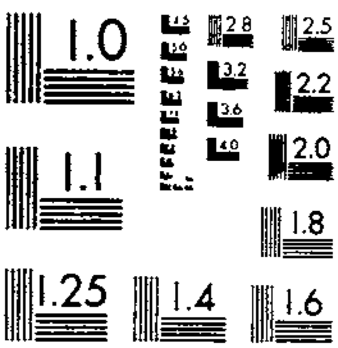
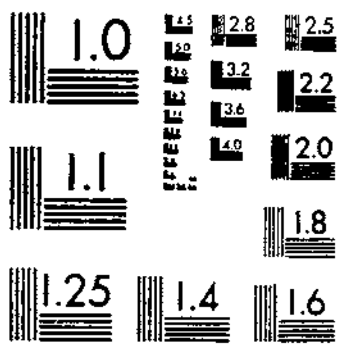
TB 1321 (1965) USDA TECHNICAL BULLETINS UPDATA
BIOLOGY AND CONTROL OF THE LIMA BEAN POD BORER IN SOUTHERN CALIFORNIA
STONE, M.W. 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Biology and Control of the LIMA-BEAN POD BORER in Southern California

By M. W. STONE

Technical Bulletin No. 1321

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D.C. Issued April 1965

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 25 cents

Contents

BIOLOGY AND CONTROL OF THE LIMA-BEAN POD BORER IN SOUTHERN CALIFORNIA

By M. W. Stone,[1] *Entomology Research Division, Agricultural Research Service*

The lima-bean pod borer (*Etiella zinckenella* (Treitschke)) is one of the most serious insect pests of lima beans in California. It has been known as a pest of lima beans in this area since 1885. It attacks all varieties of lima beans and numerous wild host plants, principally species of lupines, wild pea, and locoweed. Losses by this pest were so great that studies were undertaken in 1931 at Ventura, Calif., to determine its life history and habits and to develop methods of control. The work was discontinued in 1943, but owing to the demand for more effective methods of control, the work was resumed at Whittier in 1958 and at Riverside in 1961. This is a report of the results of this work and not a recommendation of any of the materials used.

Distribution in the United States

According to Chittenden (*3*),[2] Albert Koebele first observed the lima-bean pod borer as a pest of lima beans in the United States during 1885 in El Dorado County, Calif. At that time he reported that the beans in that vicinity were much infested by larvae of this species. In this same publication Chittenden also recorded observations by H. O. Marsh, who reported in 1908 that lima bean pods were infested by larvae of this species at Santa Ana, Garden Grove, and Anaheim in Orange County and at Watts and Compton in Los Angeles County, Calif.

A. O. Larson (*11*) recorded in 1926 the presence of pod borer larvae in lima beans at the following locations in California: San Diego, Ventura, Irvine (Orange County), Puente (Los Angeles County), and in San Bernardino and Stanislaus Counties.

Hyslop (*10*) reported that the lima-bean pod borer occurred at Pullman, Wash., and that there are specimens in the U.S. National Museum collection from the following places: Hampton, N.H.; Weekapaug, R.I.; Key West and Archer, Fla.; Oxbow, Saskatchewan, Canada; Texas; Stillwater, Okla.; Denver, Colo.; and specimens of the variety *E. zinckenella schisticolor* (now recognized as a synonym of *E. zinckenella*) from Stockton, Utah; El Dorado, Claremont, Alameda, and San Diego, Calif.;

---

[1] Retired 1963.

Rodney Cecil (deceased) of the former U.S. Bureau of Entomology and Plant Quarantine conducted the work from 1931 until his retirement in 1943. Grateful acknowledgment is due D. F. Millen of the University of California, South Coast Field Station, Irvine, for his excellent cooperation in maintaining the experimental plots of lima beans used for insecticide tests, and P. V. Vail, Entomology Research Division, for assisting with the field experiments in 1962.

[2] Italic numbers in parentheses refer to Literature Cited, p. 44.

Springfield, Idaho; and Nogales, Ariz. Hulst (*9*) on distribution gives Florida, North Carolina, South Carolina, Texas, Colorado, and California.

Flanders (*6*) reported in 1930 that the pod borer had been found from Sacramento to San Diego and that its distribution probably extended the length of California. In 1929 he reared it from native hosts near Mazatlán in the State of Sinaloa, Mexico.

In addition to these reports, the following records on distribution were furnished by the former Office of Insect Pest Survey and Information, Bureau of Entomology and Plant Quarantine:

Kansas.—H. R. Bryson. In report to Insect Pest Survey, August 1931. "Legume pod moths reported working in beans at Great Bend. The beans were adjacent to locust trees."

Nevada.—Specimens in U.S. National Museum.

Oregon.—D.C. Mote, report July 1936. "Ninety percent of the pods of *Lathyrus* (beach pea) at Sunset Beach are infested with *E. zinckenella.*" Specimens from Dufur, Astoria, and Hillsboro, July 1936, determined by C. Heinrich.

Washington, D.C. — Specimens from District of Columbia, determined by C. Heinrich. (No date.)

During the investigations conducted at Ventura, Calif., pod borer larvae were collected in pods of wild or cultivated host plants in every county of California. In Ventura County in 1946, a survey in 12 bean fields showed 4 to 8 percent of the pods infested with the pod borer. In one 60-acre field near Saticoy 48 percent of the pods were infested, and it was necessary to plough under the entire crop. In 1959, inspection of warehouse samples of beans from 87 fields comprising 9,000 acres in the Irvine area (Orange County) showed that on an average 13 percent of the beans were damaged by the pod borer. In 22 of the 87 fields damage exceeded 20 percent and in one field 42 percent of the beans were unmarketable. In untreated experimental plots at the University of California, South Coast Field Station at Irvine, in 1958 and 1959, 72 and 40 percent of the pods, respectively, were infested with the pod borer.

Foreign Distribution

W. D. Pierce (*14*) stated that the lima-bean pod borer occurs in Europe, Africa, Asia, and the West Indies. Hulst (*9*), on distribution, added South America. C. P. Clausen (*4*) reported its presence in Japan. Other records on distribution are Dutch East Indies (Indonesia) (*21*), Russia (*16*), Queensland, Australia (*7*), Cuba (*20*), Dominican Republic and Puerto Rico (*20*), Mexico (*20*), and Egypt (*8*).

Leonard and Mills (*12*) reported rearing the lima-bean pod borer from the pods of lima and string beans, pigeon peas, and one or two other legumes in Puerto Rico in 1931. Scott (*18*) stated that it was found commonly in 1935 and 1936 infesting wild and cultivated leguminous plants in all parts of Puerto Rico.

In correspondence in 1962 with D. F. Waterhouse, Division of Entomology, Canberra, Australia, he reported that Turner's unpublished card-index catalog lists six species of *Etiella* as occurring in Australia.

These are *sincerella* Meyrick, *chrysoporella* Meyrick, *zinckenella* (Treitschke), *walsinghamella* Ragonot, *melanella* Hampson, and *holozona* Low.

I. F. B. Common of this Division at Canberra compared the genitalia of both sexes of specimens taken from the series labeled by Turner as *E. zinckenella* with the figures of *E. zinckenella* given by Heinrich in his revision of the North American species of the Phycitinae. These have proved to be quite different from each other and indicate that the species Turner presumed to be *E. zinckenella* is in fact another species, possibly *E. behri*.

Technical and Common Names

In 1832, the lima-bean pod borer was described by Treitschke (*19, p. 201*) and named *Phycis zinckenella*, a new species from Sicily. In 1881, P. C. Zeller (*23*) described the variety *Etiella zinckenella schisticolor* as *E. schisticolor*. In 1890, Hulst (*9*) in his article entitled The Phycitidae of North America gave a technical description of three species of *Etiella* Zeller and named them *zinckenella* Treitschke, *schisticolor* Zeller, and *rubribasella*, n. sp., Hulst. Chittenden (*3, p. 26*), quoted from a letter that he received from Dr. Dyar, May 28, 1909, as follows: "I have compared the *Etiella* species and find only one and that it is the same as the European *zinckenella*. Hulst's *rubribasella* is evidently a synonym, founded on an imperfect or badly mounted specimen; *schisticolor* Zeller is paler gray, less reddish tinted, the costal strip less sharply defined, but I think it a racial form only . . . ."

In 1912, Hyslop (*10, p. 90*) in giving a possible explanation for the different technical names said, "It may be that the variety *schisticolor* is a native of the Pacific Slope of this continent, while the forms found in the eastern United States are the typical *E. zinckenella* recently introduced into this country from the old world or South America."

