UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
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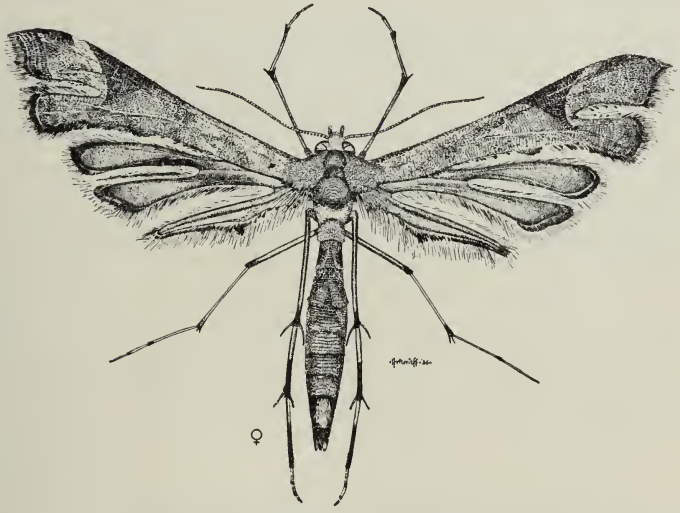
THE ARTICHOKE PLUME MOTH AND OTHER PESTS INJURIOUS TO THE GLOBE ARTICHOKE

W. H. LANGE, JR.



Adult of the artichoke plume moth. (× 3.5.)

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CONTENTS

THE ARTICHOKE PLUME MOTH AND OTHER PESTS INJURIOUS TO THE GLOBE ARTICHOKE[1]

W. H. LANGE, JR.[2]

INTRODUCTION

WITH THE INTRODUCTION of a commercially grown plant into a new locality there is often a possibility that it will be selected as a food plant by one or more native insects. This happened with the globe artichoke: since as early as 1922 the artichoke plume moth, *Platyptilia carduidactyla* (Riley), has been causing considerable loss in the artichoke-growing areas of California. In 1922 the damage became so severe that growers requested aid from the University of California and at that time a survey was made and preliminary control measures were offered. Again in 1936, at the request of artichoke growers in San Mateo, Santa Cruz, and Monterey counties, further investigations were undertaken.[3] The present work is the result of the investigations begun in May, 1936, and carried through May, 1940. During the course of the study it seemed desirable to make observations on the other important pests and on diseases of the globe artichoke. All this information has been brought together in this bulletin for the convenience of the artichoke grower.

The globe, or French, artichoke (*Cynara Scolymus* L.) is a member of the large family Compositae and is cultivated chiefly for its edible floral heads; it should be differentiated from another member of the same family, the Jerusalem artichoke (*Helianthus tuberosus*), which yields underground edible tubers.

It is the general belief that the globe artichoke is a cultivated form of the cardoon (*Cynara Cardunculus* L.). Sturtevant (Hedrick, 1919)[4] lists cardoon as being indigenous to the Mediterranean region and a part of central Asia. It was known and its leaf stalks eaten by the ancient Romans. In California, chiefly among the Italians, cardoon is utilized for its succulent leaf stalks, which are blanched and prepared in many ways.

It was not until the beginning or the middle of the fifteenth century

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[3] The funds necessary to carry out this investigation were in part contributed by the following counties: San Mateo, Santa Cruz, and Monterey.

[4] See "Literature Cited" at the end of this paper for full data on citations which are referred to in the text by author and date of publication.

that the first cultivation of the artichoke for its edible floral heads was reported at Naples, Italy (Hedrick, 1919). From Naples it spread to other parts of Italy, was introduced into England in 1548 and the United States in 1806. The French people of Louisiana were among the first to raise the artichoke for its edible floral heads in the United States, for Swingle and Fairchild (1899) reported that shipments had been made from New Orleans to St. Louis and Chicago, and to New York from Florida. The same authors also reported it to be grown to some extent in the vicinity of San Francisco.

In general, the varieties of artichoke can be divided into those with spines, and those without spines. Sturtevant divided the varieties into conical-headed types and globular-headed types. The conical-headed varieties would include those having well developed spines, being generally known as French artichokes, whereas the globular-headed forms usually lack spines, are somewhat flattened at the ends, and would include the true globe artichokes. There is considerable confusion existing in California in the naming of the different varieties in that conical types with spines have been grown for many years by the Italians with the result that these types have come to be called Italian varieties. On the other hand the globular, spineless varieties have assumed the name of French artichokes. Although most plants in the present artichoke fields have buds of a conical, spined nature, an occasional plant produces heads of a more globular form, with the spines reduced, or entirely lacking and the tips of the bracts grooved. The nature of the soil, climatic differences, age of the plants, irrigation, and fertilizer application are among the factors which may influence the form, color, spininess, and compactness of the artichoke heads, and account for a part of the variations which cannot be attributed to genetic differences. Rava (1937) and Cremonesi (1937) may be consulted for further information on varieties of the artichoke.

There is no definite information available in regard to the date of introduction of the globe artichoke into California, or whether it was first propagated by shoots or seeds. Stokdyk (1932) reported that although there are no detailed records available concerning the acreage of artichokes prior to the 1924–25 season, it was estimated that in 1900 there were 500 acres devoted to this vegetable in the Pedro Valley and Half Moon Bay districts. The greatest acreage occurred during 1925–26, with 11,760 acres, which gradually decreased to 6,330 acres in 1931–32 (Tavernetti, 1933). This was followed by a gradual increase in the 1934–35 season when 9,000 acres were planted. Since 1934 the total acreage has remained fairly constant, ranging from 9,000 to 10,600 acres. The de-

tailed acreage for the important artichoke-growing counties during the 1939–40 season is shown in the following tabulation:[5]

County	Acres
Marin	1,000
Monterey	4,950
San Luis Obispo	550
San Mateo	2,500
Santa Cruz	1,500
Santa Barbara	100

Although the total acreage has varied little since 1934, there has been a reduction in the acreage of artichokes in San Mateo and Santa Cruz counties chiefly as a result of decreased soil fertility combined with losses caused by the artichoke plume moth. The acreage in Marin and Monterey counties, on the other hand, has been steadily increasing since 1934.

DESCRIPTION AND HABITS OF THE ARTICHOKE PLUME MOTH

HISTORY AND DISTRIBUTION

The artichoke plume moth was described by C. V. Riley in 1869 from *Cirsium lanceolatum* in the first annual report of the state entomologist of Missouri.

Its first record in California was given by Walsingham (1880) in his *Pterophoridae of California and Oregon,* where he reported it as flying in "northern California" during June, 1872. Just when it first became established on artichoke is not known; in fact it was not until Essig (1922) presented a short account of its life history and suggestions for control, that any published information was available. It is very probable that the plume moth went over to artichoke from several thistles of the genus *Cirsium* which harbor this insect in all the present artichoke-growing areas of California. With the gradual spread of the artichoke industry from Pedro Valley and Half Moon Bay districts southward into Santa Cruz and Monterey counties, there must have been in addition, a spread of eggs, larvae, or pupae with the offshoots which are used in the propagation of this plant.

The known distribution of the artichoke plume moth in California is shown in figure 1. With further search it will undoubtedly be found over a much wider area in California.

Records obtained in the literature and through correspondence with entomologists have shown it to occur in the following states: Arizona,

[5] Acreages of artichokes are from the California Coöperative Crop Reporting Service, prepared by Carl M. Schiller (courtesy of John B. Schneider).

California, Colorado, Idaho, Illinois, Kansas, Kentucky, Ohio, Oregon, Maryland, Massachusetts, Minnesota, Missouri, Montana, Nevada, New Mexico, New York, North Carolina, Pennsylvania, South Dakota, Texas, Utah, and Wisconsin. In Canada the plume moth has been reported from the provinces of Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia.[6] Walsingham (1915) reported it from Central America at Guatemala and Costa Rica.

Fig. 1.—Known distribution of the artichoke plume moth in California, on both thistles and artichoke. Each dot represents the approximate location of infestations.

SYSTEMATIC POSITION

The artichoke plume moth belongs to the family Pterophoridae, members of which possess, with the exception of several minor genera, characteristic fissured wings.

It has been subject to little taxonomic confusion or synonomy. *Platyptilia percnodactyla* Walsingham is a closely related species, differing in certain structural details of the adult and in the immature stages (see McDunnough, 1927). *P. williamsii* Grinnell, also found on artichoke, shows many affinities to *carduidactyla,* especially in the life history and

[6] Records in the Canadian National Collection, supplied by Dr. J. McDunnough in correspondence, February 17, 1938.

immature stages. *P. ardua* McDunnough (1927) and *P. comstocki* Lange (1939*a*) are related species described in more recent years.

In the chronological review of the taxonomy given below, only the salient references are cited:

1869. Described from Missouri by C. V. Riley as *Pterophorus carduidactylus,* and reared from *Cirsium lanceolatum.*

1871. Zeller placed it in the genus *Platyptilia.*

1873. Zeller referred to it as *Platyptilia cardui.*

1908. Grinnell described it as *Platyptilia hesperis* from the San Bernardino Mountains of California.

1921. Barnes and Lindsey in their monograph presented it as *Platyptilia carduidactyla,* gave its known distribution and references, and listed *P. hesperis* as a synonym.

1922. Essig suggested that the immature stages of the insect known as the artichoke plume moth resembled those of *Platyptilia carduidactyla* (Riley), and not those of *P. acanthodactyla* Hübner.

1927. McDunnough separated *P. carduidactyla* from *P. percnodactyla* Walsingham on the basis of the adults and immature stages, and figured the pupae of both species.

1929. Essig listed it as the artichoke plume moth, and gave a description and figures of the larvae and pupae.

FOOD PLANTS

The artichoke plume moth selects as food plants several thistles of the family Compositae, in addition to artichoke and cardoon. Undoubtedly one or several of the thistles were its native hosts before the artichoke was introduced. It is of economic importance only on the artichoke and cardoon. The recorded food plants of the moth and the localities where infestations have been found are presented in the following tabulation:[7]

Cynara Scolymus L. (artichoke) ..... California; Kansas, Oregon (specimens in U. S. National Museum, correspondence with Carl Heinrich, August 20, 1938); New Mexico (correspondence with J. R. Eyer, September 30, 1939)

Cynara Cardunculus L. (cardoon or artichoke thistle) ..... California

Cirsium edule Nutt. (Indian thistle) .. California

Cirsium lanceolatum (L.) Scop. (common or bull thistle) ..... California; Oregon; Illinois (Walsingham, 1915); Missouri (Riley, 1869); New York (Kellicott, 1882)

Cirsium occidentale (Nutt.) Jepson ... California

Cirsium occidentale var. *venustum* Jepson ..... California

[7] Records without reference in parentheses are those obtained by the author. Names in parentheses with year citations indicate references in "Literature Cited." The other records were secured by correspondence with individuals as indicated by the dates of letters.

Cirsium quercetorum (Gray) Jepson
(brownie thistle) ..... California
Cirsium discolor (Muhl.) Spreng.
(roadside or field thistle) ..... Minnesota (Marcovitch, 1916)
Cirsium undulatum (Nutt.) Spreng.
(wavy-leaved thistle) ..... Washington (correspondence with R. D. Shenefelt, February 16, 1938)
Cirsium species ..... New York (Kellicott, 1882); Ohio (correspondence with Anette F. Braun, October 15, 1939); Washington (correspondence with R. D. Shenefelt, February 16, 1938)
Centaurea melitensis L. (Napa thistle) ..... California
Silybum Marianum Gaertn. (milk thistle) ..... California (Essig, 1922)

In certain experiments moths reared from either thistles or artichoke were caged with various thistles, artichoke, and other plants, to observe which of the food plants were most readily selected for oviposition by the females. These tests indicated that thistles of the genus *Cirsium* were often more readily selected than artichoke. The most highly preferred host along the central coast area is *Cirsium edule* (fig. 7), although *C. lanceolatum* is also commonly selected. Cardoon is often preferred to the artichoke. *Cirsium occidentale* is readily selected for oviposition but its distribution is limited, with the variety *venustum* maintaining populations of the moth in drier localities. Little information is available concerning the preferred host plants in the rest of the United States.

INJURY AND ECONOMIC IMPORTANCE

Larvae of the artichoke plume moth feed on any part of the plant, but their chief injury is to the floral heads (artichokes). The small larvae begin their feeding on the new heads just as they are forming, first selecting the outer bracts and later boring inside where they can feed on the tender inner parts. In this manner the larvae develop along with the growth of the heads, rendering them unsightly by the eaten out portions of the bracts, borings inside the heads, and a blackening of the heads resulting from feeding and frass exudation. Often the heads are permanently stunted, or disfigured by the feeding of the larvae, especially when the receptacle is fed upon; typical injury is shown in figure 2.

At times, considerable injury to the plants results from the feeding of the larvae on the center leaves and the crowns of the individual shoots, especially in areas where the plants do not grow vigorously, or do not receive an adequate supply of water. As the leaf stalks develop, the larvae bore directly inside, but their feeding does not cause much injury

at this time. Usually feeding is done solely aboveground, but occasionally mature larvae bore for short distances into the crowns, below the surface of the ground.

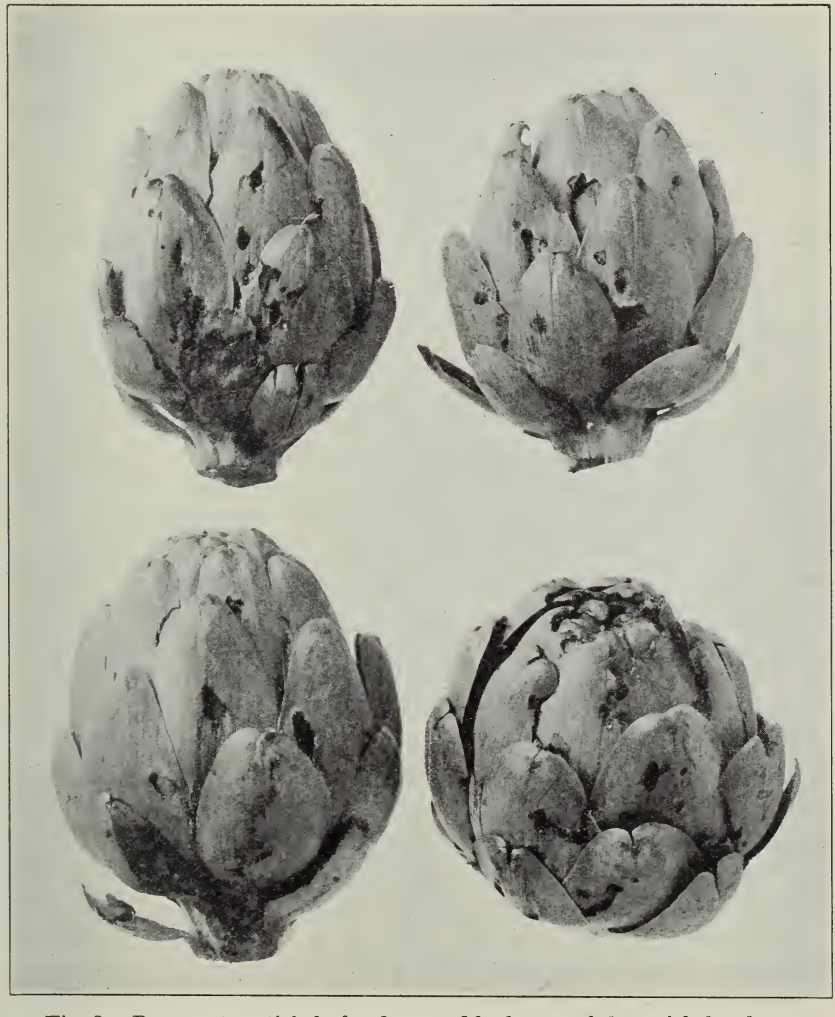

Fig. 2.—Damage to artichoke heads caused by larvae of the artichoke plume moth. (From Ext. Cir. 87.)

During the period 1936 to 1939, damage to floral heads in artichoke fields was found to range from less than 1 per cent to 80 per cent, with an average of from 10 to 15 per cent. In general, damage was most severe in older plantings where the plants were from three to six or more years

old, and was less severe in new plantings. Other factors which influenced the amount of worminess were fertilizer application, irrigation, type of soil, whether the field was part of a large acreage or isolated, cultural and sanitation methods used, prevailing temperatures, and the effectiveness of parasites.

The seasonal trends in losses to artichoke heads in a field at Half Moon Bay, for a five-year period, are presented in table 1 and shown graphically in figure 3. This is fairly representative of trends found in other fields in the chief artichoke-producing areas. During the five-year period,

TABLE 1

SEASONAL TRENDS IN THE PERCENTAGE OF ARTICHOKES DAMAGED BY THE ARTICHOKE PLUME MOTH FOR A 22-ACRE FIELD AT HALF MOON BAY DURING THE PERIOD 1934 TO 1939

Month	Number of wormy artichokes	Total number of good and of wormy artichokes	Per cent of wormy artichokes*
September	1,006	18,829	5.52
October	4,705	60,141	7.82
November	6,844	93,374	7.34
December	9,511	100,957	9.42
January	13,454	104,983	12.81
February	12,052	95,126	12.67
March	12,332	142,143	8.67
April	8,075	131,759	6.13
May	2,454	44,006	5.58

* The average per cent of damaged artichokes for the five-year period was 8.90.

