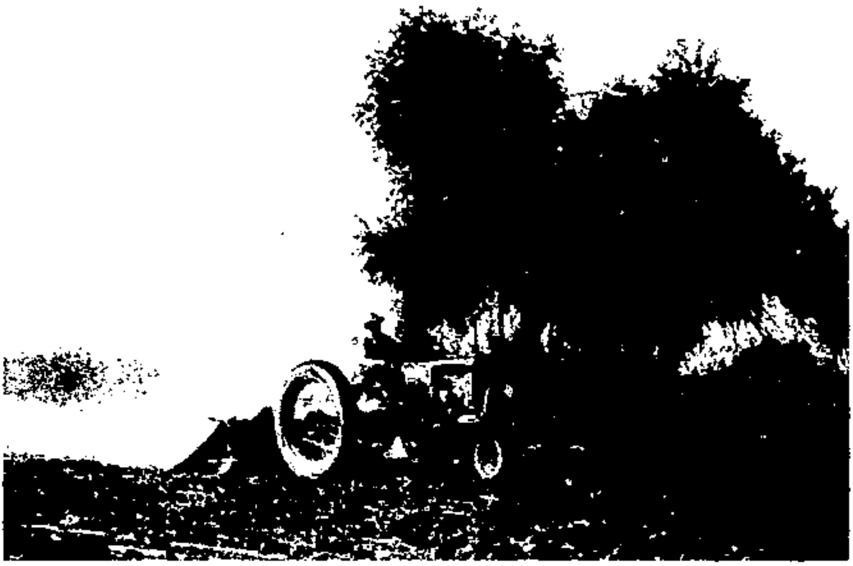

FIGURE 10.—A power-operated multi-row duster that gives a satisfactory distribution of the insecticide. Note the canvas used to confine the dust.

The above rates of application for the insecticides may seem rather high, but a quick kill of the loopers is necessary, especially when they appear on the plants immediately after the lettuce has been thinned, and, furthermore, a thorough coverage of the plants with the insecticide is essential. Figure 10 shows a power-operated duster which will give satisfactory coverage of the lettuce plants. An efficient hand duster has been shown in figure 9.

The looper infestation may not be so heavy as to cause severe losses every year, but as a safeguard it is a good practice to apply insecticides a few days previous to the thinning. A thorough coverage of the plants is essential, and this can be obtained only by applying the insecticides when there is very little or no wind. In the irrigated valleys of the Southwest the air is usually still late in the evening, at night, or early in the morning.

U. S. GOVERNMENT PRINTING OFFICE 1944

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