In 1931, the synonymy of this species was referred to the former Division of Insect Identification of the Bureau of Entomology and Plant Quarantine. Harold Morrison, in a letter dated February 25, 1931, relative to the correct name of the lima-bean pod borer, wrote, "C. Heinrich reported that *Etiella schisticolor* Zeller is now regarded as a synonym of *E. zinckenella* (Treitschke). The latter name would therefore be the proper one to use."

The lima-bean pod borer has been known and mentioned in the literature under the common names of the legume pod moth (*10*) and the lima-bean pod borer (*3, 5, 6*). In 1931, the common name "lima-bean pod borer" was approved by the American Association of Economic Entomologists (*1*).

Host Plants

In southern California the lima-bean pod borer has been observed attacking all varieties of lima beans and several species of leguminous plants. Larson (*11*) reported that the pod borer may occasionally attack the black-eyed cowpea and the common bush or pole bean. Hyslop (*10*) reared the pod borer from pods of the common lupines and Canada field peas at Pullman, Wash., in 1910 and 1911. According to E. O. Essig (*5*), "Bush lima beans are seriously injured in many sections, but small whites, pinks, red kidney, peas and the seed of locust and wild vetches are also attacked." In addition to these host plants, the pod borer has been reported attacking many other cultivated and wild plants, as shown in the following list.[3]

[3] All host plants listed are cultivated except the last four entries under Russia.

AFRICA

Scientific name	*Common name*[1]
Cajanus indicus Spreng	Pigeonpea (*14*).
Dolichos lablab L	Hyacinth-bean (*14*).

CALIFORNIA (U.S.A.)

Astragalus antiselli Gray	Locoweed.
Astragalus asymmetricus Sheld	Do.
Astragalus leucopsis (Torr.) T. & G	Do.
Astragalus trichopodus (Nutt.) Gray	Milkvetch.
Isomeris arborea Nutt	Bladderpod.
Lathyrus vestitus Nutt. ex T. & G	Wild pea.
Lupinus albifrons Benth. var. *eminens* (Greene) C. P. Sm	Lupine.
Lupinus arboreus Sims	Tree lupine.
Lupinus bicolor Lindl. var. *microphyllus* (Wats.) C. P. Sm	Lupine.
Lupinus caudatus Kell	Do.
Lupinus formosus Greene	Do.
Lupinus hartwegii Lindl	Garden lupine (*6*).
Lupinus hirsutissimus Benth	Hairy lupine.
Lupinus latifolius Agardh	Lupine.
Lupinus laxiflorus Dougl. var. *calcaratus* (Kell.) C. P. Sm	Do.
Lupinus sparsiflorus Benth	Do.
Lupinus subvexus C. P. Sm	Do.
Lupinus succulentus Dougl	Common lupine.
Lupinus truncatus Nutt	Lupine.
Phaseolus limensis MacF	Lima (*3*).
Phaseolus lunatus L. var. *lunonanus* Bailey	Dwarf lima (*6*).
Phaseolus vulgaris L	Pole and bush bean (*14*).
Vigna sinensis (L.) Savi	Black-eyed cowpea (*5*).

CEYLON

Tephrosia candida DC	Vetch (*13*).

CUBA

Crotalaria incana L	Rattlebox (*20*).

DUTCH EAST INDIES (INDONESIA)

Glycine max (L.) Merr	Soybean (*21*).

FLORIDA (U.S.A.)

Crotalaria incana L	Rattlebox (*14*).
Pisum sativum L	Canada field pea (*14*).

See footnote at end of list.

GERMANY

Scientific name	*Common name* [1]
Lupinus sp	Lupine (2).

JAPAN

Phaseolus vulgaris L	Beans (*4*).
Pisum sp	Peas.

KANSAS (U.S.A.)

Phaseolus vulgaris L	Pole and bush bean (*14*).

MEXICO

Vicia faba L	Horsebean (*20*).

OKLAHOMA (U.S.A.)

Crotalaria sagittalis L	Common rattlebox (*14*).

PUERTO RICO

Cajanus cajan (L.) Millsp	Pigeonpea (*20*).

RUSSIA

Caragana arborescens Lam	Yellow acacia (*17*).
Glycine max (L.) Merr	Soybean (*17*).
Lens culinaris Medic	Lentils (*20*).
Pisum sp	Pea (*20*).
Robinia pseudo-acacia L	White acacia (*17*).

WASHINGTON (U.S.A.)

Pisum sativum L	Canada field pea (*14*).

[1] Host plants without reference numbers were identified by C. P. Smith, San José State College, San José, Calif.

Kind and Extent of Injury

The larva is the only stage of the lima-bean pod borer that injures lima beans. It feeds only on the immature bean, boring an entrance hole through the bean pod immediately after emerging from the egg. The entrance hole through the green pod heals and leaves little evidence that the pod is infested. On dry pods, under slight magnification, the hole is visible as a brownish sunken area about the size of a pinhead. When larvae enter pods less than 2 inches in length, a large percentage of these pods usually drop from the plant. The larvae either perish or emerge and enter other pods. If the pods do not drop, the larvae remain until mature, feeding on the immature beans. The entire bean is seldom consumed, but a small quantity of larval feeding renders it unfit for use as food or seed. (Figs. 1 and 2.)

The economic loss caused by larval feeding can be divided into four classes. First, yield is reduced from

TC–1564 AND TC–7505

FIGURE 1.—Larvae of lima-bean pod borer in pod, showing damage and characteristic frass: *A*, Natural size; *B*, enlarged

dropping of pods. The amount of this loss is difficult to determine, but in some mountainous areas where several larvae enter each pod it is impossible to get any pods to remain on the plants until late in the season, when low night temperatures prevent oviposition by the lima-bean pod borer adults. This loss is present in every field, but is much less in areas of lower pod borer population, where seldom more than one larva enters a pod.

Second, a direct loss results when beans are partially or entirely eaten by larvae so that they are unfit for sale as food or seed. A third and indirect loss caused by the lima-bean pod borer is the cost of removing damaged beans. The lima beans received at the warehouse must be cleaned to meet the requirements of the California Lima Bean Growers Association. This standard permits not more than 2 percent by weight of culls in beans sent to market. The damaged beans are removed with machinery and by hand. In an average season this cost amounts to $1 per 100 pounds of beans, and if the beans are exceptionally wormy, there is an additional charge of 75 cents for the second cleaning. Fourth, a reduction in market price and loss of sales result when larvae are present in green lima beans sold commercially. No records are available on the amount of this loss to the market operator.

TC–7501

FIGURE 2.—Lima beans damaged by lima-bean pod borer. Note pinhole injury in bean to left, caused by young larva that failed to develop.

Other Pod-Boring Insects

Several insects in the larval stage that feed on lima beans in pods may be confused with the lima-bean pod borer. In California the larval feeding damage to lima beans by the cotton square borer (*Strymon melinus* (Hübner)), the corn earworm (*Heliothis zea* (Boddie)), and the lima-bean pod borer is often difficult to distinguish, although the larvae are not similar and each has characteristic feeding habits by which the damage can be distinguished.

The cotton square borer adult has a wing expanse of 25 to 30 mm. The upper surface is a uniform mouse gray and the under surface is pale gray with an indistinct oblique row of orange and blue spots on the front wings and a more distinct row on the hind wings, which also have two red spots. Each hind wing terminates in two slender tails, one long and the other very short. Each wing has a submarginal row of small blue spots and a large red spot near the margin, which partially encloses a black spot to give it the appearance of an eye.

The mature larvae are 10 to 12 mm. in length and 6 to 7 mm. in width (fig. 3). They are a pale green and have a velvetlike appearance. They eat a hole through the bean pod and feed on the immature bean (fig. 4). The frass is voided on the exterior surface of the pod, since the larvae seldom entirely enter the pod. The feeding damage can be recognized by a round section eaten out of the side of the bean without any attached frass or webbing, in contrast to the tunnel-type feeding scars by the lima-bean pod borer with webbing and adhering frass. According to Essig (*5*), this species is distributed over most of the United States and is abundant throughout the western region.

The corn earworm adult is about 20 mm. long and has a wing expanse of 35 to 40 mm. It varies from light olive green to dark reddish brown. The mature larva is 35 to 40 mm. in length and very robust. It varies from pale green to dark brown, with characteristic lighter and darker markings. The larva is about three-fourths inch in length before it

FIGURE 3. Cotton square borer larva feeding on lima bean. (Courtesy of K. L. Middleham, Univ. of Calif., Riverside.)