1934 to 1939, the percentage of wormy artichokes gradually reached a peak in January and February, then diminished again until the time the plants were cut in May. It appears that the increased worminess during January and February is caused by an increase in larval populations resulting from the overlapping of two generations; this is because of a carryover of the fall generation and a start of the spring generation, at a time when floral heads are produced in abundance. The peak in the production of artichokes is usually during March and April, although it varies from year to year according to the prevailing temperatures. The percentage of worminess also varies from year to year; this depends upon the peaks in production, and again, judging from the available data, it is correlated with prevailing temperatures. During years of increased populations of the moths and decreased production, as during 1937–38, the worminess increased considerably as can be seen in figure 3. It is significant that these peaks in worminess occurred simultaneously in all the artichoke-producing areas. The worminess trends of ten fields in the

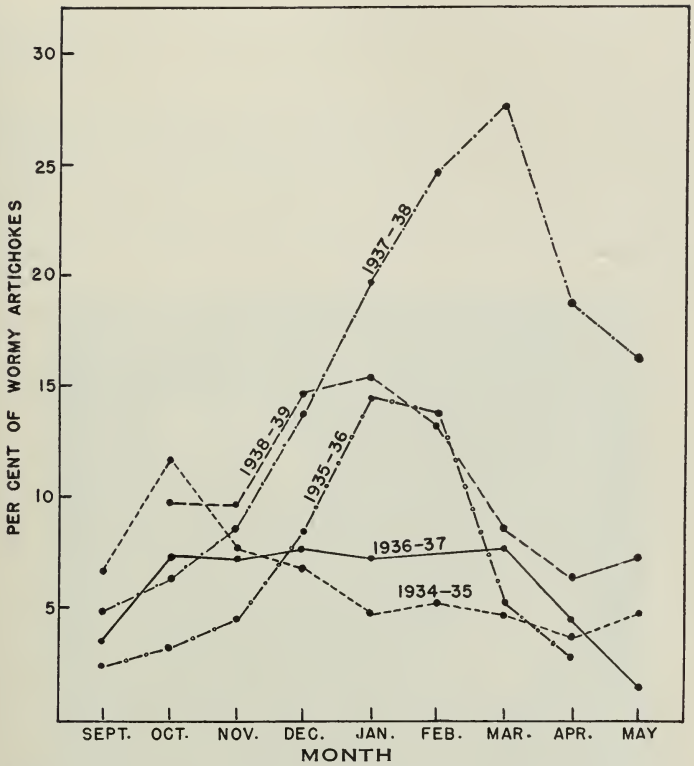

Fig. 3.—Seasonal trends in the percentage of wormy artichokes in a 22-acre field at Half Moon Bay. (From data summarized in table 1.)

TABLE 2

PERCENTAGE OF ARTICHOKES DAMAGED BY THE ARTICHOKE PLUME MOTH IN SAN LUIS OBISPO COUNTY FOR THE CROP SEASONS 1937–38 AND 1938–39*

Field no.	October		November		December		January		February		March		April		May		Average	
	1937	1938	1937	1938	1937	1938	1938	1939	1938	1939	1938	1939	1938	1939	1938	1939	1937–38	1938–39
1	14.0	...	10.3	...	16.6	7.2	24.3	8.2	25.6	10.8	28.0	14.3	26.3	11.6	...	6.9	25.1	10.4
2	15.5	...	11.5	...	8.0	...	18.5	4.2	53.8	9.4	40.9	9.0	32.6	9.0	...	...	31.4	9.3
3	14.4	...	11.8	...	7.9	...	14.6	5.0	34.6	5.8	30.9	7.0	26.6	6.9	3.4	...	25.5	6.7
4	....	...	3.6	...	6.8	...	8.5	...	6.4	10.7	....	8.7	....	9.1	...	...	7.0	9.8
5	20.0	...	9.2	...	12.4	...	18.3	...	42.8	...	28.7	....	17.2	....	...	...	20.3	....
6	11.5	...	13.8	...	10.4	...	14.3	...	23.2	....	19.8	....	....	....	...	...	18.2	....
7	....	...	14.7	...	11.7	5.6	16.2	7.2	30.6	8.1	25.2	9.8	13.8	9.6	...	3.6	20.6	8.7
8	....	...	0.0	...	2.0	...	4.6	...	7.4	7.2	8.2	5.2	....	5.5	...	1.6	6.7	4.6
9	5.0	0.0	5.5	0.3	4.7	0.5	6.95	1.4	10.2	1.7	6.2	1.5	3.4	1.9	2.4	1.4	5.2	1.4

* Records obtained from weekly counts kept by growers through the courtesy of R. M. Drake, Office of Agricultural Commissioner of San Luis Obispo County.

San Luis Obispo region are presented in table 2, and show the peak of worminess during the 1937–38 season, as compared to the great reduction during the 1938–39 season.

It is difficult to estimate the populations of larvae on a plant that will cause a specific per cent of wormy artichokes, because it depends upon the number of heads produced and whether the larvae are distributed on a young plant with a single shoot or on an older plant with a dozen or more shoots. Another factor which should be mentioned is that the

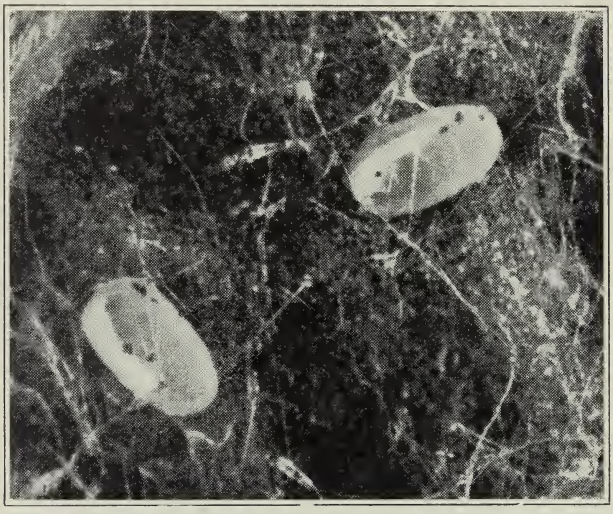

Fig. 4.—Eggs of the artichoke plume moth among the woolly hairs of the artichoke leaf. (× 33.)

rate of growth of the heads is important, for heads that form slowly allow a longer time for the larvae to crawl into them.

DESCRIPTION OF THE STAGES

Adult.—The adult artichoke plume moth is yellowish brown in color with a wing expanse of from 18 to 27 millimeters (¾–1 inch). The forewing is divided at two thirds the distance from the base. Just before the cleft is a well-defined dark-brown triangular mark which extends to the costal margin. There is usually a lighter outlining of the triangle on its outer face. The hindwings are trifid and uniformly dark brown; the fringes have darker scales near their bases. The third lobe of the hindwing has a very definite triangular scale mark at approximately the center with a few scattered dark scales to the base of the wing. The undersides of the wings are uniform brown except for yellowish markings on

the forewings. The hind legs are banded with dark brown, and each tibia has two pairs of spurs. The adult is shown in the frontispiece.

Egg.—The egg (fig. 4) is oblong-elliptical to oval, smooth, and glossy, and in size ranges from 0.52 to 0.66 mm long, and from 0.26 to 0.35 mm high. When first laid the eggs are pale lemon yellow, later turning darker. They can be laid on a horizontal or vertical axis in relation to the leaf surface.

Larval Stages.—The larva molts three times and therefore passes through four instars. Head-capsule measurements have verified rearing

TABLE 3

HEAD-CAPSULE MEASUREMENTS OF LARVAE OF THE ARTICHOKE PLUME-MOTH

Instar	Number of larvae measured	Observed head-capsule width, millimeters	Calculated width of head capsule, millimeters*
1	16	0.24	....
2	9	0.43	0.39
3	11	0.67	0.64
4	9	1.06	1.05
4 (prepupal)	7	1.07	....
5 (theoretical)	..	....	(1.72)

*The average of the ratios of increase for this species, as far as these measurements are concerned, is 1.64. The ratio of increase for each instar was obtained by dividing each of the series of observed measurements by the preceding number in the series. Calculations were made by Dyar's rule.

records in regard to the presence of four instars. It can be seen by reference to table 3 that the difference between actual and calculated head-capsule measurements is so slight that there is little probability of having overlooked an instar.

The first instar larva is about 1 mm long (approximately $\frac{1}{25}$ inch) and pale yellowish in color, with the cervical shield and anal plate brown. There are four pairs of prolegs, one pair each on segments 6, 7, 8 and 9, and an anal pair. The prolegs are stalklike and of the same color as the body. The primary setae are moderately long, colorless, and arise from minute, black-spotted tubercles. Soon after emergence the setae turn darker as do the true legs, cervical shield, and anal plate. The head is rather large in proportion to the rest of the body. Larvae in this instar feed for the most part externally on the tender new leaves, but may bore directly into the leaf stalks or floral heads.

The second instar larva resembles the first instar, but is about 3 mm long (approximately $\frac{3}{25}$ inch). As in the first instar larva the body is

yellowish except for the darker head, cervical shield, anal plate, and true legs.

The third instar larva is pale yellowish in color and about 5 mm long (approximately 1/5 inch) with markings similar to those of the second instar. They feed for the most part internally, but can also feed externally.

The fourth instar larva soon after molting is a dirty-white color, and approximately 7 millimeters long (7/25 inch). In about 5 days it turns yellowish to pinkish yellow, reaching at maturity a length of about 12 mm (approximately 1/2 inch). The head, cervical shield, anal plate, and

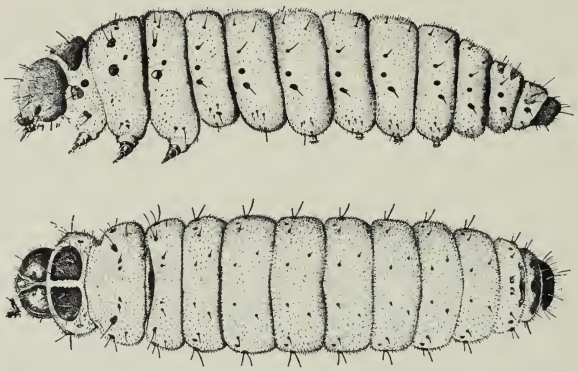

Fig. 5.—Mature larva of the artichoke plume moth from the lateral and dorsal aspects. (× 6.)

true legs are black as in the previous instars, and the setae arise from darker tubercles. The body is covered with characteristic short, black, secondary setae. The stalklike prolegs are conspicuous. Larvae in this last stage are for the most part internal borers, in the buds, leaf stalks, or stems, but can also feed externally. The prepupal larva is essentially the same as the fourth instar larva, except the body becomes swollen and all feeding ceases. The fourth instar larva is shown in figure 5.

Pupa.—The pupa is slightly angulate, varying in color from a pale yellowish brown to dark brown and is from 10 to 12 mm long (approximately 1/2 inch). Often the abdomen shows a dorsal, longitudinal dark-brown line, and similar subdorsal and subspiracular lines. The abdominal segments possess very distinct toothlike spines which project posteriorly. The pupa is attached nakedly at the cremasteric end by two areas of attachment. The front is produced downwardly in beaklike fashion. Sometimes a very thin silken cocoon is formed, especially if pupation occurs in an exposed location. The pupa is shown in figure 6.

LIFE HISTORY AND HABITS

In the coastal artichoke-growing areas the artichoke plume moth has three overlapping generations a year, making it possible to find all stages during every month. In common with most plume moths the life history is completed chiefly aboveground, although occasionally, especially on thistles, the larvae may bore for short distances into the crowns or roots of the plants. There is no evidence of any prolonged hibernation or estivation habits. Eggs are laid chiefly at night, singly and externally, among the woolly hairs on the undersurface of the leaves, or occasionally on

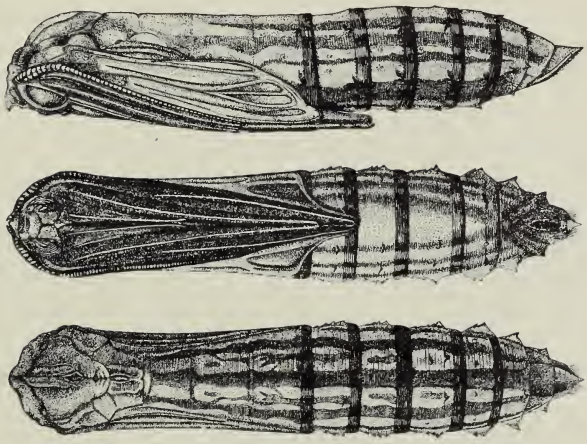

Fig. 6.—Pupa of the artichoke plume moth. (× 6.)

other parts of the plants. The larvae are active, feeding on the tender interfolded leaves during their earlier stages and later boring inside the leaf stalks or floral heads. Pupation occurs on any part of the plant, but usually takes place in the larval burrows inside the leaf stalks or on the outer bracts of the floral heads. Adults emerge throughout the year, flying chiefly at night, and during favorable temperature conditions deposit eggs during most of their lives. There is no evidence that moths reared from artichoke vary biologically or anatomically from those reared from thistles, and numerous experiments have demonstrated that moths mate with each other readily, regardless of the host plant. The life history on thistles conforms fairly closely to that on artichoke as there is a succession of thistle hosts throughout the year along the coastal humid belt. Caging experiments in the different artichoke-growing areas demonstrated that the life history of the moth is similar, although minor fluctuations do occur.

Habits of the Adult.—Adults of the artichoke plume moth are not commonly encountered in artichoke fields as they rest during the day on the undersides of the leaves well down in the plants where they are protected. They can be "flushed," however, when the foliage is disturbed, and they fly for short distances to nearby plants.

At rest, the wings are held outstretched, almost in a horizontal position and they have a very interesting habit of "flitting" the wings up and down. The hindwings are folded under the forewings, giving the impression that only two wings are present.

In the laboratory, adults were found to live as long as 30 days, although the life span under natural conditions was usually less than this period.

Mating usually occurs within 3 days after emergence and can take place without previous feeding. In mating the abdomens are brought together, with the male often being suspended in mid-air, attached to the female. The pair remain in this position for as long as 24 hours, and it is not uncommon for a pair to mate two or three times.

Adults have been observed to fly from one-half hour before sunset to midnight, the time depending chiefly upon the temperature. They may also fly during the day, but usually only when disturbed. The minimum flight temperature was found to be 46° F, the observation being based on the capture of a male on the night of January 15, 1938, at 6:30 P.M. at white light, in a field at Half Moon Bay. During the running of light traps in that area it was found that practically all flight ceases at 50°, with a change of 2° often determining flight activity. At Moss Landing on May 18, 1939, at dusk, a male was observed to fly a total of 546 yards in eleven individual hops, or approximately an average of 50 yards to a single hop. There was no wind during this observation so the moth could be followed at a fast walk. Usually the flight is rather jerky, or zigzag in nature, reminding one of the flight of a crane fly.

The adult females are active chiefly at night, at which time the eggs are laid on the undersides of the leaves among the woolly hairs. Occasionally the eggs are deposited on the floral heads, veins of the leaves, leaf stalks, or stems. In the case of thistles, however, an example being the very tomentose species, *Cirsium occidentale,* the floral heads are readily selected as egg-laying sites because of their woolly nature. In general, tomentose surfaces are preferred to smooth surfaces as places for egg deposition.

After a preovipositional period of from 3 to 8 days, adult females were found to deposit from 70 to 300 eggs, with an average of approximately 170 eggs. The number of eggs laid by isolated pairs of moths, kept in battery jars at outside temperatures and fed on a 10 per cent sucrose

solution, is given in table 4. An examination of the ovaries of the dead females showed that from 2 to 49 mature eggs remained unlaid.

Habits of the Larva.—The larvae in hatching from eggs which are laid on the underside of the foliage, start an immediate migration to the base

TABLE 4

NUMBERS OF EGGS LAID BY CAGED PAIRS OF THE ARTICHOKE PLUME MOTH

Pair no.	Date of emergence of adults	Date of first eggs	Total number of eggs laid
1	Male: January 29; female: January 30	February 4	135
2	January 29	February 2	210
3	Male: January 31; female: February 1	February 9	159
4	February 28	March 3	281
5	March 29	April 3	99
6	April 8	April 13	292
7	April 9	April 12	185
8	April 13	April 17	192
9	April 13	April 18	184
10	Male: April 17; female: April 22	April 29	107

of the plants to seek out tender interfolded leaves. They bore directly into a bud if one is present, or into the leaf stalks. Usually the first two instars are spent more or less externally among the tender leaves, while the last two instars are spent inside the leaf stalks or buds. The buds are usually

TABLE 5

DURATION OF THE EGG STAGE OF THE ARTICHOKE PLUME MOTH

Female no.	Number of eggs laid	Length of incubation period, days	Mean temperature, degrees Fahrenheit
1	3	24	50.80
2	9	22–23	50.33
3	12	20	51.92
4	12	13–15	57.74
5	34	14–15	57.57
6	14	14–15	57.89
7	35	13–15	58.40
8	28	12–15	58.51
9	6	12–13	60.93
10	39	11	59.64
11	3	10	61.25

preferred, but if none are present the larvae bore inside the leaf stalks. There is a certain amount of migration from one bud to another, or from a leaf stalk to a bud; but once a bud grows out from the protection of the leaves, it usually escapes selection by the larvae. The larvae in the buds

grow with the developing buds, or may bore 6 to 18 inches up or down inside the leaf stalks. It was found that the first heavy fall rains cause those larvae boring more or less externally, to immediately enter heads to gain more protection. Also, rain collecting between the bracts often drowns a small percentage of molting larvae which cannot escape.

TABLE 6

DURATION OF STAGES OF THE ARTICHOKE PLUME MOTH AT LABORATORY TEMPERATURES*

Stage	Number of records	Maximum, days	Minimum, days	Average, days
First instar	26	8	8	8
Second instar	26	6	5	5.19
Third instar	26	12	5	7.07
Fourth instar	23	24	14	16.82
Prepupal	19	4	2	2.63
Pupal	18	28	22	24.27

* The average for 18 completed records was 63.16 days, from the hatching of the egg to emergence of the adult. The mean average temperature during these rearings was 62.68° F.

Duration of the Immature Stages.—The duration of stages of the artichoke plume moth from the time the egg is laid until emergence of the adult was observed to vary from 80 to 110 days at outside temperatures. If the estimated life of the adult, 30 days, is added to these figures, a complete cycle would be 110 to 140 days.