FIGURE 4.—Lima beans damaged by cotton square borer. (Courtesy of K. L. Middleham, Univ. of Calif., Riverside.)

starts to feed on lima bean pods (fig. 5). It eats entrance holes about one-fourth inch in diameter and devours all or only part of the immature beans in a pod (fig. 6). The corn earworm larvae differ from the pod borer larvae in size and coloration. The damage is differentiated by lack of webbing and a larger amount of frass.

In Puerto Rico two other pod borers—*Maruca testulalis* (Geyer) and *Fundella pellucens* Zeller—are associated with the lima-bean pod borer on lima beans and wild host plants (Leonard and Mills (*12*), Wolcott (*22*), and Scott (*18*)). Wolcott (*22, p. 244*) described the adult of *M. testulalis* "as very active and, when not flying about, stands with wings outspread . . . . The forewings are chocolate brown, with a large white triangular spot on the front margin and the hind wings are silvery white with a brown spot at the corner more distant from the body. The larvae are generally of a creamy white and can most readily be distinguished by their spotted appearance, for they have four large black or dark gray spots on the back of nearly every segment." The larvae always make an exit hole in the pod through which they dispose of their frass.

From Wolcott's description this adult can be distinguished from adults of the lima-bean pod borer

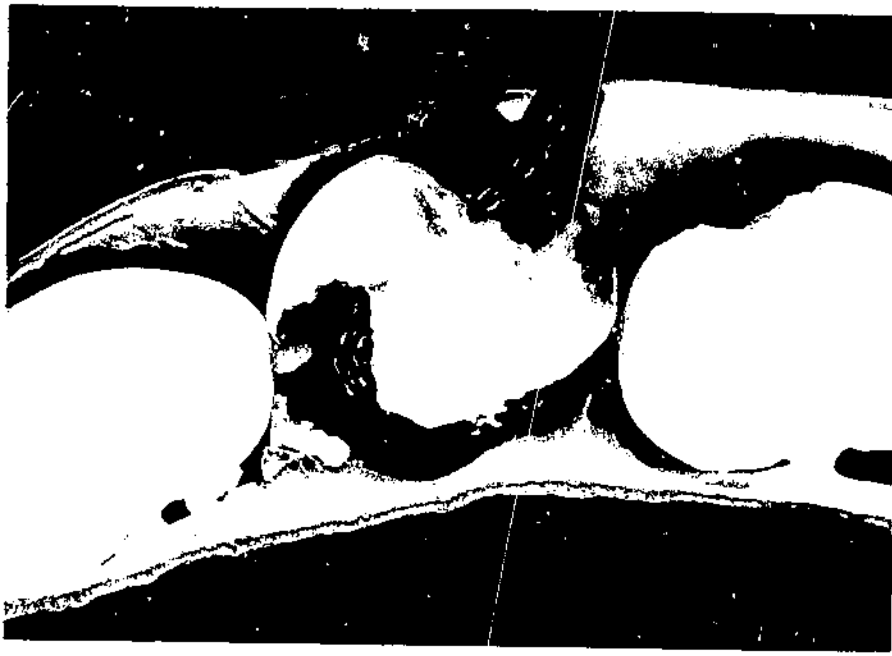
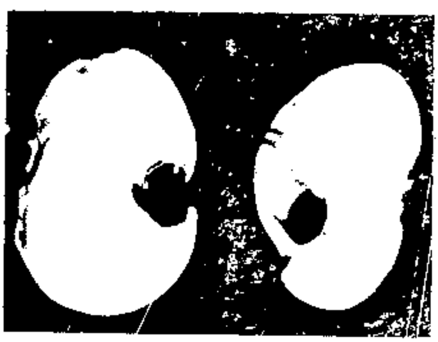


FIGURE 5.—Corn earworm larva feeding on lima beans. (Courtesy of K. L. Middleham, Univ. of Calif., Riverside.)



TC 7499

FIGURE 6. Lima beans damaged by corn earworm.

by its markings and outspread wings when at rest, in contrast to the tightly folded wings of the pod borer in similar position. The larvae of these two species, although approximately the same size, have different coloration and markings. The presence of frass on the outside of pods damaged by *M. testulalis* would distinguish it from injury by the pod borer, which always leaves frass in the pod. *M. testulalis* does not occur in the United States. Leonard and Mills (*12*) reported that this species seems to be generally distributed throughout the subtropical and tropical zones of both the New and Old Worlds. It is of economic importance as a pest of lima beans in Puerto Rico and Cuba.

The adults of *F. pellucens* and the pod borer are similar in that they both tightly fold their wings parallel to their body when at rest. Wolcott (*22*) reported the adult of *F. pellucens* as "characterless, inconspicuous greyish brown, with no marked or well defined pattern on the wings, but with the interesting habit of often keeping the ends of its antennae underneath its folded wings." The larvae of the pod borer and *F. pellucens*, according to Wolcott, are almost indistinguishable. According to Leonard and Mills, *F. pellucens* is known only in the West Indies.

Descriptions of Stages

Egg

The egg (fig. 7) is elliptical and approximately two-thirds mm. in length and one-third mm. in diameter. It is glistening white when first deposited and adheres securely to whatever it touches. The chorion is almost colorless and transparent. The developing embryo, observed through the eggshell, is first pink and later changes to gray just before the larva emerges.

Larva

The larva when first hatched is slightly over 1 mm. in length, with a white or cream-colored body and a black head. Mature larvae range from 12 to 15 mm. in length and from 2.5 to 3.5 mm. in diameter (fig. 8). The head is black or yellow with similar-colored mandibles. The dorsal surface of the body is reddish pink or tan. The ventral surface has three pairs of thoracic legs and five pairs of prolegs situated on the third, fourth, fifth, sixth, and ninth abdominal segments.

Pupa

The pupa (fig. 9, *A* and *B*) ranges from 8 to 10 mm. in length and from 2.5 to 3 mm. in width. It is light green when newly formed, later changing to light brown or amber. The pupal case shows the outline of

FIGURE 7.—Eggs of lima-bean pod borer on bean pod. (× 5.)

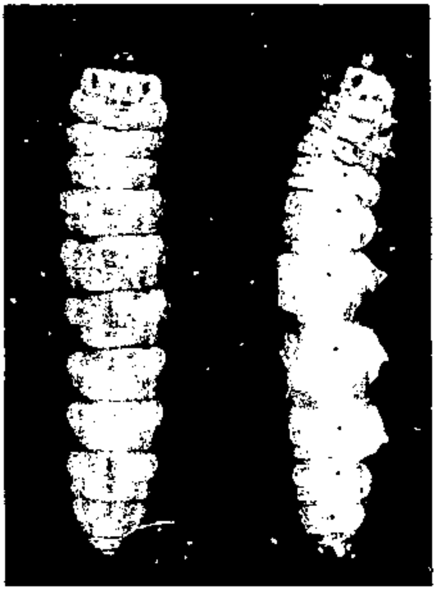


FIGURE 8.—Mature larvae of lima-bean pod borer. (× 5.) (Courtesy of K. L. Middleham, Univ. of Calif., Riverside.)

the wings from a side view, and on the ventral surface the proboscis, eyes, and head are outlined.

Adult

The adult of the lima-bean pod borer (fig. 10) is a gray moth. In a resting position it is from 15 to 20 mm. in length and from 3 to 4 mm. in width. With the wings spread it is from 24 to 26 mm. The forewings are marked with an orange band across the inner third of each wing and a white stripe along the outer margin from base to apex of each wing. The head appears to terminate in a snout, which is formed of two labial palpi, slightly less than 3 mm. in length and one shorter labial palpus. The hair-like antennae are approximately 7 mm. in length. The male may be distinguished from the female by an enlargement at the base of the antennae.

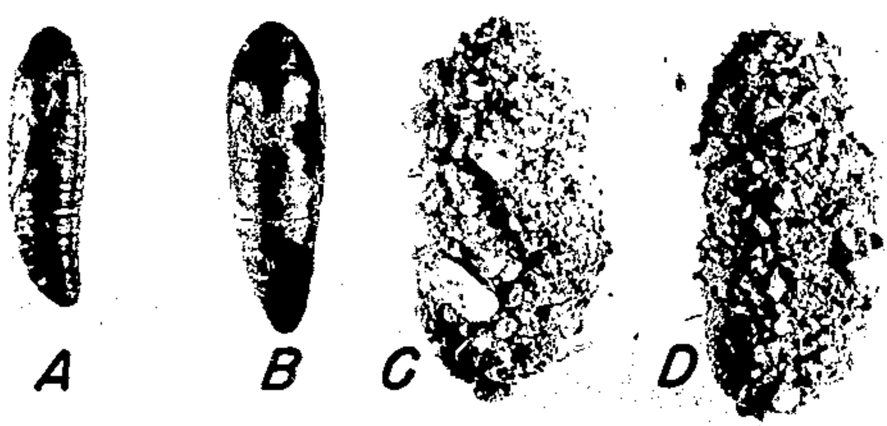


FIGURE 9.—Pupae (*A* and *B*) and cocoons (*C* and *D*) of lima-bean pod borer. (× 5.)

FIGURE 10.—Adult of lima-bean pod borer. (× 6.) (Courtesy of K. L. Middleham, Univ. of Calif., Riverside.)

Life-History Studies

The life-history studies were conducted in a screen-wire insectary, supplemented by field observations at Ventura, Calif., from 1931 to 1935. Observations were made on 2,318 adults for preoviposition, oviposition, and length of life. The length of the incubation period was determined for 24,000 eggs, and 631 larvae were reared to determine the length of the larval period. Because of natural mortality, only 1,960 records were obtained on the prepupal period, 1,804 records on the pupal period, and 9,672 records on the overwintering period. The temperature and relative humidity, determined with hygrothermographs in the insectary, were approximately identical with outdoor conditions.

To obtain oviposition records and eggs, a pair of newly emerged adults were placed in a cage and provided with food and pods of lima beans or lupines to stimulate oviposition. The cages were 8 inches square and 14 inches high, with a hinged glass door on one side and with the other sides and top covered with medium-weight muslin. The food was a 10-percent honey solution, placed in a watchglass, filled with strips of yucca pith. The strips of yucca pith floated in the food and provided a resting place for the feeding adults.

The eggs were deposited on immature lupine or lima bean pods on the floor of the cage. Each day the eggs were removed with a thin shaving of the pod and placed in small glass vials. When the eggs hatched, the larvae were transferred to immature lima beans and placed in individual vials. Fresh food was added as necessary until the larvae matured. The mature larvae were transferred to glass-covered cocooning racks (fig. 11), where they could be observed spinning cocoons, transforming to pupae, and emerging as adults.

Incubation Period

A summary of the incubation period for 24,000 eggs deposited from March to November 1931–35, inclusive, is given in table 1. These records show that the duration of the incubation period varies with the temperature. For instance, in 1931 when temperatures averaged 71° F. in July and August, the minimum period was only 5 days and the seasonal average was 10.9 days, which was the shortest recorded during the 5-year period of these studies. The maximum incubation period, 33 days, occurred in April 1933, when temperatures averaged 56°. This year also had the lowest temperatures and the longest seasonal incubation period, 18.9 days. The incubation period for all eggs under observation averaged 15.4 days. A total of 69 percent of the eggs hatched. Hatching usually occurs from 10 a.m. to 2 p.m. The larva emerges through a circular hole cut in the free end of the eggshell.

Larval Period

The duration of the larval period varies with the temperature and the kind of food. The larvae, of course, develop more rapidly on lima beans during June, July, and August. The minimum period was 13 days for a larva hatching in July 1931, and the maximum 65 days was for a larva hatching in April 1932, as shown in table 2. The average duration of the larval period for the 631 individuals under observation was 35 days.

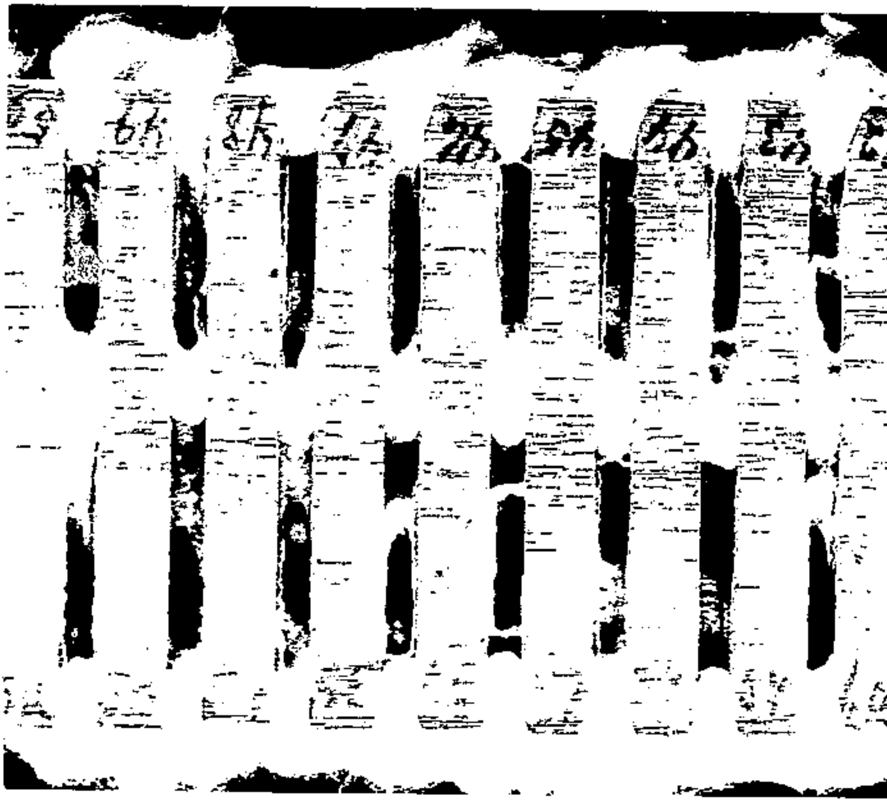


FIGURE 11.—Glass-covered cocooning rack used in life-history studies to determine length of prepupal and pupal periods.

The newly hatched larvae are positively phototropic and, therefore, always crawl upward on host plants toward stronger light. This reaction aids them in locating pods borne on the outer periphery of wild host plants and some varieties of lima beans. They prefer immature pods, probably because of easier entrance to the beans. When suitable pods are located, they immediately bore an entrance hole to the beans, where they feed until mature. Larval entrance holes heal quickly and leave no exterior indication that the pod contains a larva. The larvae, when mature, eat an exit hole through the pod and drop to the soil.

Prepupal and Pupal Periods

The mature larva, after leaving the pod, enters the soil to a depth ranging from one-half to 2 inches and spins a cocoon (fig. 9, *C* and *D*). The length of time it may remain as an inactive larva or prepupa in its cocoon depends on the time of year the larva matures, as shown in table 3. Those that mature from May to August will transform to pupae in from 8 to 24 days, but practically all that mature after August will pass the winter in the mature larval stage. When the temperature during the spring and summer is

744-014 O—65——3

Table 1.—*Duration of incubation period of eggs of lima-bean pod borer in outdoor insectary and temperatures during months shown, Ventura, Calif., 1931–35*

Year	Total eggs	Incubation period											Temperature range
		March	April	May	June	July	August	September	October	November	Average	Range	
	Number	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*° F.*
1931	6,643	------	15.6	13.2	9.4	6.7	7.2	9.8	14.6	------	10.9	5–20	63–71
1932	6,392	14.8	19.5	15.9	14.1	12.9	13.1	14.3	14.7	------	14.9	8–29	58–64
1933	4,627	------	25.9	22.6	17.6	13.1	14.8	18.3	17.8	21.1	18.9	9–33	56–64
1934	3,648	16.7	17.3	12.7	13.7	10.0	12.1	12.1	16.8	------	13.9	7–23	60–66
1935	2,690	------	18.2	19.6	14.3	12.2	10.8	11.8	17.2	------	14.9	8–24	57–69
Total or average	24,000	15.7	19.3	16.8	13.8	11.0	11.6	13.3	16.2	21.1	15.4	5–33	56–71

Table 2.—*Duration of larval period of lima-bean pod borer in outdoor insectary and temperatures during months shown, Ventura, Calif., 1931–35*

Year	Total larvae	Larval period									Temperature range
		April	May	June	July	August	September	October	Average	Range	
	Number	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*° F.*
1931	190	34	35	18	20	21	27	39	28	13–49	63–71
1932	100	54	40	35	33	38	44	36	40	20–65	58–64
1933	160	44	43	38	33	--------	--------	--------	40	26–58	54–64
1934	122	36	37	33	34	35	30	--------	34	26–48	59–66
1935	59	--------	--------	29	27	28	34	41	32	23–41	63–69
Total or average	631	42	39	31	29	31	34	39	35	13–65	54–71

TABLE 3.—*Duration of prepupal period of lima-bean pod borer in outdoor insectary during months shown, Ventura, Calif., 1931–35*

Month	Total prepupae	Prepupal period	
		Average	Range
	Number	*Days*	*Days*
April	23	47	9–84
May	224	19	14–24
June	426	15	10–22
July	845	11	9–14
August	412	11	8–14
September	30	15	13–22
Total or average	1,960	20	8–84

below normal, some larvae will remain inactive for two winters and one summer before transforming to pupae.