TABLE 7

DURATION OF STAGES OF THE ARTICHOKE PLUME MOTH AT OUTSIDE TEMPERATURES*

Stage	Number of records	Maximum, days	Minimum, days	Average, days
First instar	16	23	10	14.25
Second instar	16	23	5	13.00
Third instar	16	28	9	16.50
Prepupal	5	12	8	8.80
Pupal	16	31	9	23.18

* The average for 16 completed records was 96.42 days, from the hatching of the egg to emergence of the adult. The mean average temperature during these rearings was 56.16° F.

The duration of the egg stage varies directly with the temperature, showing a range of from 8 to 24 days for coastal conditions during the year (table 5). Eggs can be found on thistles and artichoke during every month of the year.

The length of the larval stage varies considerably, the time depending

primarily upon the temperature. Under laboratory conditions, during 1937, at a mean average temperature of 62° F the larval period ranged from 34 to 54 days, whereas at outside temperatures, during 1938, at a mean average temperature of 56°, a range of from 32 to 86 days was recorded. In the rearing records summarized in tables 6 and 7 the larvae

Fig. 7.—Indian thistle, *Cirsium edule*, a preferred host of the artichoke plume moth, showing a badly deformed head (in the upper right-hand corner) caused by feeding of the larvae.

were reared on pieces of artichokes in Stender dishes. During cold temperatures, as recorded during January, 1937, when a minimum of 26° was reached, no killing of larvae was found, although there was a definite prolongment of the fourth instar.

In the field the pupal period varies from approximately 10 to 30 days, whereas in the laboratory it has a range of from 22 to 28 days.

Succession of Thistle Hosts.—Cirsium thistle hosts of the plume moth in California, with the exception of *C. quercetorum,* are biennials, starting their growth during the fall of one year, and flowering the next summer. In the case of *C. edule* (fig. 7), the preferred host in the coastal artichoke-growing districts, the flowering plants are usually completely dried up by the end of September, and adults emerging from the summer generation have no plants on which to deposit eggs. Along creeks or in moist localities, of course, new plants may come up continuously throughout the year. It so happens, however, that at this time many small plants of *C. lanceolatum* are present, as this species is more adapted to dry conditions, and the fall generation of the moth is started on this host. The growth habit of *C. occidentale* and its variety *venustum* are similar to that of *edule,* although *venustum* is more adapted to drier localities. In the case of all the thistles, during years of summer or early fall rains, new plants may come up earlier, and the plume moth can carry over directly to small plants of the same species. *C. quercetorum* is a perennial, drying up completely during the summer, but with the roots remaining alive in the ground to send up shoots the following spring.

SEASONAL CYCLE

In order to understand the seasonal cycle of the artichoke plume moth it is necessary to call attention to the nature of growth of the artichoke and the cultural practices employed in its commercial production. The artichoke is a perennial and will grow for fifteen years or longer in the same location without being moved. It is the customary practice among commercial growers of the artichoke, however, to replant with "stumps" or offshoots about every third year in order to obtain a more vigorous plant and a more satisfactory marketable size of heads. A grower usually divides his field into blocks so that he can have plants of different ages, which will yield a crop throughout the year and also making available a supply of offshoots for new plantings. From April 20 to June 15 the tops of the artichoke plants are cut off entirely, usually by a machine which severs the stems several inches below the surface of the ground. Some fields are left to produce a summer crop. In localities where no irrigation is used, the plants are cut later in the year after the peak of production, in May or June.

Often within 4 to 5 days after the plants are cut, new shoots start up. The cutting of the plants and their destruction kills a large proportion of eggs and small larvae on the plants, but some adults have already emerged and also continue to emerge from any debris left in the fields. These adults deposit eggs on the new shoots, often when they are only

a few inches high and the emerging larvae start the summer generation and feed among the interfolded new leaves at the axils of the shoots or bore directly inside the tender leaf stalks. The summer generation does little damage to the floral heads as only a few are formed on the plants during this cycle of the moth. The first adults emerge during the latter part of August and lay eggs which upon hatching start the fall generation. The fall generation larvae begin to crawl to the axils of the artichoke plants at about the time the heads are being produced in

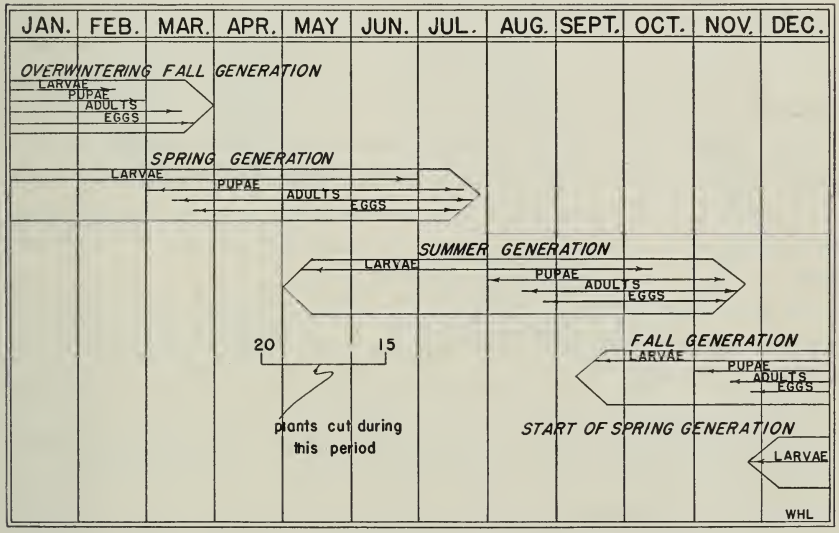

Fig. 8.—The seasonal cycle of the artichoke plume moth.

abundance with the result that damage to the heads becomes more severe at this time. A few adults of this generation emerge in November and December while the rest emerge the following spring. The spring generation starts at the end of November and continues to the following summer. The increase in wormy heads during January and February is caused by the combined fall and spring generations. The seasonal cycle is portrayed in figure 8.

The seasonal cycle on thistles in the coastal artichoke-growing areas is similar to that on the artichoke. There is a succession of thistle plants throughout the year allowing a continuous development of the moth. The cycle on thistles is not recorded in detail for any other part of the United States, although Kellicott (1882) in New York found but one brood, and Marcovitch (1916) for Minnesota indicated two broods on *Cirsium discolor*.

DISTRIBUTION IN RELATION TO CLIMATIC FACTORS

The distribution of the artichoke plume moth is not known well enough, even in California, to propose temperature, rainfall, or other climatic limitations which might be used as determinants of its natural spread. Certain facts have been presented, however, which seem significant in determining its known distribution in California.

The most important factor in determining its ability to maintain populations in any area, as far as its natural distribution on thistles is concerned, is the succession of thistles throughout the year, either as one or several species. In years where small plants of *Cirsium edule* do not come up during the summer, especially during July, August, and September, when the rainfall along the coast is at a minimum, the moth is not able to maintain itself because it is not adapted to an estivation period. The thistle *C. lanceolatum,* however, is widely distributed along dry roadsides, and for this reason can serve as a summer host. In the fall when new plants of *C. edule* again appear, the moth is again able to select this host.

On artichoke, irrigation during the summer in the most extensive commercial producing areas enables the moth to maintain populations throughout the year. In areas such as Marin County, where no irrigation is used, the plants dry up during the summer, usually between July and October or November, and the ability to maintain populations depends upon the occurrence of early rains which produce new shoots again. The production of artichokes without irrigation therefore offers a natural check on the maintenance of large populations of moths. It has also been observed that when artichoke fields which maintain large populations of moths are allowed to dry up during the summer, the populations are reduced to a minimum.

CONTROL OF THE ARTICHOKE PLUME MOTH

NATURAL ENEMIES

The artichoke plume moth has a number of natural enemies, most of which parasitize the larvae.

Primary Larval Parasites.—The ichneumon, *Angitia platyptiliae* Cushman, a parasite of the larvae was recently named by Cushman (1939) from the artichoke plume moth and is the most effective and widespread parasite of this moth, both on artichoke and thistles. It is a black species with reddish legs, from 5 to 7 mm in length (approximately ⅕ inch). The antennae are about 4.5 mm long and in the female

the ovipositor sheath is 2 mm long (fig. 9). Reflecting the continuous generations of the host, this parasite is found throughout the year. The adult female seeks out the larval burrows of the moth apparently inserting her eggs in the bodies of half-grown larvae. The larva of the plume moth often goes into a prepupal state, but it is consumed in a few days by the larva of *Angitia*. The *Angitia* larva soon spins a brown, silken cocoon (fig. 9). During the period 1937 to 1939, parasitism by *Angitia*

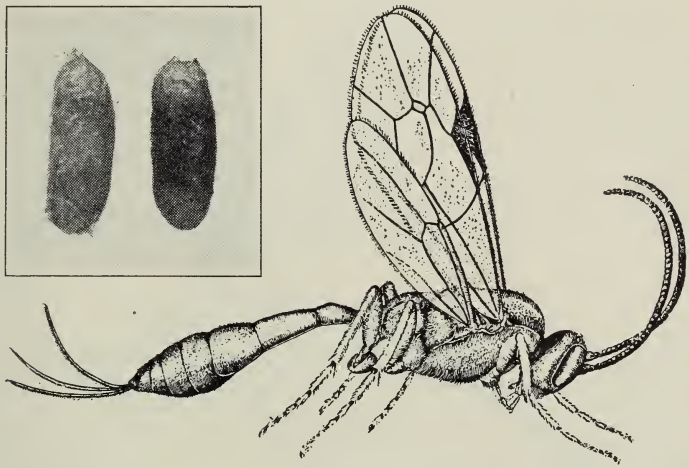

Fig. 9.—Adult female of *Angitia platyptiliae*, a larval parasite of the artichoke plume moth. (× 17.) The inset shows cocoons of the species. (× 3.9.)

ranged from 2 to 90 per cent. In general, a higher parasitism on thistles was found as the larvae are more exposed and congregate in larger numbers than on artichoke. It is not uncommon to find from 2 to 10 per cent parasitism of plume moth larvae in artichoke fields. The effectiveness of this species is reduced by two secondary parasites, *Dibrachys cavus* (Walk.) and *Gelus* sp. Larvae of the greenhouse leaf-tier, *Phlyctaenia rubigalis* Guen., are also parasitized by this species.

The larval parasite, *Epiurus bicoloripes* Ashm., is effective only on larvae feeding on thistles, especially during the period from May to August. The female stings the fourth instar plume moth larva, depositing the torpedo-shaped egg on the outside of the paralyzed larva. The parasite develops rapidly, consuming the plume moth larva, and then spins a cocoon externally. The male is approximately 7 mm long, glossy black, with the legs reddish; the hind tibias are darker. The antennae are 4 mm long. The female is larger, 8 to 9 mm long, similar in color to the male, although the dark color on the hind tibias is more restricted. The ovipositor sheath is 5 mm long. The per cent parasitism during 1937

to 1938 ranged from 1.2 to 17 per cent, with the greatest parasitism recorded during the months of June and July. The adult female is shown in figure 10.

Another larval parasite, *Phaeogenes* sp., parasitizes larvae of the plume moth on thistle hosts both in California and Oregon; occasionally it selects larvae feeding on artichokes. It is black with reddish abdomen and legs, and is from 7 to 7.5 mm long. In the male the antennae are about

Fig. 10.—Adult female of *Epiurus bicoloripes*, a larval parasite of the artichoke plume moth. (× 8.)

4.5 mm long, but are shortened in the female to 2.5 mm. The petiole area in the male is noticeably darker than the ferruginous abdomen. Adults of this species emerge from June to the following January, with the parasitism of plume moths on artichokes being insignificant, but on thistles ranging from 4 to 10 per cent. A secondary species, *Pachyneuron allograptae* Ashm., has been reared from this parasite.

Parasites of Secondary Importance.—The ichneumon, *Colpognathus helvus* (Cress.), was reared on one occasion from a larva of the plume moth as was the braconid, *Microbracon nevadensis* (Ashm.). The tachinid parasites—*Hyalomyodes triangulifera* Loew, two *Lispidea* spp. and *Plectops* sp.—have been reared occasionally from larvae of the plume moth.

Predators.—Coleopterous larvae of the family Staphylinidae have been taken several times feeding on larvae of the plume moth in the larval burrows. Several undetermined species of spiders, also, have been found preying on the larvae. During the summer of 1938, the cliff swallow, *Petrochelidon lunifrons* (Say), was observed feeding on the adults. A large red mite of the family Anystidae, *Anystis agilis* Banks, often feeds upon newly laid eggs (Lange, 1940*a*).

Egg Parasites.—No internal egg parasites have been observed in the field. In the laboratory, *Trichogramma evanescens* Westw. and *T. embryophagum* (Hartig) were tested, and one light phase of the latter species, originally from the codling moth in Georgia, readily selected eggs of the plume moth for egg deposition. The woolly nature of the artichoke foliage and the climatic conditions of the coast do not seem favorable for the successful establishment of *Trichogramma* spp. although further experimentation along these lines is needed.

CHEMICAL CONTROL

During 1937–38 extensive chemical control experiments were conducted but there was little indication that toxic sprays and dusts could be applied to artichoke plants for practical control of the artichoke plume moth. The failure of chemicals to give adequate control was attributed to the following factors: (1) The three overlapping generations of the moth, with all stages occurring every month of the year; (2) the occurrence of at least two generations from the time plants start in May and June, making applications necessary against two generations; (3) the internal boring habits of the larvae; and (4) the physical structure of the plants which made it difficult to penetrate the axils of the shoots.

In general, spray materials applied by a power sprayer at approximately 400 pounds' pressure gave a control superior to dusts. Cubé powder, nicotine sulfate, and fixed nicotine materials applied as sprays gave the most consistent control. The difficulty in entering the fields with spray equipment and the numerous applications which were necessary did not indicate that an economic spraying program could be initiated in commercial fields. Table 8 presents the details of experiments conducted with spray materials during 1938. The plots were for the most part single and unreplicated but checked against several untreated areas, and, of necessity, located in fields where spray equipment could enter. The degree of control obtained was calculated by determining the reduction of the larval populations on the treated plants in comparison with the untreated plants.

TABLE 8

RESULTS OF SPRAYING EXPERIMENTS FOR THE CONTROL OF THE ARTICHOKE PLUME MOTH; 1938

Materials and amounts per 100 gallons of spray*	Number of plants treated	Date of application	Date examined	Per cent reduction in larval populations on plants†
Calcium arsenate, 4 pounds; bordeaux (5-5-50); light-medium oil emulsion, 1 gallon	138 138 221	May 31 June 10 June 23	July 18	61‡
Cubé powder (4 per cent rotenone and 16 per cent ether extractives), 4 pounds; light-medium oil emulsion, 1 gallon§	72 72 72 72 72 72	Aug. 31 Sept. 9 Sept. 21 Oct. 3 Oct. 18 Nov. 15	Dec. 21	67 (without use of wetting agent) 80 (with use of Vatsol-OS, 1 pound)
Nicotine sulfate (Black Leaf 40), 1 pint; light-medium oil emulsion, 1 gallon	76 76 68 68 52 44	Sept. 12 Sept. 22 Oct. 3 Oct. 19 Nov. 14 Nov. 23	Dec. 27	73
Pyrethrum extract (2 grams of pyrethrins per 100 cc), 1 pint; light-medium oil emulsion, 1 gallon§	76 76 76 76 76 76	Sept. 12 Sept. 22 Oct. 3 Oct. 19 Nov. 14 Nov. 23	Dec. 29	32 (without use of wetting agent) 29 (with use of Ultrawet, 1 pound)
Rotenone extract (5 per cent rotenone) in Camphor Sassafrassy oil, 1 pint; light-medium oil emulsion, 1 gallon	80 80 80 80 61	Sept. 21 Oct. 3 Oct. 19 Nov. 14 Nov. 23	Jan. 7	74
Phenothiazine, 3 pounds; resin sticker, 1 pint	68 68 68 68	Sept. 12 Sept. 29 Oct. 20 Nov. 15	Dec. 14	71
Cuprous cyanide (Kutane), 3 pounds	52 52 52	Sept. 12 Sept. 29 Nov. 16	Dec. 14	35
Nicotine bentonite and calcium oleate mixture, 4¾ pounds (Nol 30, ¾ pint, and Fixator A, 4 pounds)	60 60 60 60	Sept. 21 Oct. 3 Oct. 20 Nov. 16	Dec. 8	85
Nicotine bentonite (Black Leaf 155), 8 pounds	72 72 72 36 36 48	Aug. 31 Sept. 9 Sept. 21 Oct. 3 Oct. 18 Nov. 15	Dec. 8	47
Acid lead arsenate, 4 pounds; light-medium oil emulsion, 1 gallon	63 63 63 63	Sept. 12 Sept. 29 Oct. 20 Nov. 16	Dec. 16	41

* Sprays applied with power sprayer at 400 pounds' pressure, at the rate of 50 gallons spray for each date of application (artichoke plantings range from 500 to 700 plants per acre).

† Calculated by formula as given by Abbott (1925).

‡ On December 8, 1938, the population of larvae on the checks and treated plots were the same.

§ Half of the application used with wetting agent.

The results of two experiments conducted during 1937 and 1938 are presented in tables 9 and 10. For the most part the plots were single blocks of plants, with the control calculated as a reduction in the number of wormy artichokes in the treated as compared to untreated plants over a period of several months. These experiments indicated that the appli-

TABLE 9

COMPARISON OF DUST AND SPRAY MATERIALS IN THE CONTROL OF THE ARTICHOKE PLUME MOTH

Materials*	Number of plants treated	Total number of wormy artichokes	Total number of good and of wormy artichokes	Average per cent wormy artichokes	Per cent control†
Derris dust (0.75 per cent rotenone)	130	104	635	16.37	8
Derris powder (4 per cent rotenone and 16 per cent ether extractives), 4 pounds to 100 gallons of water; Penetrol, 1 gallon	32	29	197	14.72	9
Pyrethrum-sulfur dust (Dry Pyrocide, 10 per cent and conditioned sulfur, 90 per cent)	120	102	610	16.72	7
Pyrethrum extract (2 grams pyrethrins per 100 cc), ½ gallon to 100 gallons of water; white oil, 1 gallon	56	54	310	17.41	7
Acid lead arsenate dust, 50 per cent (carrier, hydrated lime)	120	127	485	26.18	0
Acid lead arsenate, 4 pounds to 100 gallons of water	46	30	178	16.86	7
Nicotine bentonite (Black Leaf 155), 8 pounds per 100 gallons of water	66	49	287	17.04	7
Check (untreated)	...	612	2,552	23.98	...
Phenothiazine, 4 pounds per 100 gallons of water	150	125	579	21.58	1
Phenothiazine dust, 15 per cent (carrier, talc)	150	125	458	27.29	0
Check (untreated)	...	256	1,133	22.59	...