The pupal period is passed in the cocoon formed by the larva in the soil near the host plant. The length of the pupal period varies with the season of the year and with the temperature. Low temperatures during the spring and fall increase the length of the pupal period, whereas higher temperatures during the summer decrease it. The minimum pupal period for the 1,804 individuals observed during 1931–35 was 16 days, the maximum was 101 days, and the average was 36 days, as shown in table 4.

Adult Period

Emergence From Pupa

The first indication of the emergence of an adult from the pupa is a darkening of the pupal case, caused by the change from pupa to adult. The moth emerges from the pupal case through an opening in the dorsal region and crawls through a trap door in the cocoon. It next kicks and digs its way to the soil surface, crawls on some upright object, and spreads and dries its wings. The moth emerges in the early morning usually before 9 o'clock. When its wings are dry, it seeks cover on the undersurface of leaves and remains inactive until night. Moths are strong fliers and capable of migrating long distances to reach their host plants.

Mating

The newly emerged adults migrate to and feed on the nectar of flowering plants. Males apparently locate the females while feeding, and after a preliminary courtship in the air, they settle on a plant to mate. Adults in cages mate several times, but the females that mate only once deposit fertile eggs the remainder of their lives.

Preoviposition Period

The length of the preoviposition period, or the elapsed time from adult emergence to first oviposition, may vary from 1 to 44 days, as shown in table 5. There is some variation with individual moths, but in general the effect of temperature on activity of the moth controls the length of this period. Long preoviposition periods usually occur during March and April, when the average daily temperature is lower than from May to October.

TABLE 4.—*Duration of pupal period of lima-bean pod borer in outdoor insectary and temperatures during months shown, Ventura, Calif., 1931–35*

Year	Total pupae	Pupal period								Temperature range
		April	May	June	July	August	September	Average	Range	
	Number	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*° F.*
1931	171	30	29	21	18	27	33	26	16–47	63–71
1932 [1]	414	----	45	39	39	40	44	41	27–69	62–63
1933	377	----	----	38	42	53	49	46	18–67	61–63
1934	573	----	37	31	30	41	51	38	22–101	62–66
1935	269	----	----	35	30	37	46	37	20–56	64–67
Total or average	1,804	30	37	33	32	40	45	36	16–101	61–71

[1] Two larvae transformed to pupae between Feb. 15 and 22 and remained in the pupal stage 49 days.

TABLE 5.—*Preoviposition period and oviposition records of lima-bean pod borer in outdoor insectary and temperatures, Ventura, Calif., 1931–35*

Year	Period of emergence or egg deposition	Females	Length of preoviposition period			Eggs deposited			Average temperature
			Maximum	Minimum	Average	Maximum	Minimum	Average	
		Number	*Days*	*Days*	*Days*	*Number*	*Number*	*Number*	° *F.*
1931	Mar. 11–Sept. 16	37	28	3	11	121	1	26	67
1932	Mar. 7–Oct. 3	80	38	2	9	232	1	58	62
1933	Mar. 13–Nov. 27	68	30	2	12	259	1	45	60
1934	Feb. 26–Oct. 22	99	44	1	12	143	1	17	63
1935	Feb. 25–Nov. 11	91	44	1	10	167	1	21	62
Total or average	Mar. 7–Nov. 27	375	37	1.8	11	184	1	33	63

Oviposition

The lima-bean pod borer deposits its eggs during the night on pods, flower bracts, or stems of the host plants. Low temperature retards activity and oviposition, but it also prolongs life. When ovipositing, the female curves the abdomen forward beneath the body, extends the slender ovipositor, and deposits the eggs singly or in groups of from 2 to 12 eggs.

A summary of the oviposition records for 375 females shows that the eggs deposited ranged from 1 to 259 and averaged 33 (table 5).

Longevity

The data on longevity include the length of life of adults from time of emergence until death, as shown in table 6. Adult longevity varies with the individual and the prevailing temperature when emergence occurs. Their life span is longest during periods of low temperature in March, April, October, and November and shortest in the warmer interval from May to September. In these studies the adults emerged between February 18 and November 27 and lived from 1 to 69 days; the average period was 19 days. There was no difference in the length of life of males and females.

Overwintering

Lima-bean pod borers pass the winter as mature larvae in their cocoons. During this period they can be found in the soil of lima bean fields and under perennial lupine bushes. The length of the overwintering period varies, depending on the time of year the larvae mature and the weather conditions in the spring, which may hasten or retard adult emergence.

Table 7 shows the length of the overwintering period for 4,287 larvae that survived overwintering in three different media from 1930 to 1937. The larvae that were overwintered in cocooning racks and sand jars were kept in a screen-wire insectary. The larvae that were overwintered outdoors were in soil in screen-wire cages and exposed to conditions prevailing at Ventura during this period. The length of the overwintering period under insectary conditions averaged 7 months for larvae confined in co-

TABLE 6.—*Longevity of adults of lima-bean pod borer in outdoor insectary and temperatures, Ventura, Calif., 1931–35*

Year	Period of emergence	Adults	Longevity			Average temperature
			Maximum	Minimum	Average	
		Number	*Days*	*Days*	*Days*	*° F.*
1931	Mar. 4–Nov. 11	197	61	2	21	66
1932	Mar. 7–Nov. 14	276	48	2	20	62
1933	Mar. 13–Nov. 27	629	69	1	20	60
1934	Feb. 26–Nov. 26	444	52	1	16	62
1935	Feb. 18–Nov. 11	397	67	1	19	62
Total or average	Mar. 4–Nov. 27	1, 943	59	1. 4	19	62

cooning racks to 7.2 months for larvae confined in sand. Outdoors the period varied from 5 to 9.3 months and averaged 7 months. The place of overwintering did not affect the length of the period, but a greater percentage survived when overwintered indoors, as shown in table 8.

The maximum overwintering period of 16.9 months was for a larva that entered hibernation in the fall of 1932 and did not emerge as an adult until the spring of 1934. This

TABLE 7.—*Time of emergence and duration of overwintering period of larvae of lima-bean pod borer reared under different conditions, Ventura, Calif., 1930–37*

Month emerged	Cocooning racks in insectary		Sand jars in insectary		Outdoor cages	
	Larvae emerged	Duration of overwintering period	Larvae emerged	Duration of overwintering period	Larvae emerged	Duration of overwintering period
	Number	*Months*	*Number*	*Months*	*Number*	*Months*
January	4	2. 8	3	3. 0		
February	11	4. 8	18	3. 4		
March	58	4. 1	29	6. 2	1	5. 0
April	108	5. 8	126	6. 5	165	6. 3
May	571	6. 9	857	7. 3	280	6. 8
June	365	8. 5	754	8. 1	47	7. 6
July	201	9. 1	533	9. 1	6	9. 3
August	6	10. 5	88	10. 3		
September	1	10. 7	55	10. 7		
Total or average	1, 325	7. 0	2, 463	7. 2	499	7. 0

TABLE 8.—*Survival of overwintering larvae of lima-bean pod borer reared under different conditions, Ventura, Calif., 1930–37*

Year	Cocooning racks in insectary		Sand jars in insectary		Outdoor cages	
	Larvae observed	Survival	Larvae observed	Survival	Larvae observed	Survival
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1930–31	118	64. 4			935	5. 0
1931–32	385	66. 2	637	70. 6	1, 523	11. 2
1932–33	573	50. 8	1, 139	70. 0	883	23. 1
1933–34	257	62. 3	163	66. 9		
1934–35	572	46. 7	502	75. 3	200	12. 0
1935–36	421	65. 6	364	88. 2	350	15. 1
1936–37			650	62. 9		
Total or average	2, 326	59. 3	3, 455	72. 3	3, 891	13. 3

prolongation of the overwintering period may have been due to the unusually low temperature prevailing during the spring and summer of 1933, since this was the only instance when this phenomenon was observed during 1930–37.