* Materials applied with wheelbarrow sprayer or hand-duster at Half Moon Bay, July 3, 13, 24, and October 19, 1937. The amounts of spray materials used to the acre ranged from 60 to 216 gallons and of dusts from 30 to 60 pounds, according to the size of the plants.

† This degree of control calculated by averaging counts made of the number of good and of wormy artichokes found on the plants on the following dates: September 23, 30; October 12, 20, 28; November 15; December 3; and January 22.

cation of dust or spray materials to the small plants during the summer generation had little effect upon decreasing worminess in the fall, because of the rapid build-up in populations of the moth during October to December. It was found during 1939 that it was possible to reduce the populations of larvae on treated plants from 60 to 70 per cent up to September, but after this period, with the start of the fall generation, the populations of treated and untreated plants became equalized.

Dust materials which were used during the course of this investigation included calcium arsenate, standard lead arsenate, synthetic cryolite,

cubé and derris, cuprous cyanide (Kutane), phenothiazine, pyrethrum, 2, 4 dinitro 6-cyclohexylphenol, nicotine sulfate (as Black Leaf 40), and tetramethylthiuram disulfide.

The spray materials used were calcium arsenate (undiluted and with oil), standard lead arsenate, synthetic cryolite, cubé and derris, cuprous cyanide (Kutane), phenothiazine, pyrethrum extracts, nicotine sulfate (as Black Leaf 40), nicotine bentonite (as Black Leaf 155), nicotine-

TABLE 10

RESULTS OF DUSTING EXPERIMENTS FOR THE CONTROL OF THE ARTICHOKE PLUME MOTH

Materials applied and average number of pounds per acre for each application*	Total number of wormy artichokes	Total number of good and of wormy artichokes	Per cent of wormy artichokes	Average per cent control
Cubé dust (0.75 per cent rotenone), 46 pounds	159	1,199	13.26	4
Barium fluosilicate (40 per cent in talc), 48 pounds	143	922	15.50	2
Calcium arsenate (undiluted), 33 pounds	161	954	16.86	0
Phenothiazine (15 per cent in talc), 36 pounds	128	745	17.18	0
Cuprous cyanide (20 per cent in talc; commercial form, Kutane), 34 pounds	117	706	16.57	1
DN-Dust† (1 per cent of 2,4 dinitro 6-cyclohexylphenol in walnut shell flour), 20 pounds	64	462	13.85	3
Cryolite (synthetic, 40 per cent, in talc), 38 pounds	108	633	17.06	0
Check (untreated)	559	3,269	17.10	..

* Materials applied with hand-duster at Half Moon Bay on the following dates: June 18, 29; July 8, 18, 28; and October 3, 1937. Plants examined for degree of control on the following dates: August 31; September 27; October 8, 20, 28; November 19; December 4; January 10; and February 28.

† None applied subsequent to June 29 because of severe burn to the plants.

bentonite calcium-oleate mixture (as Nol-30 and Fixator A), rotenone extracts, Lethane 440, and Diesel-oil emulsion.

ATTRACTANTS AND REPELLENTS

Although numerous attempts were made to attract adult plume moths to various sugar solutions and aromatic chemicals, no favorable results were obtained. A solution of diamalt and yeast as recommended by Borden (1932) attracted very few moths; neither did fruit juices, solutions of cane sugar, or molasses. In general, adult plume moths did not fall into the pans as is the case with certain noctuids and other moths, so a trap cage had to be placed above the pan of bait material to catch moths as they took off after coming to the baits. In testing the chemical materials, two pans with trap cages were set up. In the first one a cubic centimeter of the chemical to be tested was placed in a small glass vial and floated on a cork in a saucepan containing distilled water; in the other

pan, used as a check, the vial contained only distilled water. The chemical materials tried for at least a period of a week were: amyl acetate, cinnamaldehyde, ethyl acetate, ethyl acetoacetate, ethyl benzoate, ethyl butyrate, methyl ethyl ketone, ethyl salicylate, isovaleric acid, methyl benzoate, methyl salicylate, n-nitrobenzaldehyde, nitrobenzene, and propionic acid. Crushed artichoke plants and heads failed to attract moths.

During the fall of 1939 certain materials considered as having possible repellent action were applied on a field at Moss Beach, with negative

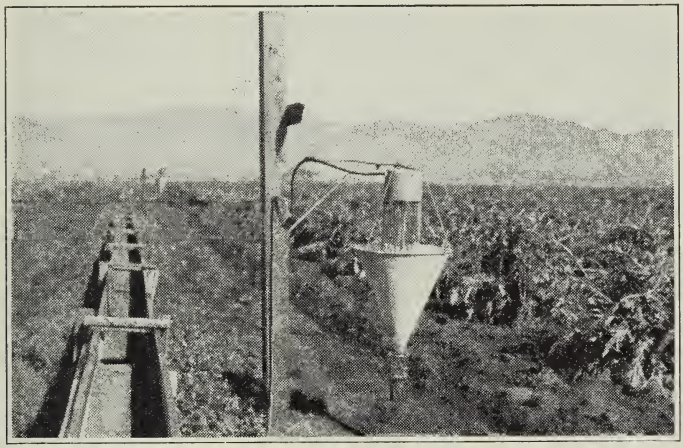

Fig. 11.—Electrocuting type of light trap used in experimental work on the artichoke plume moth.

results. The materials tried included tetramethylthiuram disulfide; a mixture of 85.3 per cent sulfur dust and 14.7 per cent aluminum sulfide; a mixture of 70 per cent sulfur and 30 per cent resin, heated at 180°C for 1.5 hours; undiluted paradichlorobenzene; and undiluted naphthalene flakes. Two applications were made using each material, and 100 plants were treated with each.

LIGHT TRAPS

Extensive light-trap experiments conducted during the period 1936 to 1938 did not indicate that they offer adequate protection against the plume moth when used as a sole means of control. The moth was found to be highly phototropic, but unfavorable weather conditions, especially low temperatures and wind currents, the weak flight of the moth, and the difficulty encountered in successfully operating the light traps under coastal conditions were among the factors which resulted in the capture of relatively few moths. The type of light trap used in the experimental work is shown in figure 11.

Important factors which were found to influence the capture of moths at light traps were, first, the height of the traps, second, night temperatures, and third, the intensity of wind currents. An experiment in which light traps were placed at different heights from the ground, demonstrated that most moths were taken about the level of the artichoke plants, usually from 3 to 5 feet, with a few taken at 8 feet, but none at

TABLE 11

ARTICHOKE PLUME MOTHS COLLECTED DURING THE TORRE LIGHT-TRAP EXPERIMENT AT MOSS BEACH*

Month	Moths captured at eight traps			Ratio of males to females
	Male	Female	Sex undetermined	
July	36	2	7	18.0:1
August	33	5	1	6.6:1
September	78	12	20	6.5:1
October	156	40	45	3.9:1
November	44	9	11	4.9:1
December	199	32	72	6.2:1
January	308	51	89	6.0:1
February	137	39	45	3.5:1
March	28	6	11	4.7:1
April	98	12	24	8.2:1
May	73	12	34	6.1:1
June	39	11	35	3.5:1
July	17	1	6	17.0:1
August	15	1	7	15.0:1
September	37	7	24	5.3:1
October	41	6	22	6.8:1
November	16	3	7	5.3:1
December	11	0	7	11.0:0
Total, or average	1,366	249	467	5.5:1

* Eight dark-blue light traps on an 8-acre field for the period July, 1937, to December, 1938.

12 feet. The moths were found to be capable of reaching considerable heights in the air when aided by wind currents, but were not able to direct their flight sufficiently to hit a light trap placed at 12 feet in the air. Night temperature was found to be an important factor in that often a difference of only 2° F determined the difference between moths flying or not flying. For purposes of light-trap operation, 50° was determined as the minimum flight temperature, although flight was observed down to 46°. Wind currents played an important part in the capture of plume moths at light traps in that once the moths were carried beyond the traps they could not fly back. During the summer it was found that most flight begins at dusk and continues until midnight, the time depending primarily upon temperature.

Different colors of monochromatic light were tried during 1937 and 1938. These included dark blue, light blue, red, yellow-green, and ultraviolet. A dark blue as was found effective by Herms and Ellsworth (1934) caught the largest proportion of females. A 60-watt incandescent lamp was also tried, but few females were attracted to this white light.

During the period July, 1937, to December, 1938, lights were installed on the Torre Bros. field at Moss Beach, in which 8 dark-blue lights were placed in an 8-acre field, and counts made weekly of the number of moths in each of the traps. The traps were automatically turned on at sunset

TABLE 12

SEX RATIOS OF VARIOUS SPECIES OF MOTHS COLLECTED AT DARK-BLUE LIGHT TRAPS; HALF MOON BAY*

Species	Moths captured		Ratio of males to females
	Male	Female	
Platyptilia carduidactyla (Riley)	53	10	5.3:1
Leucania unipuncta (Haw.)	512	68	7.5:1
Agrotis ypsilon (Rott.)	62	7	8.8:1
Feltia anneza (Treit.)	43	3	14.3:1
Orthodes rufula (Grt.)	215	32	6.7:1
Laphygma exigua (Hbn.)	32	3	10.7:1
Euxoa messoria (Harr.)	248	24	10.3:1
Heliothis armigera (Hbn.)	384	226	1.7:1
Peridroma margaritosa (Haw.)	51	9	5.7:1
Sabulodes caberata Guen.	27	17	1.6:1
Phlyctaenia rubigalis (Guen.)	87	5	17.4:1

* Based on four lights run August 1 to 30, 1936.

if the temperature was above 50° F and off at sunrise. The number of moths captured for an 18-month period was 2,082, or an average of 3.85 moths a day for 8 traps, or 0.48 moth captured each day by each trap (table 11). The average sex ratio obtained was 1 female to 5.5 males, which was in accordance with the ratios obtained for other artichoke moths (table 12) where more males than females were captured in all the species considered.

An attempt was made to determine the control effected in the Torre field by counting the number of good and of wormy artichokes on certain plants with respect to their position in the field, such as at the traps, near the traps, and away from the traps. These counts (total of 909 artichokes) made November 9, December 21, and February 19, 1938, were as follows: at the traps, 24 per cent of wormy artichokes; near the traps, 18 per cent; and away from the traps, 27 per cent. These data indicate that a certain reduction in worminess was effected through the installation of light traps but not sufficient to give adequate control.

SANITATION AND CULTURAL CONTROL

The obvious effect of field sanitation and cultural practices on losses caused by the plume moth made it seem desirable to place considerable emphasis upon this phase of control.

Movement of Larvae Through the Soil.—On December 10, 1936, at Half Moon Bay, 125 damaged artichokes (floral heads) were buried 2 inches in the ground, and a screen cage placed over the top to record the emergence of any adult moths. In a like manner an equal number were buried under 6 inches of soil. On December 17, a mature larva was found on the surface of the soil in each of the cages and on March 2, 1937, an adult male emerged from the heads buried 2 inches deep. Again on May 17, 1937, 100 damaged artichokes (probably 80 per cent of which contained larvae) were buried 12 inches under the soil and a cage placed over the top. On June 16 and 18, a total of 4 adults emerged, indicating that approximately 5 per cent of the larvae were able to crawl through the soil. In December of 1938, damaged artichokes were placed alongside of artichoke roots, but no movement to the roots was found and no adults emerged. These experiments indicated that it was possible for a small percentage of mature larvae to crawl through the soil and pupate on the surface of the soil or crawl back to nearby plants. The ability of the larvae to crawl through the soil depends upon the type and compactness of the soil, the moisture content, and the depth to which the artichokes are buried. It was also found that mature larvae could leave drying debris in the fields and crawl back to the roots of nearby plants, where they bored for short distances into the crowns.

Emergence of Adults from Heads Thrown in the Field.—It was found by making numerous counts, that from 3 to 30 per cent of damaged floral heads thrown in the fields were infested with larvae and that the percentage varied considerably with the season of the year. The migration of larvae from one head to another, often results in damage to several, caused by a single larva. Furthermore, many larvae may complete their development before the heads are picked. If small heads are examined before they are cut from the plants in the field, however, as many as 80 per cent may contain larvae.

Sanitation Experiments During 1937.—The E. Giovannoni field at Half Moon Bay was chosen for a sanitation experiment, because this 4-acre field was practically isolated from other plantings, by several miles. The plants were cut on May 29. On June 2 all the debris was removed on two acres and burned. The migration of adults from the other parts of the field, and the fact that wormy artichokes had been thrown

in the field throughout the year, resulted in little control through this measure. The experiment did indicate, however, that it was possible to remove all the cut plants from the fields and destroy them within a period of a few days, should this be necessary.

On several fields entire plants were removed from the fields after they were cut and placed in large screen cages to record the emergence of

Fig. 12.—*A*, The throwing of wormy artichokes into the field, as shown in the photograph, is a dangerous practice because moths often emerge in large numbers from such decaying material. *B*, A rotary plow in operation, for the disposal of artichoke tops. *C*, A satisfactory method for the disposal of the plant debris, with a maximum destruction of immature stages of the plume moth: ditch made and plants cut ready to be thrown in. *D*, The second step in debris disposal: plants placed in ditch and ready to be covered.

adult moths. It was found that the first adults emerged in about 20 days, with an emergence of from 40 to 50 adults to the acre.

Sanitation Measures Effective in Control.—The practical sanitation measures that will aid in averting severe plume moth injury can be summarized as follows:

(1) All wormy artichokes picked during the harvesting of the crop should be destroyed by burying, burning, or feeding to livestock, instead of throwing in the fields or near the packing sheds (fig. 12, *A*). Especial care in this regard should be enforced during March, April, and May,

as artichokes thrown in the field at this time do not rot readily, but gradually dry, and often allow the larvae to feed for a month or more and complete their development. These hard, drying artichokes thrown in the fields are difficult to destroy by disking or other methods, and often adults emerge just in time to deposit eggs on the new shoots as they are coming up. Figure 13 shows pupae on the insides of bracts of

Fig. 13.—Pupae of the artichoke plume moth on the outer bracts of artichokes thrown in the field. The bracts have been removed from the artichokes.

several artichokes which had been thrown in the fields, indicating the danger of this practice.

(2) All thistles, especially of the genus *Cirsium,* should be removed from the vicinity of artichoke plantings, as a precautionary measure. This is particularly important in areas where new plantings are to be started. *Cirsium edule,* Indian thistle, is found in San Mateo and Santa Cruz counties in the vicinity of artichoke plantings and these plants should be rated as potential sources of moths, as they can move directly over to artichokes at any time of the year. *Cirsium lanceolatum,* bull thistle, is also found throughout the artichoke-growing districts, and is very abundant in the Castroville area where it grows along drainage ditches in or near artichoke plantings. It is adapted to drier localities than is *C. edule.* One should destroy all thistles, because other genera than those mentioned may occasionally be selected, for example, *Cen-*

taurea or *Silybum*. The clearing of drainage ditches and the edges of fields also has the advantage of reducing sites for the adults to rest.

(3) The prompt removal of all plant debris from the fields during the summer prevents the emergence of many moths. It was found that burying the plants in a deep ditch between the rows and burning within two weeks after cutting were the most efficient methods for destroying

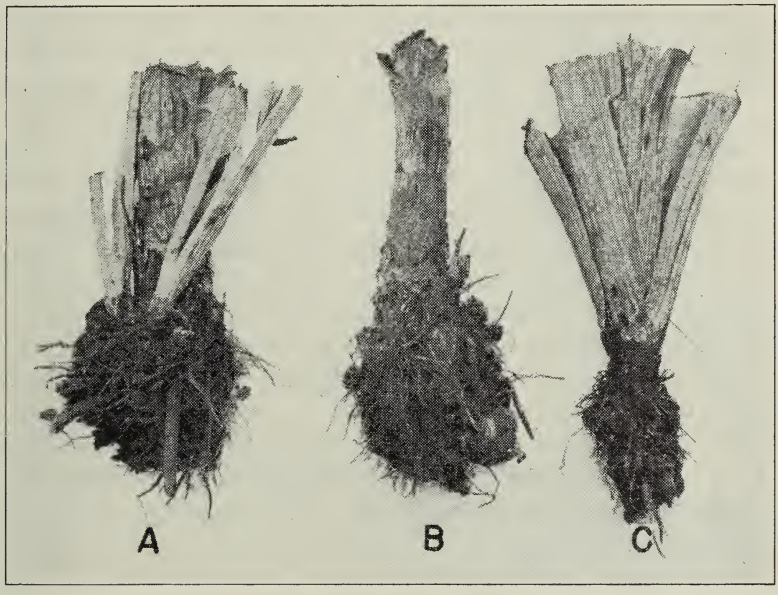

Fig. 14.—Methods of propagating the artichoke: *A*, stump with offshoots; *B*, stump, with offshoots removed (most satisfactory from the sanitation standpoint); *C*, pruned offshoot.

eggs, larvae, and pupae. A further account of the various methods used in the disposal of the tops will be found in the next section.

(4) The planting of "clean" stock is essential; for eggs, larvae, or pupae of the plume moth can be carried in the planting stock to new fields. Offshoots can be selected from fields having little worminess, or they can be fumigated with methyl bromide at the rate of 1 pound per 1,000 cubic feet for two hours, with a temperature around 72° F and a vacuum of 20 inches. The results of experiments with methyl bromide have been presented in an article by Lange (1940*b*). The use of vapor heat, with an exposure of 1 hour at 110° gives a good kill of the larvae, but is too severe on the plants. The planting of a part of the old plant, called a "stump" can be done with less danger of carrying the insect, especially if the offshoots are removed as shown in figure 14, *B*.

Cultural Methods Effective in Control.—It perhaps should be mentioned at this point that the cultural methods employed in the commercial production of artichokes vary considerably in the different areas according to the size of the fields, the equipment available and whether irrigation during the summer and fall is possible. In most of the artichoke-growing areas it is the usual custom to cut the plants off during the period between April 20 to June 15, and dispose of the tops in various ways according to the equipment used. Irrigation begins after the debris is disposed of; once started it has to be continued until the fall rains. The frequency of irrigations depends primarily upon the type of soil, some soils requiring water every 10 days, and others only three or four times during the entire season. These cultural practices allow a crop of heads to be picked from September until the following May, with a peak of production during the winter and early spring when other vegetables are less abundant. In certain areas, however, as in the hills of San Mateo County and Marin County, irrigation is not practiced and there is usually a period of several months during the fall when the tops of the plants are completely dried up. With the beginning of fall rains, shoots again come up, but a peak in the production of heads is not reached until the following May or June.

The cutting of plants during the summer and the start of new shoots fits in very well with the life cycle of the plume moth in that adults present in the fields and emerging from debris readily select the new shoots for egg deposition.

A detailed study has been made of the best method for disposal of the plant debris so as not to interfere with the usual cultural methods. This study has indicated the following methods for disposal of the cut tops, with their advantages and disadvantages:

(1) In the burning method, the plants are cut with a blade, several inches below the ground surface, allowed to dry, and then piled up and burned. This method is effective in destroying a large percentage of immature stages of the moth; but if the plant debris is not burned within two weeks after cutting many moths emerge in the fields. A study conducted during 1937 showed that the period between the cutting of the plants and their burning varied from 10 to 43 days. A disadvantage of this method is the fact that humus is not returned to the soil.

(2) In the burying method the plants are cut as in method (1), but are immediately placed in a ditch between the rows, which is usually 15 to 20 inches deep and about 4 feet wide at the top; they are then covered with 12 inches or more of soil. If the plants are placed in the soil while green, they decay rapidly and in most instances do not interfere to

any great extent with later cultivation or irrigation. This method has the advantage of destroying most of the immature stages of the plume moth on the plants, and also adds humus to the soil. It has the disadvantage that with certain types of soils, the plants do not decay rapidly, and the debris may interfere to some extent with subsequent cultivation. In using this method it is better to cut and bury small blocks at a time, rather than cut the entire field at one time. If the plants are too heavy to handle satisfactorily immediately after cutting, several days' exposure to the sun will make them considerably lighter. If plants are cut deeply, and the ditches are not deep enough, there may be some annoyance from the sprouting of the buried plants, but usually the shoots can be weeded out with the first cultivation of the field. A modification of this method is used in certain localities where a shallow ditch is made beside the plants, in which the cut plants are buried. This procedure is not recommended as a method of destroying immature stages of the plume moth. Figure 12, *C* and *D* shows the best method of making ditches and covering the debris.

(3) A rotary plow is used in the Castroville area which chops up the plants and returns them to the upper 4 to 5 inches of the soil. This machine can cover a large acreage in a short time, and is advantageous in returning humus to the soil. Counts have shown that the machine destroys from 80 to 90 per cent of plume moth larvae and pupae on the plants. The rotary plow is shown in figure 12, *B*.

(4) The disking method consists in running over the plants with a disk from three to six times to destroy the tops. Counts have shown this method to be unsatisfactory in destroying stages of the plume moth since many heads are left on the surface of the ground.

(5) The use of the green plants for silage is not extensively practiced. This method would prove of value only when the entire plants could be chopped and removed from an extensive area. Usually by the middle of May there are many tough stems on the plants which cannot be utilized, and a certain selection must be made in order to make silage of a satisfactory quality. Folger (1934) demonstrated that artichoke silage is similar in essential characteristics to that of corn.

In addition to these methods, various modifications are found—even to hand-cutting of old tops, leaving high "stumps." The hauling off of the debris to be dumped into the nearest ravine is not to be encouraged as the moths can be carried by wind currents for considerable distances to reinfest artichoke plantings.

The cultural practices which have been found to have the greatest value in reducing populations of the plume moth, are as follows:

(1) The plants should be cut several inches below the surface of the

soil during the period April to June and buried in a ditch within three days, so as to have at least 12 inches of soil over the top of the plants.

(2) The planting of new offshoots between old plantings, as is often done, should be avoided because adult moths readily select the new shoots for oviposition.

(3) Replanting every third or fourth year with new offshoots or with stumps should be carried out, as the moths "build up" in older plantings.

(4) When possible, the planting of stumps of old plants (fig. 14) is preferred to offshoots, as there is less likelihood of setting out infested plants. The planting of stumps has the further advantage in that the plants bear heavily the first year they are set out.

(5) The proper application of fertilizers and proper irrigation practices will aid in averting plume moth damage since weak plants produce fewer heads and slower growth of the heads which allows larvae of the moth a greater opportunity to work into them. On hills or where the furrow and check systems of irrigation cannot be used, the overhead sprinkler system often gives better results.[8]

(6) The timing of the cutting of the plants can often be arranged so that neighboring growers can cut at approximately the same time, and in this manner avert the movement of moths from uncut fields to those in which new shoots have already started. It is also helpful to avoid planting new shoots in the vicinity of old plantings, although in smaller fields this may be impossible.

(7) The rotation of artichokes with other crops is to be recommended, although it has been impossible to demonstrate any marked value along these lines because of the present tenant-farmer program in force in the main artichoke-growing districts. In certain areas where artichokes have been grown on the same fields for over thirty years, a rotation in crops would not only aid in reducing populations of the plume moth, but would also be advantageous to the fertility of the soil.

During 1939 an attempt was made to record in detail the various sanitation and cultural practices carried out on 34 fields, selected in San Mateo, Santa Cruz, and Monterey counties in order to give a cross section of the most important artichoke-growing areas. The method of disposal of the tops was recorded, and after the new shoots started up weekly counts were made during May through July to record egg deposition. A count was also made of any immature stages of the moth left in the fields on plant debris, and the numbers of moths emerging from this source were then calculated. Later on, another count was made on the

[8] For a further discussion of the cultural methods employed in artichoke production the reader is referred to the circular by Tavernetti (1933).

actual number of larvae boring in the plants, and after deducting the per cent parasitism, a calculated emergence of moths per acre was derived. Counts made of the numbers of wormy and of good artichokes produced on these fields from September, 1939, through February, 1940, showed a definite relation between the percentage of wormy artichokes and the method employed for the disposal of the cut tops. In fields where the tops were buried the average loss from the plume moth was 2.54 per cent in contrast to a loss of 4.14 per cent where the tops were burned; 4.95 per cent where they were cut with the rotary plow; and 6.17 per cent where the tops were disked. The summary of these data is presented

TABLE 13

RELATION OF THE METHOD OF DISPOSAL OF ARTICHOKE TOPS TO THE AMOUNT OF INJURY BY THE ARTICHOKE PLUME MOTH

Method of disposal of tops	Number of fields examined	Average weekly number of eggs laid per plant	Moths emerged per acre from debris	Moths emerged per acre from plants	Average seasonal per cent of wormy artichokes
Burned	8	0.95	56	248	4.14
Buried	13	0.38	24	344	2.54
Rotary plow	6	1.25	108	641	4.95
Disked	7	1.57	77	744	6.17

in table 13. The results of this study indicate that as far as the control of the plume moth is concerned, the best method of debris disposal is burning or burying the plants, and that the rotary plow and disking methods are not satisfactory. There were also more eggs laid on the plants in fields where a rotary plow or disk was used. These data have their limitations, because it was difficult to ascertain the population of moths about the fields at the time the sanitation methods were employed; but, with some exceptions, fields were selected which had received the same treatment for several years or longer.

It was also found during 1939, that it is possible to disk or cut down the new shoots several times during the summer, if large numbers of eggs are being deposited, without killing the plants, and in this way cut down the population of developing larvae materially. This procedure, however, delays the development of the crop, since it has to be repeated several times in order to allow for the six-week peak of oviposition by the moths. In one field, at Castroville, in which the plants were disked six times between April 18 and June 8, a population of 9.30 eggs per plant was recorded on May 12; but on May 18 the plants were cut off below the surface of the ground, so that on May 24, there was a population of only

2.70 eggs per plant. On June 8 the plants were again disked, and on July 27 a count on the plants showed a larval population of only 0.26 larvae per plant. This same field, during the previous year had reached as high as 40 per cent wormy artichokes.

The enactment of a field sanitation program throughout the year combined with certain cultural practices offers the most adequate and economical control of the artichoke plume moth. The fact should be called to the attention of artichoke growers, however, that in the larger areas where one field is adjacent to another, the problem is chiefly one of community action, since a program carried out by only a few growers may have definite limitations. The continuous development of the moth throughout the year makes it necessary, also, to carry out sanitation practices at all times, and no single practice in itself will give a lasting control.

SUMMARY OF CONTROL MEASURES FOR THE ARTICHOKE PLUME MOTH

Several very effective larval parasites were found, the most important of which was *Angitia platyptiliae* Cushman, which parasitized from 2 to 90 per cent of larvae of the artichoke plume moth, during the period 1936 to 1939.

Predators on the larvae included several coleopterous larvae of the family Staphylinidae, several species of spiders, and the barn swallow. A predator of the eggs was found, namely, *Anystis agilis* Banks, a large red mite of the family Anystidae.

No internal egg parasites were found in the field, although *Trichogramma* sp. parasitized eggs in the laboratory.

Chemical control measures on a commercial field basis were not found adequate, nor economically feasible. Sprays were found more effective than dust materials, and of the sprays, cubé powder, nicotine sulfate, and fixed nicotine materials gave limited degrees of control.

The use of several attractant and repellent materials did not indicate very favorable results along these lines.

Light traps during the 1936 to 1938 period did not offer adequate protection when used as a sole means of control, at the rate of one dark-blue light to the acre. Factors influencing the use of light traps included the difficulty in their operation under humid coastal conditions, height of the traps off the ground, night temperatures, and intensity of wind currents. The minimum flight temperature was found to be 46° F, with most flight ceasing at 50°. Different colors of monochromatic light were tried and a dark blue was found to capture more adults with the highest percentage of females. A light-trap experiment at Moss Beach during an

18-month period showed an average daily capture of 0.48 moth to a trap with a sex ratio of 1 female to 5.5 males.

A combination of cultural and sanitation methods conducted throughout the year was found to offer the most adequate and economical control of the plume moth. The most satisfactory means of disposal of the tops, giving the best control of the plume moth, was placing the cut tops in a ditch between the rows, and covering within several days with at least 12 inches of soil. Burning the plants was found to destroy a large percentage of immature stages of the moth, if accomplished within two weeks after cutting, but has the disadvantage of not returning humus to the soil. The use of a rotary plow or disking the plants was not found very effective so far as the destruction of the immature stages of the moth was concerned.

THE CALENDULA PLUME MOTH

In addition to the artichoke plume moth discussed in the preceding section, a related species, *Platyptilia williamsii* Grinnell, is the only plume moth which has been found feeding on the artichoke. Differing from the artichoke plume moth this insect selects many species of Compositae in several genera, and, although it has not been found to be of significant economic importance on artichoke, it should be rated as a potential pest of this plant. The adults are often confused with those of the artichoke plume moth. The known hosts of this moth, with locality, are presented below, arranged in order of their preference by the moth:

Erigeron glaucus Ker. (seaside daisy).....Coastal Monterey County to Oregon
Calendula spp. (calendula or pot-marigold)..Central and southern California
Grindelia robusta Nutt. (gum plant).....Central California
Achillea Millefolium L. (common yarrow)...Central California
Chrysanthemum spp. (chrysanthemum).....Central California
Eriophyllum staechadifolium Lag. (lizard tail).....Coastal Monterey County to Del Norte County
Cynara Scolymus L. (artichoke).....San Mateo and Santa Cruz counties
Tanacetum camphoratum Less. (dune tansy).....Central California
Layia hieraciodes (DC.) H. & A.....San Mateo County
Hemizonia corymbosa (DC.) T. & G. var. (coast tarweed).....San Mateo County
Artemisia vulgaris L. var. *discolor* Jepson (wormwood).....San Mateo County
Gnaphalium decurrens Ives var. *californicum* Gray (California everlasting).....Central California
Aster sp. (michaelmas daisy).....Central California

Madia sativa Molina (Chilean tarweed) . . . . . San Mateo County
Franseria bipinnatifida Nutt. . . . . Los Angeles County
Senecio aronicoides DC. (?) . . . . . Monterey County
Senecio Blochmanae Greene (?) . . . . . San Luis Obispo County

Injury and Economic Importance.—The larvae of *Platyptilia williamsii* are for the most part borers inside the stems or flower parts of the composites selected. On artichoke the damage is similar to that of *P. carduidactyla* (fig. 15). This species does its most severe damage, as

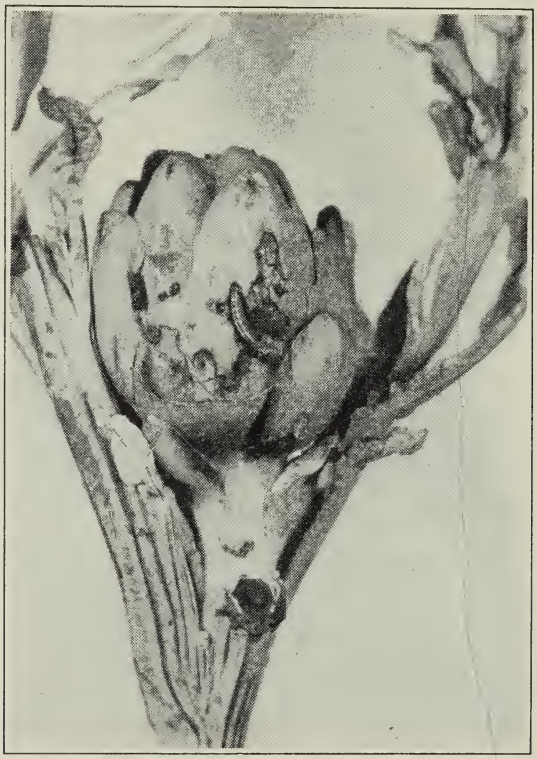

Fig. 15.—Mature larva of *Platyptilia williamsii* feeding on artichoke.

far as plants of any economic significance are concerned, to *Calendula* spp. (pot-marigolds) where it is often a severe pest, especially in southern California. The larvae bore inside the stems and feed on the green flower structures and the green seeds. A larva was first found boring inside a leaf stalk of artichoke at Davenport, Santa Cruz County, on October 1, 1937, and was found at Half Moon Bay on November 18 of the same year. Since these initial discoveries it has been found occa-

sionally on artichoke, although this host is not so readily selected as others.

Description of the Stages.—The adult varies in wing expanse from 17 to 22 mm and differs from that of *Platyptilia carduidactyla* in the grayish-brown coloration of the wings and in structural details. The forewings are brown, irrorated with grayish scales, and usually marked with a conspicuous dark dash in the first lobe, crossed with a subterminal white line which goes through both lobes. The triangular mark as found in *P. carduidactyla* is usually only weakly developed, but in some specimens may be present. Some individuals are a uniform brownish gray with little indication of darker markings. The palpi project noticeably beyond the short frontal tuft, and considerably more than in *P. carduidactyla.* The antennae, palpi, and thorax are a grayish brown in color. The hindwings usually show a tuft of triangular scales on the inner margin of the third feather, but this is not so conspicuous as in *P. carduidactyla.* The legs are brownish gray and white. The adult is shown in figure 21, *A.*

The egg is oblong-ovate, glossy, and pale yellowish in color and in size slightly smaller than that of the artichoke plume moth, ranging in width from 0.22 to 0.31 mm and in length from 0.44 to 0.53. As in *Platyptilia carduidactyla,* the egg can be laid on the horizontal or vertical axis in relation to the leaf surface.

Four instars are found. The mature larva is smaller than that of *Platyptilia carduidactyla,* and in addition can be distinguished at a glance by the brown head and the prominent longitudinal reddish lines.

The body is robust, with a length of from 8 to 10 mm. The color is a dirty yellow, with longitudinal reddish lines: a dorsal line, a subdorsal rather interrupted line, and often an indefinite spiracular line. As in the artichoke plume moth the body is covered with short, black, secondary setae, which can be seen under low magnification. The true legs are black, and the prolegs are stalklike and concolorous with the underside of the body. The cervical shield differs from that of the artichoke plume moth in being yellowish, with black outlining. The anal plate is dark only at the center, and the primary setae are inconspicuous and arise from dark tubercles. The larvae of both species of plume moths are shown in figure 16, *A* and *B.*

The pupa is smaller than that of *Platyptilia carduidactyla,* from 7 to 9 mm long, but with the same general shape and with the front prominent. When newly pupated the color is greenish with dorsal and lateral reddish lines on the abdomen, but later the color changes to various shades of brown. The abdominal segments lack the spinelike projections

so conspicuous in the pupa of *P. carduidactyla.* The cremaster is set with numerous hooked setae. In figure 16, *C* and *D* show the pupae of both species of plume moths.