Total Life Cycle

The total life cycle from egg to adult under insectary conditions in southern California during 1931–35 ranged from 2 to 9.8 months and averaged 5.5, as shown in table 9. The complete life cycle was shorter from April to August when there was no overwintering period. Temperature was a factor in lengthening or shortening this cycle, since low temperature retards all the developmental stages and therefore lengthens the complete life cycle.

TABLE 9.—*Average duration of egg-to-adult period of lima-bean pod borer in outdoor insectary and temperatures during months shown, Ventura, Calif., 1931–35*

Month eggs deposited	Amount of eggs deposited	Duration of egg-to-adult period	Average temperature
	Number	*Months*	*° F.*
March	42	4.1	61
April	79	3.5	63
May	121	3.2	64
June	105	3.9	64
July	92	3.4	64
August	88	8.3	60
September	30	8.8	58
October	4	8.5	56
Total or average	561	5.5	61

Seasonal History

In southern California the lima-bean pod borer completes one brood on annual wild host plants, primarily on lupines, wild peas, and locoweeds, from March to June. From two to four broods develop on lima beans and perennial lupines from June to December. The number of broods that develop each year is affected by prevailing weather conditions, since below-normal temperatures retard and above-normal temperatures accelerate growth of the developmental stages.

The pod borer overwinters as a mature larva in a cocoon in the soil near the host plant on which it developed. Observations made of several thousand larvae over a 5-year period showed that all those maturing before July did not overwinter. Of those that mature in July, an average of 8 percent overwinter, in August 53 percent, in September 89 percent, and all that mature later overwinter. Larvae overwinter in the field the entire year, since some start in July and not all emerge as adults until October of the following year.

Some prepupae are in the field every month, but the largest number occur from overwintered larvae from February to July and from the broods developed on lupines and lima beans from April to November (fig. 12). The greatest number would be in the field during July with some variation, depending on weather conditions due to seasonal variation.

Emergence of adults from overwintered larvae starts in January and continues into September (table 7). Although adults emerge over a long period, most egress in May and June. Adults that emerge from January to May migrate from old bean fields and oviposit on wild host plants, whereas those that egress from June to October oviposit on lima beans (fig. 12).

The adults from the brood that develop on annual lupines emerge and migrate to the dry lima bean crop from the last part of June to August (fig. 12). Adults are in the field each month of the year, but they are present in greatest numbers during August and September.

In southern California egg deposition begins on annual lupines in March and continues through May. Eggs are deposited on perennial lupines from May to November. Oviposition occurs on the dry lima bean crop mainly during July, August, and into September on late-planted beans.

Pod borer larvae are present on annual and perennial lupines from March to December and on lima bean crops from July to October. They are most abundant on both hosts from August to October.

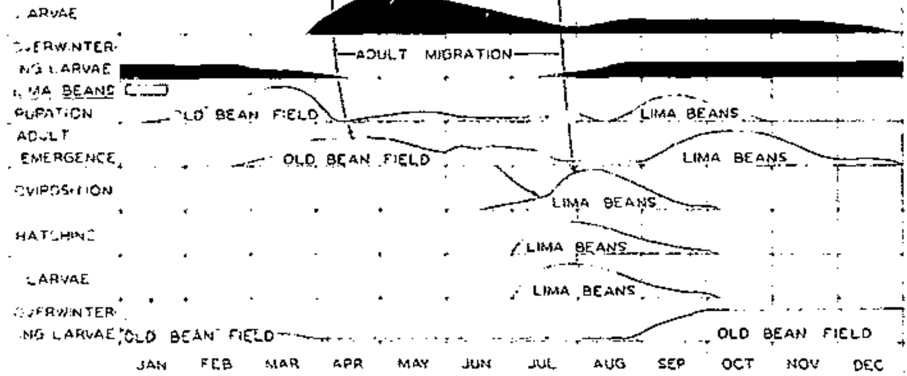


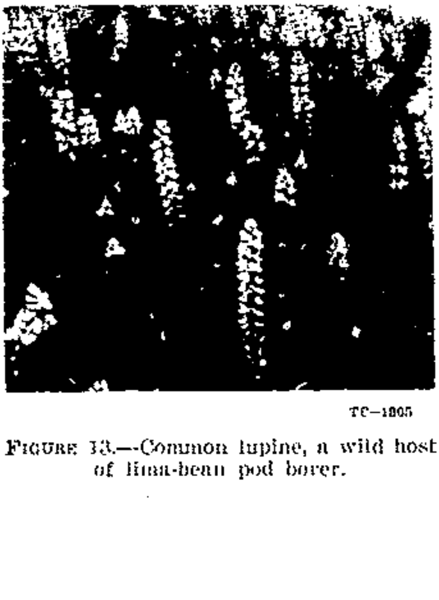
FIGURE 12.—Seasonal development of lima-bean pod borer, showing relationship between infestation in wild host plants, principally lupines, and in lima beans. (Overwintering larvae are in prepupal stage.)

Ecological Relationship Between Infestation in Wild and Cultivated Hosts

The relationship between the lima-bean pod borer infestation in wild and cultivated host plants can be correlated with the seasonal life history and habits of the insect. Pod borers overwinter as mature larvae in cocoons in the soil under lupine plants or in the soil of the old bean field from the time they mature in the fall until they transform and emerge as adults from January to October the following year. In southern California no lima bean plants are living from November to May on which adults can oviposit; therefore, those borers that overwinter in the old bean fields migrate to nearby wild host plants.

The two most economically important wild host plants in this area are the common lupine (fig. 13), an annual, and the tree lupine (fig. 14), a perennial. The common lupine grows in all the coastal counties of southern California on uncultivated land adjacent to bean fields and in the foothills and mountain areas. It sets pods and is infested with pod borer larvae from February to June, with the heaviest infestation in April. The tree lupine grows along the coast in the sand dunes and uncultivated areas. It is not so abundant as the common lupine, but has a heavy pod borer infestation from June to November.

Lima beans planted in April or May set pods in July and are harvested in September, October, or later, depending on the time of planting. The larvae that mature on these lima beans pass the winter in the soil of the old bean field and larvae that mature on perennial lupines late in the fall pass the winter in the soil under the lupine plants.



TC–1805

FIGURE 13.—Common lupine, a wild host of lima-bean pod borer.

TC–7514

FIGURE 14.—Tree lupine, a wild host of lima-bean pod borer.

The degree of infestation varies with the distance between wild and cultivated hosts and the variety of lima beans. It is obvious that bean plants located near wild host plants would have a heavier infestation than plants several miles away, since a larger number of migrating adults would stop on the nearest beans to oviposit.

In the same locality where environmental factors are apparently the same, there are always more wormy pods on lima bean varieties of the bush type, which set pods high on the plant, than on vine varieties with low pod set. This difference of infestation is due to the habit of the newly hatched positively phototropic larvae to always crawl upward on the plant in search of a pod. This reaction of the larvae serves them well in locating pods on wild host plants.

Natural Enemies

The lima-bean pod borer has very few natural enemies in this country. In California the following species were reared: *Bracon tychii* (Muesebeck), *Scambus* (*Scambus*) *aplopappi* (Ashmead), *Cryptus tejonensis* Cresson, *Trichomma maceratum* (Cresson), *Erynnia tortricis* (Coquillett), and two species of *Angitia* from pod borer larvae collected in pods of wild host plants. These parasites all attack the larvae, but their combined efforts rarely kill over 10 percent.

In addition to these parasites, Flanders (*6*) recorded rearing *Bracon gelechiae* Ashmead, *Eurytoma* sp. (near *tylodermatis* Ashmead), and *Zatropis tortricidis* Crawford from pod borer larvae in California. Hyslop (*10*) reported rearing two species of parasites—*Apanteles etiellae* Viereck and *Bracon hyslopi* (Viereck)—from pod borer larvae at Pullman, Wash.