Life History.—The life history of *Platyptilia williamsii* is similar to

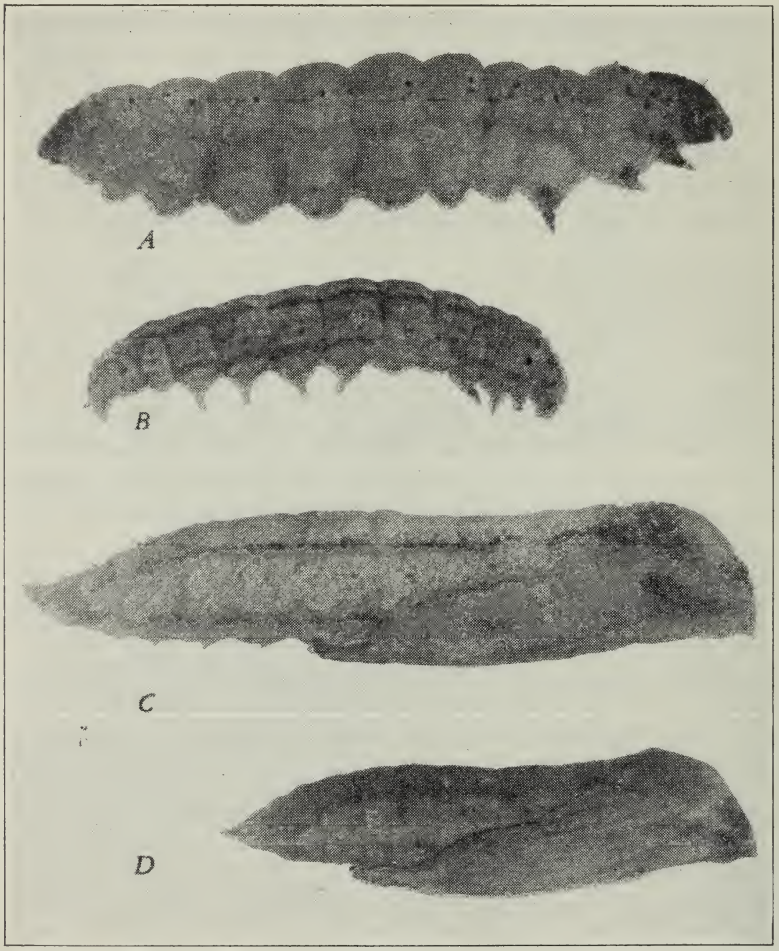

Fig. 16.—*A,* Mature larva of *Platyptilia carduidactyla,* and *B,* of *P. williamsii.* (Both × 10.) *C,* Pupa of *P. carduidactyla,* and *D,* of *P. williamsii.* (Both × 9.)

that of the artichoke plume moth except that there is a second summer generation, making four generations a year. Similarly, the stages are overlapping so that most stages can be found every month of the year. On *Calendula* and *Erigeron glaucus* where the life history has been studied in detail, the eggs can be laid on any part of the plant, but usu-

ally on the undersurface of the leaves or on the flower parts. The duration of the egg stage during the summer is from 8 to 10 days. The small larvae on hatching immediately bore into the stems, or into the flower parts, and as they grow larger can bore for considerable distances into the stems or eat out the entire receptacle, flower parts, or green seeds. Pupation occurs in the stems or flowers, or externally. The pupae are attached nakedly or by a thin silken webbing. The duration of the two summer generations on *Erigeron glaucus* during 1936 and 1937 was approximately 100 days for each; the first extending from the middle of April to the middle of July, and the second from the middle of June until the end of September. The fall generation extended from September until the following February, with some adults emerging in December. The spring generation began with the hatching of eggs laid from adults which emerged in the fall; the entire cycle extended from November to the following April.

Several natural enemies of the larvae have been found, namely, the ichneumons, *Angitia* sp., *Campoplex* sp., and *Epiurus bicoloripes* Ashm. The first-mentioned is the most effective parasite, but its effect is reduced by a secondary species, *Hemiteles* sp.

SPECIES OF PLUME MOTH ADULTS FOUND IN ARTICHOKE FIELDS

In addition to *Platyptilia carduidactyla* and *P. williamsii* whose larvae feed on the artichoke, many plume moth adults of other species were collected in artichoke fields resting on the plants or were taken at light traps. The large genus *Oidaematophorus* is represented by several species, the most common of which are *O. monodactylus* (Linn.), which feeds on *Convolvulus* spp.; *O. grandis* (Fish), whose larvae bore in the stems of *Baccharis pilularis* (see Lange, 1939*b*); and *O. phoebus* B. & L., whose larvae select *Gnaphalium* (Lange, 1939*b*). The members of *Oidaematophorus* can be distinguished from *Platyptilia* species by the long, narrow lobes of the forewings, and lack any scales on the inner margin of the third lobe of the hindwings, a feature found only in *P. albiciliata.*

Those *Platyptilia* species found in artichoke fields can be separated by the following key:

1. Scale tuft absent on third lobe of secondaries; a uniform cinnamon-brown species; the larvae feed on *Castilleia*.....*albiciliata* (Walsingham)
   Scale tuft present, species mostly with definite markings.....2
2. Scale tuft at end of third lobe of secondaries; small grayish-brown species; the larvae feed on cultivated snapdragon (see Lange, 1939*c*).....*antirrhina* Lange
   Scale tuft at center of third lobe of secondaries or ⅔ distant from base.....3

3. Color, gray to gray-brown.....4
   Color, warm-brown to yellow-brown.....5
4. Scale tuft at center of third lobe of secondaries, subtriangular; color gray to gray-brown; larvae on artichoke and other composites.....*williamsii* Grinnell
   Scale tuft triangular, ⅔ distant from base; color, gray-brown; second palpal joint with enlarged tuft of scales; larvae on sages, *Salvia* sp.....
   (*marmarodactyla* Dyar) *fuscicornis* Zeller
5. Color dull, warm-brown; scale tuft just beyond center, triangular; larvae on members of the family Scrophulariaceae (see Fletcher, 1940).....*crataea* Fletcher[9]
   Color yellow-brown; scale tuft at center, triangular; larvae on artichoke and *Cirsium* spp.....*carduidactyla* (Riley)

ARTICHOKE PESTS OTHER THAN PLUME MOTHS

In addition to the plume moths many other insects and several mollusks may occasionally cause injury to artichoke plants and floral heads. They are discussed in the following sections.

The Artichoke Aphid.—The most common aphid on artichokes is *Capitophorus braggii* (Gillette), a pale-yellow and green species with darker green markings. It is found throughout the year in California on artichoke and various thistles of the genus *Cirsium,* including *C. edule, C. occidentale, C. quercetorum, C. lanceolatum,* and *C. venustum.* In Colorado it was reported by Gillette (1915) and Gillette and Bragg (1915) to spend the winter on *Elaeagnus,* migrating to Canada thistle (*Cirsium arvense*) and artichoke as summer hosts. Patch (1938) lists the summer hosts as *Arctium lappa, Cirsium arvense, C. horridulum, C. japonicum, Cynara cardunculus,* and *C. Scolymus.*

During August and September this species often does severe damage to artichoke, although damage may occur at any time of the year. It often completely covers the undersurface of the leaves in addition to secreting honeydew which later causes a general smutty appearance of the plants and floral heads and in severe infestations causes a wilting of the plants which delays their growth for several months. Damage is usually more severe in fields where the plants are cut late in April or where they are not cut at all during the summer, but "stumped," since there is a longer period for their development during the summer. They are preyed upon by several species of coccinellids, both as larvae and adults, and by syrphid fly larvae. A fungus which turns their bodies to an orange color is commonly found.

Control experiments conducted during 1938 (table 14), demonstrated that a nicotine dust, containing 10 per cent of nicotine sulfate (Black Leaf 40), gave excellent control if the plants were dusted at the rate of

[9] This species has been known in the past as the European *P. acanthodactyla* Hübner.

35–50 pounds per acre when the aphids first appeared in numbers. A 1 per cent rotenone dust was also found effective, especially with the addition of a satisfactory wetting agent (such as Vatsol-OS). A small power

TABLE 14

RESULTS OF DUSTING EXPERIMENTS FOR THE CONTROL OF THE ARTICHOKE APHID; HALF MOON BAY

Materials applied, and pounds used for the plants treated	Number of plants treated	Number of live aphids on 15 leaves	Per cent control
Applied by hand-duster September 13, 1938; counts made September 20			
Nicotine (3.70 per cent nicotine as alkaloid and 96.30 per cent hydrated lime), 4 pounds	20	12	99
Nicotine-sulfur (2.90 per cent nicotine as alkaloid, 50.00 per cent sulfur, and 47.10 per cent talc), 4 pounds	20	47	96
Nicotine (1.60 per cent nicotine as alkaloid and 98.40 per cent hydrated lime), 3½ pounds	20	24	98
Rotenone (1 per cent rotenone in cubé, 3 per cent ether extractives of rotenone, 1 per cent Vatsol-OS, and 95 per cent inert), 2½ pounds	15	25	98
Rotenone (1 per cent rotenone in cubé and 3 per cent Vatsol-OS), 2½ pounds	15	25	98
Rotenone (0.74 per cent rotenone as cubé, 1.50 per cent extractives of rotenone, and 97.75 per cent inert), 3½ pounds	15	102	92
Pyrethrum (0.20 per cent pyrethrins and 99.80 per cent inert), 3 pounds	15	130	89
Check (untreated)	..	1,223	..
Applied by hand-duster September 23, 1938; counts made September 26			
Lethane 440 (2 per cent Lethane and 98 per cent inert), 1 pound	6	326	74
Lethane 440 (2 per cent Lethane, 90 per cent sulfur, and 8 per cent inert), 1 pound	6	325	74
Lethane 440 (5 per cent Lethane and 95 per cent inert), 1 pound	6	208	83
Pyrethrum (0.10 per cent pyrethrins and 99.90 per cent talc), 11½ pounds	60	383	69
Pyrethrum (0.20 per cent pyrethrins and 99.80 per cent talc), 7 pounds	60	74	94
Pyrethrum-sulfur (0.20 per cent pyrethrins, 30.00 per cent sulfur, and 69.80 per cent talc), 7 pounds	60	109	91
Pyrethrum-sulfur (0.10 per cent pyrethrins, 30.00 per cent sulfur, and 69.90 per cent talc), 7 pounds	60	154	88
Check (untreated)	..	1,248	..

duster which could be mounted on a sled and drawn through the fields either by horse or tractor was found to give the best results, as adequate coverage was difficult on the larger plants with a hand duster.

Liquid sprays were found very effective in spraying experiments, pre-

sented in table 15. Sprays are more effective on the larger plants if they are applied with a power sprayer at approximately 400 pounds' pressure. A nicotine-oil spray using 1 pint of nicotine sulfate (Black Leaf 40) and 1 gallon of light-medium oil emulsion to 100 gallons of water

TABLE 15

RESULTS OF SPRAYING EXPERIMENTS FOR THE CONTROL OF THE ARTICHOKE APHID; HALF MOON BAY

Materials and amounts per 100 gallons of spray	Gallons applied to plants treated	Plants treated	Live aphids on 15 leaves	Per cent control
Applied August 30, 1938, with power sprayer at 400 pounds' pressure; counts made September 3				
Nicotine sulfate (Black Leaf 40), 1 pint; light-medium oil emulsion, 1 gallon	50	50	48	99
Pyrethrum extract (2 grams of pyrethrins per 100 cc), 1 pint; light-medium oil emulsion, 1 gallon	50	60	1,318	75
Rotenone extract (2½ grams of rotenone per 100 cc), ½ pint; light-medium oil emulsion, 1 gallon	50	60	247	95
Cubé powder (4 per cent rotenone and 14 per cent ether extractives), 4 pounds; light-medium oil emulsion, 1 gallon	17	30	133	97
Cubé powder (4 per cent rotenone and 14 per cent ether extractives), 4 pounds; Vatsol-OS (wetting agent), 1 pound	33	42	46	99
Check (untreated)	..	..	5,316	..
Applied September 10, 1938, with power sprayer at 400 pounds' pressure; counts made September 13				
Nicotine sulfate (Black Leaf 40) 1 pint	25	24	24	98
Nicotine sulfate (Black Leaf 40), 1 pint; Ultrawet, 1 pound	25	36	20	99
Nicotine sulfate (Black Leaf 40), 1 pint; light-medium oil emulsion, 1 gallon	40	64	21	98
Rotenone (3 per cent rotenone), 2 pounds; light-medium oil emulsion, 1 gallon	50	85	23	98
Pyrethrum extract (2 grams of pyrethrins per 100 cc), 2 pints	12½	16	90	93
Pyrethrum extract (2 grams of pyrethrins per 100 cc), 2 pints; Ultrawet, 1 pound	12½	18	25	98
Check (untreated)	..	..	1,208	..

gave satisfactory results, as did a spray consisting of 4 pounds of cubé powder and 1 gallon light-medium oil emulsion to 100 gallons of water. Pyrethrum, both as dusts and sprays, and Lethane 440 as a dust did not give adequate control.

Other Aphids.—The bean or dock aphid, *Aphis rumicis* Linn., is very common on artichoke, especially during the summer months and,

although often prohibiting the home gardener from growing this vegetable, does not usually prove serious under field conditions. Control is the same as for the artichoke aphid. *Aphis helichrysi* Kalt. (*A. padi* Linn.) is abundant on the floral heads, on the inside of the bracts where it forms scalelike incrustations. It has not been abundant enough to warrant special control measures.

The Ragwort or Cineraria Leaf Miner.—The species, *Phytomyza atricornis* Meig., was first found on artichokes during May, 1937, at Half Moon Bay, and since this discovery has been found throughout other growing areas. The adult is a grayish species, about 3 millimeters long. The maggots mine the leaves of various plants and have been found on artichoke, sow thistle (*Sonchus oleraceus*), and cheese-weed (*Malva parviflora*) which are common weeds growing in the vicinity of artichoke plantings. Pupation occurs in the larval mines inside the leaves. It has been observed damaging artichoke plants on only a few occasions, usually the mines being difficult to see on artichoke because of the woolly covering of hairs. The mines, adults, and puparia are shown in figure 17. For a further discussion of the life history the reader is referred to the papers by Kelsey (1937) and Wallace (1938).

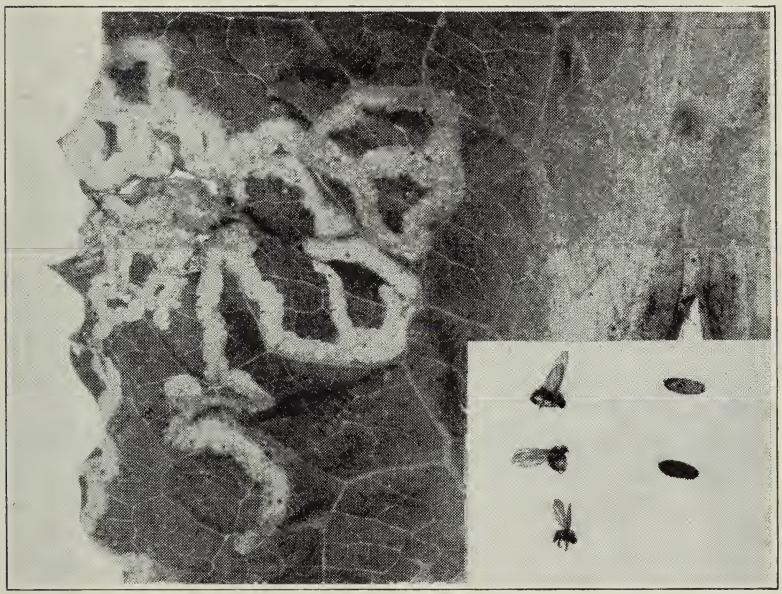

Fig. 17.—Burrowings in a leaf of *Sonchus oleraceus*, the common sow thistle, caused by maggots of the ragwort leaf miner, *Phytomyza atricornis*. The inset shows adults and puparia. (× 3.)

The Greenhouse Leaf-tier.—Larvae of the pyralid *Phlyctaenia rubigalis* (Guen.) often cause considerable injury to the floral heads during the spring by their feeding on the inside of the bracts, combined with a considerable exudation of frass and a partial webbing of the bracts. The adult (fig. 20, *B*) has a wing expanse of 24 mm (approximately 1 inch) and the wings are pale yellowish red with darker markings. The eggs are flat, disk-shaped, laid singly or overlapping in groups of several up to 16, ranging in size from 0.62 to 0.66 mm wide and from 0.84 to 0.88 mm in length. Under magnification the surface of the egg is finely reticulated. Five larval instars are found in this species, and nontechnical descriptions of these are given below.

The first instar larva is pale green in color, with a faint indication of the dorsal vessel showing through, is 1.45 mm long and the greatest width 0.17 mm. The setae and tubercles are inconspicuous.

The second instar larva is essentially like the foregoing except the length is approximately 2.2 mm, and the greatest width 0.39.

The length of the third instar is 5 mm, and the greatest width, 0.52. As in the previous instars the color is pale greenish and the dorsal vessel shows through as a darker longitudinal line. The cervical shield has a black spot on each side. The primary setae are fairly long, colorless, and arise from raised tubercles.

The length of the fourth instar is 9 mm, and the greatest width 1.23. The color is similar to the third instar, except that there is a longitudinal, laterally placed white line. The head is pale brown with darker markings and the true legs and prolegs are concolorous with the body.

The fifth instar larva is 13 to 15 mm long, and the greatest width 1.72. The color is similar to the fourth instar, and the black spots on the cervical shield will distinguish it from other artichoke caterpillars.

Pupation occurs in a white cocoon, with the pupa being reddish brown in color and approximately 15 mm long.

During April and May, 1938, adults placed in battery jars with artichoke foliage at outside temperatures, deposited from 250 to 400 eggs throughout a life span of about 40 days. During the period February to April, 1938, at a mean average temperature of 59.77° F, the time elapsing from the hatching of the eggs to the emergence of the adults varied from 66 to 72 days. The egg period varied from 10 to 12 days in the laboratory and 18 to 25 days under outside temperatures.

No control measures were undertaken for the control of the greenhouse leaf-tier.

The Scabby Sowbug.—The sowbug, *Porcellio scaber* Latreille, often eats holes out of the leafstalks and thus causes a minor injury.

True Bugs on Artichoke.—Of the numerous Hemiptera found on artichoke, only *Lygus sallei* Stål, a species found commonly on *Baccharis pilularis,* has been observed by the present writer to be doing any damage. The damage is limited to the small plants during the summer, where the injury is difficult to analyze, but is apparently a deforming of the leaves and a slight retardation of growth. The eggs are inserted into the

Fig. 18.—Damage to heads and foliage of artichoke caused by *Diabrotica 11-punctata* (*D. soror*).

leaf stalks, or midribs of the leaves, and the egg scars persist after the eggs hatch.