H. L. Parker, in unpublished notes, recorded rearing the following parasites from pod borer larvae collected in France and Hungary:

Angitia sp. (probably *Horogenes* sp.)
Anisopteromalus sp.
Ascogaster quadridentata Wesmael
Bracon pectoralis Wesmael
Bracon piger Wesmael
Campoplex tricoloripes (Schmiedeknecht)
Chelonus inanitus (L.)
Cyrtoptyx lichtensteini (Masi)
Elasmus atratus Howard
Epiurus sp., "B" (probably *Scambus* sp.)
Eurytoma appendigaster (Swederus)
Ichneumon ignotus Fonscolombe
Phanerotoma planifrons (Nees)
Pimpla punctiventris Thomson
Pristomerus vulnerator (Panzer)
Sinophorus fuscicarpus (Thomson)
Tachinid sp., "B"
Tachinid sp., "C"
Zenillia roseanae Ball & Beamer synonym of *Pseudoperichaeta insidiosa* (Robineau-Desvoidy)

In Russia the pod borer attacks soybeans, and from there the following parasites are reported:

Agrypon stenostigma Thomson (*16*)
Eupelmus urozonus Dalman (*15*)
Euplectrus bicolor (Swederus) (*15*)
Omorgus fusciplica Thomson (*16*)
Pimpla nigriscaposa Thomson (*16*)
Pimpla ventricosa Tschek (*15*)

Pod Borer Parasites Introduced and Reared (1935–39)

The injury to lima beans by the pod borer is caused by progeny of a brood reared on wild host plants from March to June. For this reason parasitic forms were imported for colonization on pod borer-infested wild host plants to reduce the number of pod borer adults that migrate from wild to cultivated host plants. In 1935, the strawberry leaf roller parasite (*Macrocentrus ancylivorus* Rohwer) was introduced and successfully reared in the laboratory on pod borer larvae. This parasite also overwintered in pod borer larvae and emerged the following spring at approximately the same time as pod borer adults. A small colony of these adults was released on pod borer-infested lupines in 1935, but none of these parasites were recovered from weekly collections of pods in the Ventura area for the next 4 years.

In 1936, 300 *M. ancylivorus* adults were received from the parasite laboratory of the former Bureau of Entomology and Plant Quarantine at Moorestown, N.J. Two hundred and fifty of these parasites were released on pod borer-infested tree lupines. The remainder of the shipment—25 males and 25 females—were placed in a large screen-wire cage in the field, in which were growing lima beans infested with pod borer larvae. The bean pods from the plants in the cage were all picked before the pod borer larvae emerged and were placed in emergence racks to catch the larvae as they matured. No parasites emerged from these larvae.

In 1936, 197 adults of *Bracon piger* and 493 adults of *Phanerotoma planifrons* were received from H. L. Parker, who had collected them in France. These parasites were released on pod borer-infested lupines. Lupine pods from the two areas where these parasites were released were collected at weekly intervals during the year, but no parasites were recovered.

In 1937, 3,195 *P. planifrons*, 314 *Bracon pectoralis*, and 1,142 *B. piger* adults were received and liberated on pod borer-infested tree lupines. This host plant grows on wasteland and is not disturbed from year to year. Pods were collected from these plants at weekly intervals, from June 11 to December 24, but no imported parasites were recovered. The pod borer infestation in these pods ranged from 20 to 80 percent, with up to 11 percent parasitized by native parasites.

During 1938, 28,404 lima-bean pod borer parasites were received from the Foreign Parasite Laboratory at Saint-Cloud, France. These parasites consisted of 1,209 *B. piger*, 1,535 *B. pectoralis*, 753 *Cyrtoptyx lichtensteini*, and 24,818 *P. planifrons* adults. All were liberated with the exception of 200 *B. piger*, 55 *B. pectoralis*, 226 *C. lichtensteini*, and 2,254 *P. planifrons* adults, which were used for breeding stock. The first three species oviposit in larvae; therefore, mature larvae of *Anagasta kühniella* (Zeller) in cocoons were exposed to them. Females of each species were observed probing the larvae with their ovipositors. The larvae exposed to *B. piger* and *B. pectoralis* left their cocoons and died a few days after being exposed. The experimental rearing with *C. lichtensteini* was successful and adult parasites emerged from the *A. kühniella* larvae. *B. piger* was recovered in 1938 from pod borer larvae in tree lupine pods. By the end of the season it was parasitizing 20 percent of the larvae.

P. planifrons oviposits in the host egg but hatches in the larvae. In 1938, from July to November, 402,000 *A. kühniella* eggs were exposed to *P. planifrons*. Using the system developed by Parker and Smith of the Foreign Parasite Laboratory in France, 15,800 *P. planifrons* specimens were reared. These were used for breeding stock with the exception of 3,000, which were released in San Diego and Santa Barbara Counties on late lima beans. The undeveloped parasitized larvae were overwintered in cold storage to be released on pod borer-infested wild host plants in the spring of 1939.

The rearing of *P. planifrons* was continued in 1939. A new species of pod borer paracite, *Chelonus inanitus*, was received from France and laboratory reared by the same technique as for *P. planifrons*, with the exception of holding the eggs 48 hours before they were exposed. During the year, 29,454 *C. inanitus* and 7,850 *P. planifrons* adults were reared. These adults were released on pod borer-infested wild host plants in Ventura and Santa Barbara Counties and on late lima beans in San Diego County. The parasites were released on perennial wild host plants located adjacent to lima bean fields. In 1942, Cecil [4] reported that small numbers of both parasites were recovered in pod borer larvae collected in bean fields adjacent to Ventura.

Between July and September 1959, Benjamin Puttler of the Insect Identification and Parasite Introduction Branch, Entomology Research Division, made surveys of bean fields and native lupines in the sand-dune area near Ventura to determine the status of the parasites *B. piger*, *P. planifrons*, and *C. inanitus*, which had been imported from Europe during 1936–38 and released in southern California. Puttler found the lupine pods heavily infested with pod borer larvae, but no pod borer infestations in the commerical lima bean fields adjacent. None of these parasites were recovered in this survey.

Cultural Control

Field Plowing

Since lima-bean pod borers overwinter as mature larvae at a depth of one-half to 2 inches below the surface of the soil in bean fields, it is possible that some control of this pest could be achieved by a cultural practice that would cover these larvae to a sufficient depth to prevent emergence of resulting adults. With the ordinary cultural methods, the seedbed for beans grown without irrigation is only given a shallow cultivation in the spring with disk and harrow and seldom plowed. On land that is irrigated, the seedbed is plowed to a depth of 8 to 14 inches or deeper in the fall and then disked and harrowed in the spring.

To determine whether covering mature larvae under several inches of soil would prevent emergence of adults in the spring, an experiment was started in the fall of 1936 and in 1937. Mature larvae in cocoons were buried at depths of 2, 4, and 6 inches in two types of soil in which lima beans are grown in the Ventura area. Yolo fine sandy loam is a loose type of soil under almost all conditions, whereas Yolo sandy loam is heavy soil and packs when worked wet. One hundred larvae

[4] See footnote 1, p. 1.

were buried at each depth each year in the two types of soil. For a check, an equal number of mature larvae were allowed to enter the soil and spin cocoons at whatever depth desired. An adult unable to fly after emerging through any depth of soil or from the checks was classified as deformed. In view of the similarity of the results each season, the data were combined and are presented in table 10.

Judging from these experiments, a large percentage of adults from overwintered larvae can be prevented from emerging by covering the larvae with 6 or more inches of soil. It is noted that the percentage of deformed adults increased with the depth larvae were buried, and this was especially true in the heavier soil. Deformed wings are undoubtedly caused by delay in spreading and drying of wings after adults emerge from the pupal cases. Examination of the soil after completion of each experiment showed that approximately the same number of adults emerged in each type of soil and that the difference in number of those that reach the surface is due to their physical inability to force themselves to the surface after emerging from the pupal cases.

These experiments indicate that fall plowing of old bean fields to a depth of 8 inches or more would be of value in reducing the emergence of adults from overwintered larvae. This practice would improve the physical condition of the soil for absorption of winter rains, and erosion could be prevented on hillsides by plowing in contours and by planting a winter cover crop. The cover crop would also increase soil fertility.

Time of Planting

Inspection of pods in early- and late-planted bean fields has shown that early-planted beans have less pod borer damage than late-planted beans. This is to be expected, because the later plantings would be subjected to the second brood of ovipositing moths and those migrating from wild hosts (fig. 12).