The black grass bug, *Irbisia solani* Heid., was reported by Tavernetti (1933) as doing considerable damage to artichoke, but has not been observed by the present writer.

A Weevil Feeding on Roots and Crowns.—The weevil *Peritelopsis globiventris* (Lec.) is a rather uncommon, broad-nosed species occurring in the sand dune areas of the coast where the larvae bore in the stems of lizard tail, *Eriophyllum staechadifolium.* Since its initial discovery on the roots and crowns of the artichoke in the Davenport area by Lange (1936), it has been found rather common there. The adult weevil is a globular species, ¼ inch long, gray in color with lighter gray scales, and the elytra with longitudinal striations. The adult weevils feed on the roots and crowns of the artichoke during May to July and often overwinter on the plants in considerable numbers; but damage to date has not been considered of much economic significance.

The Western Twelve-spotted Cucumber Beetle.—This beetle, *Diabrotica 11-punctata* (Mann.) (*soror* Lec.), is approximately ¼ inch long, yellowish green in color with black spots, and often does considerable damage to the young plants and floral heads. No control measures were undertaken during the course of this investigation, as the damage was limited to only a few months during the summer when they moved to

Fig. 19.—Pupa and mature larva of *Emboloecia sauzalitae* in stems of Indian thistle, *Cirsium edule.* (Slightly reduced.)

artichoke from native vegetation. The damage to the heads and foliage is shown in figure 18.

A Stem Borer Attacking Artichoke.—A noctuid moth, *Emboloecia sauzalitae* (Grt.), often selects artichoke, especially when the plants are allowed to go wild, or where the usual cultural methods are not employed. The adult moth averages slightly under 1⅜ inches in wing expanse, and is yellowish red to purplish in color with lighter spots. Injury is accomplished by the dirty-white to brownish larvae which attain a length of about 1½ inches, and bore for considerable distances into the stems and roots. Pupation occurs in a pupal chamber in the larval burrows, with the pupa being about 1 inch long and reddish brown in color. Host plants in addition to the artichoke include *Cirsium edule, Cirsium quercetorum, Cirsium occidentale, Centaurea melitensis, Rumex crispus, Zea mays, Castilleia latifolia,* and *Salvia spathacea.*

The larva and pupa are shown in figure 19, and the adult in figure 20, *A*. For a further discussion of this species, the paper by Lange (1939*d*) can be consulted.

A Leaf-Skeletonizer of Artichoke.—The moth, *Choreutis melanifera* Keifer, is of a metallic color with white and olivaceous scales and characteristic, raised, leaden scale patches on the forewings (fig. 21, *B*). It

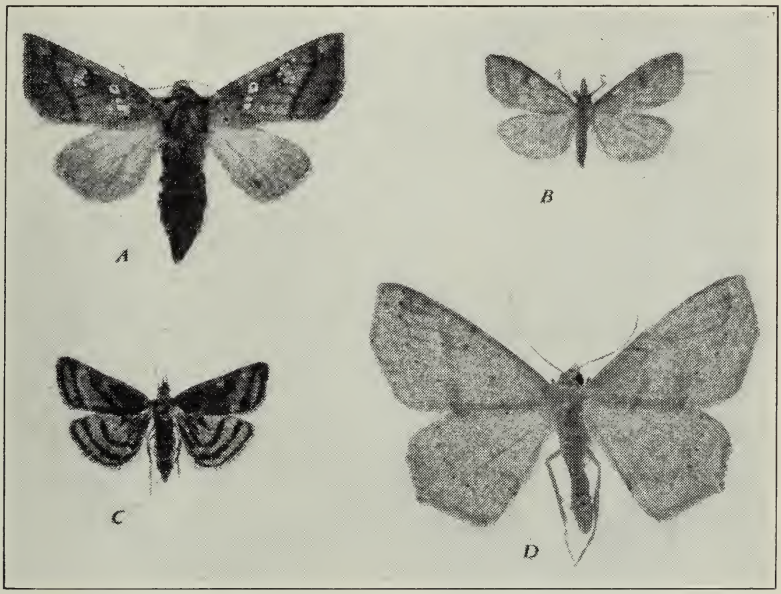

Fig. 20.—Large moths that feed on the artichoke: *A, Emboloecia sauzalitae* (Grt.); *B, Phlyctaenia rubigalis* (Guen.); *C, Pyrausta subsequalis* Guen.; *D, Sabulodes caberata* Guen. The moth shown in *C* is a female, and differs in markings from the male. (× 1.4.)

attains a wing expanse of approximately 12 mm. The larvae skeletonize the undersurfaces of the artichoke leaves, living under the protection of a silken webbing. No damage has been observed to the floral heads. It is found widely distributed on artichoke, from San Mateo County to San Luis Obispo County, where two generations a year are found. Adults emerge during the summer and again during the winter and spring. The egg is pale yellow, urn-shaped, with a flat top and sculptured sides, about 0.31 mm wide at the base, 0.22 mm wide at the top, and 0.35 mm high, and is inserted among the woolly hairs on the undersurface of the leaves. The larva can be easily distinguished by the cylindrical body which tapers to both ends, the greenish color with dark tubercles, and a length of about 10 mm. Pupation occurs in a silk cocoon on the leaves, and the pupa is 6 mm long, light brown in color, and has a characteristic

pair of small spines at the anal end. The native host is wormwood (*Artemisia vulgaris*), and for a technical description of the stages the reader is referred to the paper by Keifer (1937).

The Corn Earworm.—Larvae of the corn earworm, *Heliothis armigera* (Hübner), occasionally select artichokes growing in the vicinity of corn

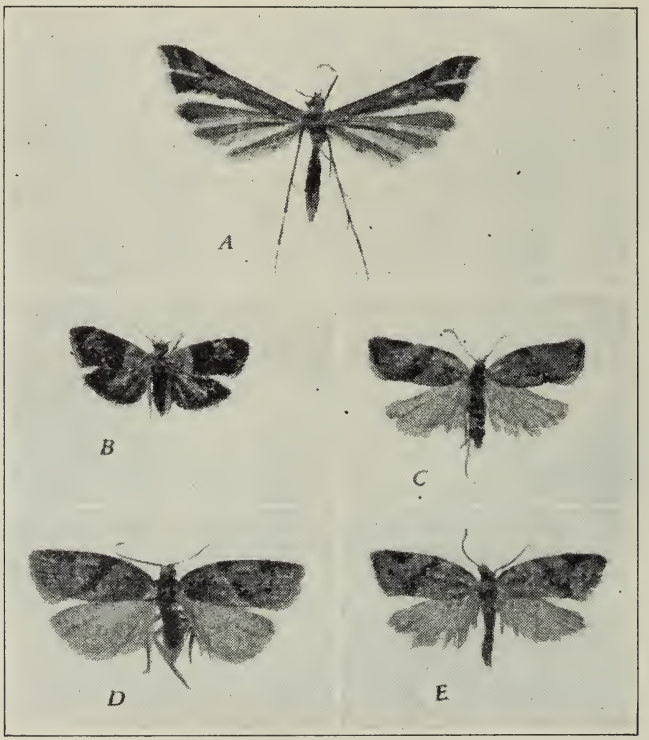

Fig. 21.—Small moths that feed on the artichoke: *A, Platyptilia williamsii* Grinnell; *B, Choreutis melanifera* Keifer; *C, Argyrotaenia franciscana* (Wlshm.); *D, Clepsis busckana* Keifer; *E, Argyrotaenia citrana* (Fern.). (× 2.)

plantings. A larva collected on October 20, 1937, at Half Moon Bay, pupated on November 11, and the adult emerged October 17, 1938.

The Acraea Moth.—During September and November the caterpillars of *Estigmene acraea* (Drury), which are known as salt marsh caterpillars or woolly bear caterpillars, often feed on the floral heads, eating off the ends of the bracts; but damage has not been severe enough to warrant special control measures.

The Omnivorous Looper.—The caterpillars of the geometrid moth, *Sabulodes caberata* Guenée (fig. 20, *D*) are general feeders and during

the fall are often found feeding on the floral heads of the artichoke. The damage usually is of minor importance.

The Painted Lady.—This widely distributed butterfly, *Vanessa cardui* L., is found commonly on artichoke from May to August, when the caterpillars web and feed on the leaves. The damage has not been severe during the course of this investigation and no control measures were needed.

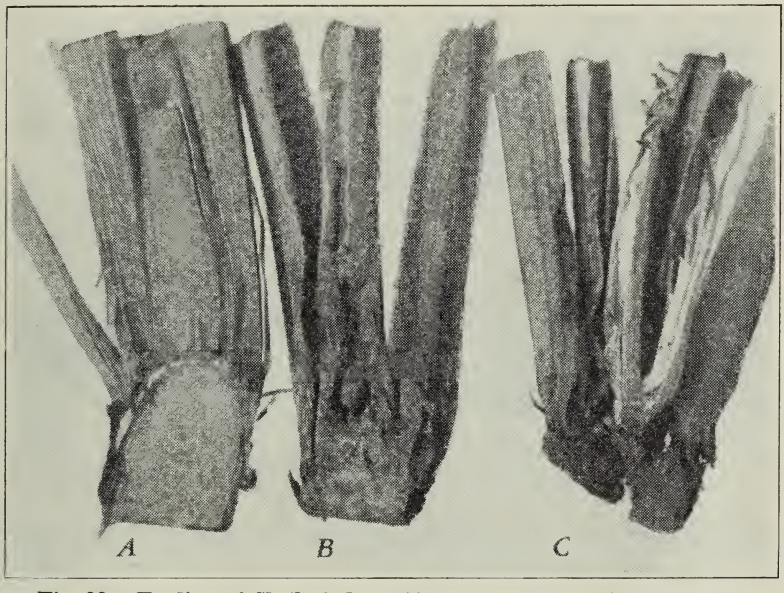

Fig. 22.—Feeding of *Cheilosia baroni* in the crowns of artichoke plants: *A*, healthy crown; *B* and *C*, damaged by the maggots.

Tortricid Larvae on Artichoke.—The orange tortrix, *Argyrotaenia citrana* (Fern.) (*Tortrix*), and the apple skin worm, *Argyrotaenia franciscana* (Wlshm.) (*Tortrix*), occasionally feed on the floral heads during the spring of the year, along with larvae of another tortricid, *Clepsis busckana* Keifer. The adults of these three moths are shown in figure 21. *Clepsis* is a beautiful chestnut brown to golden-colored moth with a wing expanse of from 16 to 20 mm and the larvae are similar to the *Argyrotaenia* species, except larger when mature. It is also found on *Scrophularia californica,* and for a technical treatment of the stages reference to the paper by Keifer (1933) is suggested.

Other Moths Feeding on Artichoke.—In addition to the moths already mentioned, there are many more which feed during the larval stage on artichoke and which may occasionally become pests. These include the larvae of many noctuids, namely, *Autographa californica* Speyer, *A.*

brassicae Riley, *Leucania* (*Cirphis*) *unipuncta* (Haw.), *Euxoa messoria* (Harr.), *Zosteropoda hirtipes* Grt., and *Peridroma margaritosa* (Haw.). The pyralid, *Pyrausta subsequalis* Guen., a moth (fig. 20, *C*) found very commonly on various thistles, occasionally selects artichoke. Of the noctuids, the caterpillars of the variegated cutworm, *P. margaritosa* (Haw.), often do considerable injury by feeding on the tender leaf stalks and eating out the insides of the floral heads.

The Thistle Crown Fly.—The maggots of the syrphid fly, *Cheilosia*

Fig. 23.—Maggots (left) and puparia of *Cheilosia baroni.* (× 5.)

baroni Williston, are found most commonly as crown borers in various thistles, especially *Cirsium edule,* and *C. lanceolatum,* but occasionally are found boring in the crowns of artichoke shoots. This damage is shown in figure 22. The first infestation was found in a field near Davenport, Santa Cruz County, on July 21, 1937. The adult *Cheilosia* is a metallic, greenish-bronze species, attaining a length of ½ inch, and the head, thorax, and abdomen are clothed with short hairs. The wrinkled maggots are about 9 mm long and 4 wide, somewhat flattened, in color a dirty white to brownish, and are covered with short, black spines as seen under magnification. On the posterior end is a centralized posterior spiracle, surrounded by 4 spines. In appearance the puparium is similar to the maggot, but is smooth, dark reddish brown in color, and in addition has two spine processes projecting from the anterior end (fig. 23).

A Trypetid Fly Crown Borer.—A trypetid fly, *Paracantha culta* (Wiedemann), selects as preferred host plants thistles of the genus *Cirsium,* as does *Cheilosia baroni,* but artichoke is occasionally selected. The small, white maggots bore into the crowns in a similar fashion to *Cheilosia.* It was first found on artichoke in the Davenport district along with

Cheilosia, but the damage is usually of minor importance. The adult fly is 8 to 10 mm long, reddish brown in color, with darker spots on the thorax, and beautiful mottled reddish and white wings. The mature maggots are dirty white in color, tapering to both ends, and about 5 mm long. The puparia occur in the burrows, and are reddish brown in color and oblong-ovate in form.

Rodents.—Certain rodents often damage artichoke plants. Gophers are especially fond of artichoke roots and often cut the plants completely off under ground. Field mice feed on the young stems and buds, but usually the damage done by them is relatively unimportant.[10]

Slugs and Snails.—The gray garden slug, *Deroceras* (*Agriolimax*)

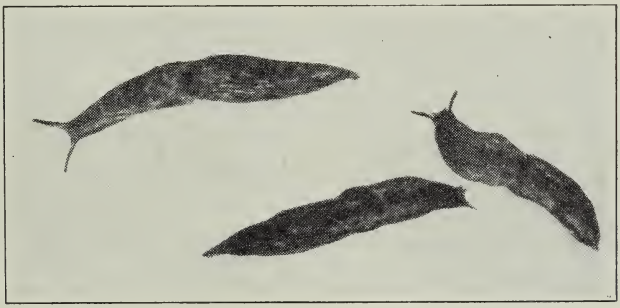

Fig. 24.—The gray garden slug, *Deroceras agreste.* (Natural size.)

agreste (L.), and the greenhouse slug, *Milax gagates* (Draparnaud) (*Limax hewstoni* Cooper), both of European origin (see Hanna, 1939), are commonly found in artichoke fields, and are responsible for considerable damage to the floral heads, especially during the winter and spring months. In certain localities the European brown snail, *Helix aspersa* Müller, also does some damage to artichokes.

The gray garden slug is a small brownish species with darker gray spots, the average specimens ranging from ⅝ to 1 inch at rest, and from 1½ to 2 inches in length when extended (fig. 24). The oval, translucent eggs are laid in masses of from several to around 40, usually in crevices in the soil, or at the axils at the base of the plants. During periods of high humidity, as during rains or foggy weather, the slugs crawl over the floral heads, and scrape off the outer surfaces. The heads later discolor and turn dark, rendering them unsightly (fig. 25) and detracting from their salability. The slugs may also feed on the young plants during May, especially during foggy weather.

[10] For further discussion of rodents and methods for their control see the circular by Storer (1938).

The greenhouse slug is usually larger than the gray garden slug, of a gray color, and with a conspicuous keel extending along the length of the body. In size it ranges from ⅝ to 1½ inches long at rest, and when extended ranges from 1½ to 2¾ inches. The eggs are similar to those of the gray garden slug except that they are larger, and are laid in carefully excavated cells in the ground in groups of from several to around 30 (fig. 26). The greenhouse slug damages artichoke heads in

Fig. 25.—Damage to artichoke heads by the gray garden slug.

the same manner as the gray garden slug, but in general it is more of a ground-burrowing species, coming out only when weather conditions are favorable.

The control of slugs and snails in artichoke fields can be accomplished through the use of metaldehyde-arsenical baits, repellent mixtures, and certain cultural practices.

Numerous mixtures containing metaldehyde and calcium arsenate have been tested. The most effective mixtures contained from 2 to 2½ per cent metaldehyde as a powder in the mixtures, and approximately 5 per cent calcium arsenate; the materials are closely adhered to bran through the use of molasses solutions or moist pulps. In these mixtures the metaldehyde serves chiefly as the attractant and the calcium arsenate as the poison. The use of these materials dry in the mixtures is not effective, partly owing to the repellent nature of the metaldehyde when the

mollusks come into contact with the baits. It was found that metaldehyde in itself is both an attractant and poison to slugs and snails, but does not give a fast kill, especially during rainy or foggy weather when the affected individuals are not exposed to the rays of the sun and linger for some time before dying, or even recover. The addition of calcium arsenate to the mixture was not found to interfere with the attractiveness of the metaldehyde and in addition, a rapid kill was assured under

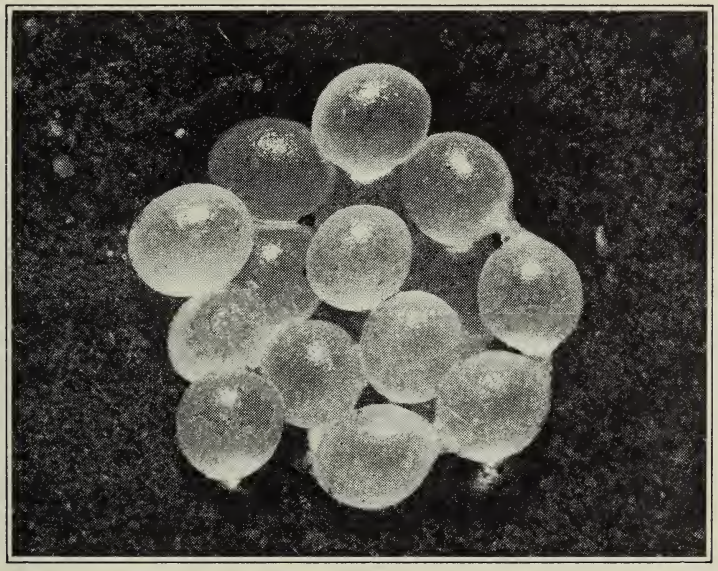

Fig. 26.—Egg mass of the greenhouse slug, *Milax gagates*. (× 5.)

all kinds of weather conditions. When metaldehyde is used alone in baits, without the addition of an arsenical, the slugs are stupefied and before they can reach refuge under debris or in crevices are desiccated by the sun. The use of metaldehyde in higher percentages without the addition of an arsenical, often kills by contact, but there is no evidence that these higher percentages attract more slugs and the high cost of the baits would not warrant their use under field conditions. For a further discussion see Lange and MacLeod (1941).

The mixtures which have to date proved best through repeated tests under field conditions are given below. The metaldehyde used in the experimental mixtures came under the name of "Meta-Meta," sold as a fuel, and contains approximately 99 per cent metaldehyde. Inasmuch as there is difficulty in obtaining metaldehyde in a pure form at present, the grower may have to rely upon commercial dry mixtures, which con-

tain 2 to 2½ per cent metaldehyde and approximately 5 per cent calcium arsenate.

Mixture No. 1

	Small quantity	Large quantity
Black-strap molasses	2 tablespoons	1 pint
Calcium arsenate	1 ounce	1 pound
Metaldehyde	½ ounce	½ pound
Bran	1 pound	16 pounds
Water	1 pint	2 gallons

This mixture is applied as a wet mash at the rate of ½ to 1 ounce per plant, placed in a pile on the ground near the center of the plant. The calcium arsenate and metaldehyde should be thoroughly mixed with the bran before the molasses solution is added.

Mixture No. 2	Per cent by weight
Boiled potatoes (low grade)	40.0
Metaldehyde	2.5
Calcium arsenate	5.0
Bran	52.5

This mixture is applied at the same rate as mixture no. 1. The metaldehyde and calcium arsenate are mixed thoroughly with the bran, then the potato added and well mixed. This bait will not keep well, if moist, but can be dried if it must be stored.

Mixture No. 3	Per cent by weight
Raisins (low grade or cull)	46.25
Metaldehyde	2.50
Calcium arsenate	5.00
Bran	46.25

This mixture should be used at the same rate as the other two. The metaldehyde and calcium arsenate should be mixed with the bran, and then the raisins added. This mixture is especially good for snails, and the hygroscopic nature of the raisins makes it a good bait for dry weather. The raisins can be replaced by an equal percentage of orange rind.

The metaldehyde baits were found to attract and kill a large proportion of slugs within a radius of about 2 feet in 3 to 5 days during moist conditions, but have to be placed out two to three times during the year in order to kill those continually hatching in the soil. The baits were found to be effective as long as 60 days but this period is usually reduced by rains or irrigation. Baits are usually more effective if placed out during moist conditions, as during foggy weather, following rains, or just after irrigating.

Both metaldehyde and calcium arsenate are poisons, and baits containing these materials should be kept out of the reach of children, and away from domestic animals. Baits should not be sprinkled on artichoke plants which are bearing buds.

Satisfactory control of artichoke slugs and snails can also be accomplished through application of a monohydrated copper sulfate and hydrated lime mixture, which kills by contact and also acts as a repellent for a period of from 15 to 30 days. The formula of the mixture, which has given the most satisfactory results, is given below:

Slug and Snail Repellent Mixture	Per cent by weight
Monohydrated copper sulfate	20
Hydrated lime	80

The copper sulfate mixture should be applied early in the morning during humid conditions when the slugs are out feeding, and can be satisfactorily applied to the bases of the shoots without covering the heads with objectionable residue by dusting with a hand duster at the rate of approximately 40 pounds to the acre. Metaldehyde baits usually give a more lasting control of slugs in artichoke fields; but for quick temporary relief the copper sulfate mixture will give satisfactory results, or it can be used in combination with a bait program.

It is possible to materially avert slug damage by frequent cultivation of the areas between the plants as this aids in destroying breeding and resting places and also destroys a certain percentage of the eggs. This can be done by setting out the plants equidistant in the rows, forming a square, so that cross cultivation can be easily accomplished.

The large carabid beetle, *Scaphinotus interruptus* (Men.), is a very effective natural enemy of slugs, and has been found preying on both the garden and greenhouse slug in most of the artichoke-growing areas.

DISEASES AND INJURIES AFFECTING THE ARTICHOKE[11]

Bud Rot, Mold, or Botrytis Rot.—Considerable damage to the floral heads is often caused by a form of *Botrytis cinerea* Pers. which may affect several bracts, or the entire heads. The bracts turn brown, and the fungus spreads by means of a grayish growth. The initial infection occurs in the field, as shown in figure 27, and during shipment it may continue to develop causing severe damage if provided with the proper

[11] This section was prepared with the assistance of the Division of Plant Pathology. For further information about artichoke diseases see Tavernetti (1933) and Smith (1940).

humidity and temperature conditions. Link, Ramsey, and Bailey (1923, 1924) found that the rot develops rapidly at temperatures of 68° to 75° F and as control measures recommended low humidity, a temperature of 41° during transit and care in handling so as not to cause unnecessary wounds. It is advisable to practice such sanitary methods as

Fig. 27.—Artichoke infected in the field with bud rot (botrytis rot), showing the discolored bracts and the grayish growth of the sporulating mycelium (in the central head).

the prompt removal of all affected buds from the plants and care in culling out all which show the slightest trace of the disease before shipment.

Yellows.—Yellows is characterized by a dwarfing of the plant, curling of the leaves, and a yellowing of the foliage, and is thought to be of a virus nature (fig. 28). It was found in a few places during 1936 to 1939, but limited to only a few fields. The plants produce few or no marketable heads. Control measures consist in digging up and destroying all affected plants.

Mosaic.—This disease appears as a typical mosaic on new growth. The leaves in the earlier stages show small yellowish-green chlorotic circles

and later the entire leaves turn yellowish. On the older plants the symptoms are often masked. Diseased plants have been found in San Luis Obispo and San Mateo counties, but mosaic has not been found to be of much economic significance.

Leaf Spot.—The symptoms of this leaf spot are manifested only on the older foliage, where circular, brown spots appear in large numbers, caused by several fungi including *Cladosporium, Cercospora obscura,*

Fig. 28.—Artichoke plant infected with artichoke yellows, showing the characteristic dwarfing of the plant and curling of the leaves.

and *Ramularia cynarae.* No apparent damage to the plants has been observed.

Root Rot.—During the winter or spring when water does not drain properly from artichoke fields, the plants may wilt and die from rotting of the roots by *Phytophthora megasperma.* The plants infrequently turn yellowish, but usually wilt so rapidly that there is no change in the color of the foliage. The only means of control is the use of adequate drainage ditches so that water is not allowed to stand in the rows.

Powdery Mildew.—The fungus, *Erysiphe cichoracearum,* occasionally causes a white mildew on the leaves and buds. It has not been observed to cause serious injury to the artichoke.

Black Tip.—Black tip is a physiological trouble associated with adverse weather conditions, which is exhibited as a blackening of the tips of the floral bracts. No damage to the rest of the bud occurs, but the blemishes do lower their salability. No control is known at present.

Frost Injury.—Artichoke plants are susceptible to frost damage,

which is exhibited as a blistering of the heads (fig. 29), a wilting of the plants, or in extreme cases the killing of the entire plants.

Fig. 29.—Artichoke damaged by frost, showing the characteristic blistered condition of the outer bracts. The resulting whitened blotches will distinguish frost injury from damage caused by insects. (From Ext. Cir. 76.)

TABULATION OF ALL INSECTS COLLECTED ON ARTICHOKE

During the course of the present investigation a total of over 100 species of insects were found associated with the artichoke. These included the species feeding directly on the plants and in addition the predators and parasites of the plant-feeding forms. Most of the first-mentioned apparently fed on thistles before the artichoke was introduced and moved over to artichoke when conditions were favorable. For this reason a few of the more important thistle insects are included as

they are potential pests of the artichoke. The following list gives primarily the plant-feeding forms and the predacious species, together with the locality in which they were collected. The species are arranged alphabetically and not systematically within the orders.[12]

Neuroptera:

Chrysopa californica Coq.[a]	General
Hemerobius pacificus Banks[a]	General

Homoptera:

Aleyrodes spiraeoides Q.[b]	Half Moon Bay
Aphis cardui Linn.[c]	Half Moon Bay
Aphis helichrysi Kalt.[c]	San Mateo County
Aphis rumicis Linn.[c]	General
Capitophorus braggii (Gillette)[c]	General
Macrosiphum granarium (Kirby)[c]	San Mateo County
Macrosiphum solanifolii (Ashm.)[c]	San Mateo County
Myzus persicae (Sulzer)[c]	San Mateo County

Heteroptera:

Anthocoris antevolens White[d]	Half Moon Bay
Chlorochroa congrua Uhler[d]	Half Moon Bay
Cixius cultus Ball[e]	General
Corizus parvicornis Sign.[e]	Half Moon Bay
Corythucha morrilli O. & D.[d]	Castroville
Draeculacephala minerva Ball[e]	General
Empoasca denaria Van D.[e]	General
Eurygaster alternatus (Say)[d]*	Moss Beach
Euryophthalmus cinctus californicus Van D.[d]	General
Euschistus conspersus Uhler[d]	Half Moon Bay
Geocoris pallens Stal[e]	General
Idiocerus verrucosus Ball[e]	Half Moon Bay
Lygus convexicollis var. *coloratus* Knight[f]	Half Moon Bay
Lygus elisus Van D.[f]	Santa Cruz
Lygus elisus viridiscutatus Knight[f]	Santa Cruz and Half Moon Bay
Lygus humeralis Knight[f]	Castroville and Half Moon Bay
Lygus sallei Stal[e]	General
Nabis ferus (Linn.)[e]	General
Nysius californicus Stal[d]	Santa Cruz
Nysius strigosus Uhl.[e]	Half Moon Bay
Orius tristicolor (White)[e]	Half Moon Bay
Peritrechus tristis Van D.[e]	Half Moon Bay
Phlepsius annulatus O. & L.[e]	Half Moon Bay
Podisus pallens Stale[e]	Santa Cruz
Scolopostethus atlanticus Harv.[e]	Point Reyes
Scolopostethus tropicus Dist.[e]	Half Moon Bay
Sphragisticus nebulosus (Fall.)[e]	Point Reyes

Diptera:

Aegilips sp.[g]	Half Moon Bay
Agromyza websteri Mall.[h]*	Santa Cruz
Anacharis sp.[g]	Half Moon Bay

[12] The superscript letters following the name of the insect refer to the entomologists who made determinations of the species, and are keyed as follows: *a*, W. H. Lange; *b*, E. D. Dorman; *c*, E. O. Essig; *d*, R. L. Usinger; *e*, E. P. Van Duzee; *f*, W. W. Stanger; *g*, L. H. Weld; *h*, C. T. Greene; *i*, D. G. Hall; *j*, A. Stone; *k*, E. C. Van Dyke; *l*, E. A. Chapin; *m*, H. H. Keifer; and *n*, C. Heinrich.

The asterisk following the insect name indicates that to date the insect has been found associated only with thistles of the genus *Cirsium*.

Diptera (*Continued*):

Cheilosia baroni Will.[h] ..... Davenport
Hylemya sp.[1] ..... Half Moon Bay
Leptocera sp.[1] ..... Half Moon Bay
Paracantha culta (Wied.)[h] ..... Santa Cruz
Pegomya sp.[1]* ..... Castroville
Scaeva pyrastri (L.)[a] ..... General
Scaptopse notata (L.)[j] ..... General
Sciara fenestralis Zett.[j] ..... Half Moon Bay
Trypeta occidentalis Snow[h]* ..... Moss Beach

Coleoptera:

Anchastus cinereipennis (Esch.)[k] ..... General
Anthicus biguttatus Lec. var.[k] ..... General
Apion proclive Lec.[k] ..... Pescadero
Apocrypha dyschirioides Lec.[l] ..... Point Reyes
Baris tenuestriata Csy.[k]* ..... Castroville
Blapstinus pulverulentus Mann.[k] ..... Half Moon Bay
Cleonus erysimi Fall[k] ..... Half Moon Bay
Coccinella californica Mann.[k] ..... General
Coninomus nodifer (Westw.)[k] ..... General
Corticaria sp.[k] ..... Half Moon Bay
Diabrotica 11-punctata (Mann.)[a] ..... General
Diabrotica trivittata Mann.[k] ..... General
Diachus auratus (Fab.)[k] ..... Half Moon Bay
Dolopius lateralis Esch.[k] ..... General
Hippodamia convergens Guérin[a] ..... General
Hippodamia sinuata Muls.[k] ..... General
Hypera punctata (Fab.)[k] ..... Half Moon Bay
Limonius californicus Mann.[k] ..... General
Limonius californicus occidentalis Cand.[k] ..... Castroville
Listroderes obliquus (Gyll.)[k] ..... General
Listronotus teretirostris Lec.[k] ..... Castroville
Lixus asper Lec.[k] ..... Santa Cruz
Peritelopsis globiventris (Lec.)[k] ..... Davenport
Phalacrus sp.[k] ..... Half Moon Bay
Psyllobora 20-maculata taedata Lec.[k] ..... General
Ptinus cognatus Fall.[k]* ..... Moss Beach
Scaphinotus interruptus (Men.)[k] ..... General
Scymnus marginicollis Mann.[k] ..... General
Sitona hispidula (Fab.)[k] ..... Half Moon Bay
Stenocellus sp.[k] ..... Half Moon Bay

Lepidoptera:

Argyrotaenia citrana (Fern.) (*Tortrix*)[m] ..... General
Argyrotaenia franciscana (Wlshm.) (*Tortrix*)[m] ..... Half Moon Bay
Autographa brassicae Riley[a] ..... General
Autographa californica Speyer[a] ..... General
Choreutis melanifera Keifer[m] ..... General
Clepsis busckana Keifer[m] ..... General
Emboloecia sauzalitae (Grt.)[a] ..... Half Moon Bay
Estigmene acraea (Drury)[a] ..... General
Euxoa messoria (Harr.)[a] ..... General
Heliothis armigera (Hbn.)[a] ..... Half Moon Bay
Leucania unipuncta (Haw.)[a] ..... General
Peridroma margaritosa (Haw.)[a] ..... General
Phlyctaenia rubigalis (Guen.)[a] ..... General
Platyptilia carduidactyla (Riley)[a] ..... General
Platyptilia williamsii Grinnell[a] ..... Davenport and Half Moon Bay
Pyrausta subsequalis Guen.[n] ..... San Mateo County
Sabulodes caberata Guen.[a] ..... General
Vanessa cardui L.[a] ..... General
Zosteropoda hirtipes Grt.[a] ..... Castroville

For insects occurring on artichoke in Italy, the work of Rava (1937) should be consulted. Jones (1918) listed 15 insects found on artichoke in Louisiana, but did not give the artichoke plume moth. Two insects have been listed by other authors as occurring on artichoke in California, which the present author has not found, namely, the erigeron root aphid, *Aphis middletonii* Thomas (see Vickery, 1910, and Essig, 1938), and *Irbisia solani* Heid. (Tavernetti, 1933). The eriophyid mite, *Eriophyes neocynarae* Keifer, is a free-living mite found among the hairs on the undersurface of the leaves at Half Moon Bay and Castroville.

The parasites which were found associated with artichoke insects, together with the rôle they play, are presented in the following list.[13]

Paracantha culta (Wied.) parasites:
- *Eupteromalus americanus* Gahan[a] ..... Primary on maggots
- *Habrocytus* n. sp.[b] ..... Primary on maggots

Cheilosia baroni Will. parasite:
- *Phygadeuon* sp.[c] ..... Primary on maggots

Scaeva pyrastri (Linn.) parasite:
- *Syrphoctonus maculifrons* (Cress.)[c] ..... Primary on maggots

Platyptilia carduidactyla (Riley) parasites:
- *Angitia platyptiliae* Cush.[c] ..... Primary on larvae
- *Gelus* sp.[c] ..... Secondary through *Angitia platyptiliae*
- *Dibrachys cavus* (Walk.)[c] ..... Secondary through *Angitia platyptiliae*
- *Epiurus bicoloripes* Ashm.[c] ..... Primary on larvae
- *Phaeogenes* n. sp.[c] ..... Primary on larvae, emerging through pupae
- *Pachyneuron allograptae* Ashm.[b] ..... Secondary through *Phaeogenes* n. sp.
- *Colpognathus helvus* (Cress.)[c] ..... Primary on larvae
- *Microbracon nevadensis* (Ashm.)[b] ..... Primary on larvae?
- *Hyalomyodes triangulifera* Lw.[d] ..... Primary on larvae
- *Lispidea* sp.[d] ..... Primary on larvae
- *Lispidea* sp.[d] ..... Primary on larvae
- *Plectops* sp.[d] ..... Primary on larvae

Platyptilia williamsii Grinnell parasites:
- *Campoplex* sp.[c] ..... Primary on larvae
- *Angitia* sp.[c] ..... Primary on larvae
- *Hemiteles* sp.[c] ..... Secondary through *Angitia* sp.
- *Epiurus bicoloripes* Ashm.[c] ..... Primary on larvae

Vanessa cardui L. parasites:
- *Madremyia saundersi* Will.[d] ..... Primary on larvae
- *Amblyteles rufiventris* (Brullé)[c] ..... Primary on larvae

Pyrausta subsequalis Guen. parasites:
- *Apanteles langei* Mues.[b] ..... Primary on larvae
- *Angitia platyptiliae* Cush.[c] ..... Primary on larvae
- *Campoplex* sp.[c] ..... Primary on larvae
- *Phaeogenes* n. sp.[c] ..... Primary on larvae, emerging through pupae

Phlyctaenia rubigalis (Guen.) parasite:
- *Angitia* sp.[c] ..... Primary on larvae

Emboloecia sauzalitae (Grt.) parasite:
- *Microbracon* sp.[b] ..... Primary on larvae

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[13] The superscript letters following the name of the species refer to individuals who made determinations of the species, and are keyed as follows: *a*, A. B. Gahan; *b*, C. F. W. Muesebeck; *c*, R. A. Cushman; and *d*, D. G. Hall.

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