To obtain definite information on the effect of time of planting on the degree of injury, lima beans were planted at 15-day intervals from April 1 until May 30 in 1960 and from April 1 until June 15 in 1961 and 1962. The May 30 planting in 1960 and the June 15 planting in 1961 did not produce sufficient pods for inspection. Plots were two rows wide and 58 feet long and replicated five times in a randomized block. When the beans were mature, dry pods in each planting were removed,

TABLE 10.—*Emergence of adults of lima-bean pod borer from cocoons buried at different depths in two types of soil, Ventura, Calif., 1936–38*

Depth buried (inches)	Yolo fine sandy loam		Yolo sandy loam	
	Adults emerged	Adults deformed	Adults emerged	Adults deformed
	Number	*Percent*	*Number*	*Percent*
2	143	4.9	113	16.2
4	106	8.5	93	24.5
6	144	31.4	37	58.3
Check	148	2.7	148	2.7

and 500, 750, and 500 pods for each year, respectively, were examined for pod borer injury. No insecticides were used on these beans.

In 1960, a year in which pod borers were especially destructive, excessive injury (52 to 71 percent) occurred in early as well as in late bean plantings, as shown in table 11. In contrast, in 1961, when pod borers were less injurious, only 6- and 3-percent injury occurred in the April 15 and May 1 plantings as compared with 62 percent in the May 30 planting. Pod damage in 1962, when pod borers were extremely destructive, followed the pattern shown in 1961. Injury ranged from a low of 14- and 13-percent in the April 1 and 15 plantings to a high of 94- and 95-percent infested pods in the May 30 and June 15 plantings.

In 1931, Cecil planted baby limas (Henderson bush) and large limas (Ventura) on successive dates to determine the degree of infestation. The results show that the early-planted beans had considerably less pod borer injury than the late-planted beans, as given in table 12.

It is obvious from these studies that pod borer injury to lima beans can be reduced by planting early in April. Years ago it was impracticable to plant early in cold soil because of excessive bean rot. Now with fungicide-treated seed available, good stands are obtained from plantings made in early April.

TABLE 11.—*Effect of time of planting on degree of pod borer injury to Ventura lima bean pods, South Coast Field Station, Irvine, Calif., 1960–62*

Date planted	Date harvested	Pods damaged by pod borer		
		1960	1961	1962
		Percent	*Percent*	*Percent*
Apr. 1	Aug. 1	67	15	14
15	Aug. 15	71	6	13
May 1	Sept. 1	52	3	43
16	Sept. 15	57	15	55
30	Oct. 1		62	94
June 15	Oct. 1			95

TABLE 12.—*Effect of time of planting on degree of pod borer injury to 2 lima bean varieties, Ventura, Calif., 1931*

Date planted	Henderson bush		Ventura	
	Date matured	Wormy pods	Date matured	Wormy pods
		Percent		*Percent*
May 15	Aug. 20	5	Sept. 20	4
June 5	Sept. 10	8	Oct. 5	40
July 7	Oct. 12	58	Oct. 31	91

Control With Traps

Bait Traps

The adult pod borer can locate host plants in its migrations between wild and cultivated hosts, possibly by smell, since the adults feed on the nectar in the flowers. In an attempt to determine what odor would attract adults, the following chemical oils were tested in the field between 1934 and 1936: Star anise, mustard, lavender, rosemary, carvone, geraniol, white thyme, peppermint, bitter almonds, sweet birch, banana, caraway, celery seed, cedarwood, cloves, coriander, fennel seed, juniper berries, lemongrass, Messina lemon, nutmeg, pennyroyal, geranium, sassafras, sandalwood, sweet basil, and wormseed; also, anisic aldehyde, amyl benzoate, nicotine sulfate, amyl and methyl salicylate, cinnamic aldehyde, and benzaldehyde.

In addition to these chemicals, brews made from lima beans and from plants, pods, and flowers of lupines were used. The chemicals were tested at concentrations of 0.025, 0.050, 0.075, and 0.100 percent in a 10-percent sugar solution. Water and a 10-percent sugar solution was used as checks in the same type of container used for testing the chemicals. The baits were exposed in granite pudding pans, 8½ inches in diameter and 3 inches in depth. These pans were placed on racks, 12 inches above the soil surface, or approximately the same height as the bean plants. The bait pans were located along the margin of a large field of lima beans and between the bean field and wild host plants in order to attract adults migrating from wild to cultivated host plants. The bait traps remained in the field from the time the beans started blooming on July 10 until harvested the first part of September. During the 3 years this experiment was in operation, none of the chemicals tested were sufficiently attractive to be of any value as a control remedy.

Light Traps

Laboratory tests showed that the pod borer was positively phototropic, with a high selectivity for monochromatic blue. In field tests conducted for 3 years the pod borer was attracted to colored light and killed with an electrocuting device (fig. 15). The results in 1936 indicated that light traps might be a means of pod borer control. How-

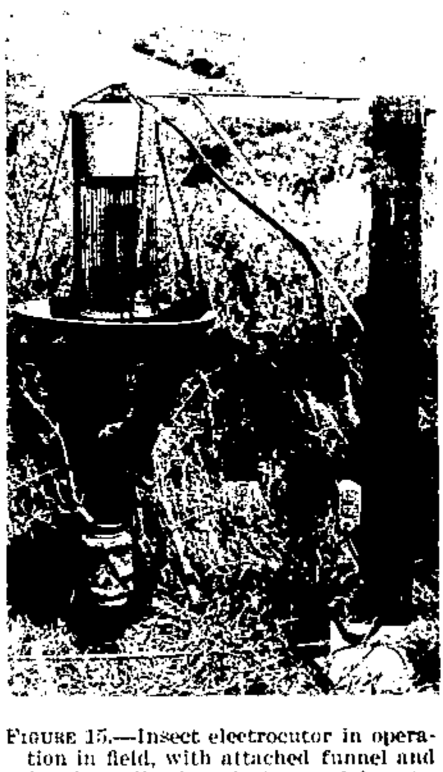


FIGURE 15.—Insect electrocutor in operation in field, with attached funnel and jar for collecting electrocuted insects.

ever, large field tests in 1937 and 1938, with one trap to an acre in 15- and 23-acre fields, gave unsatisfactory results on the basis of number of adults caught per light.

The pod borer population was small in both seasons owing to unfavorable weather conditions. The cost of installing light traps, the high ratio of males to females, the small number of moths captured, and the uncertainty of infestation made this method of control impracticable.

Control With Insecticides

Procedure

Insecticides were tested on two types of lima beans grown in southern California. The Ventura or "vining" variety is grown commercially for dry beans. The Fordhook or bush variety is grown principally for green beans and for seed. Both types were planted in rows 30 inches apart from April 10 to July 1. When there is inadequate rainfall during the winter, fields planted to dry beans are generally preirrigated in February or March and the crop may be furrow-irrigated once in July or August. Fields planted to Fordhook beans may also be preirrigated and the crop also may be irrigated two or three times or more, depending on the soil type and climatic conditions. Fordhook beans mature in 90 to 110 days, whereas the dry-bean crop requires from 120 days or longer to reach maturity.

Experiments were conducted in plots of varying size in growers' bean fields in Orange County and at the University of California, South Coast Field Station near Irvine. Large-plot experiments were generally conducted in dry-bean fields in plots 4 to 16 rows wide by 110 feet or longer. Experiments in small plots were usually conducted in plantings of Fordhook beans in single-row plots 50 to 60 feet long. All plots were arranged in randomized blocks with five, six, or eight replicates.

In small plots, emulsion sprays were applied to both sides of the row with a knapsack sprayer at the rate of 30 gallons per acre for the first application and upward to 62 gallons for the succeeding ones. Dusts were applied with rotary hand dusters at from 30 to 40 pounds per acre of the diluted dust. In large plots, sprays were applied at the rate of 25 to 50 gallons per acre with a conventional power sprayer, equipped with either a four- or eight-row boom, with three T-jet nozzles per row.

The number of applications varied from two to as many as four, depending on the infestation and rate of growth of the crop. The first application was made at the termination of blossoming or when small pods were present, the second was when the pods were 1 to 1½ inches long, and the remainder were at 10-day or 2-week intervals.

The effect of the treatments on pod borer populations was determined by picking and shelling 100 or more green or dry pods per plot and examining these for injury due to the pod borer. Yield data were obtained by harvesting and weighing the beans from 1/100-acre areas in the center of each plot. As a further check on damage, 2-pound samples of the threshed beans were retained and from 200 to 300 beans per sample were examined for injury.

An insecticide to be effective against the pod borer should have contact as well as long residual action, in order to protect the pod from newly hatched larvae that crawl about seeking to enter it. Very minute quantities of the pod surface are consumed by the newly hatched larvae in gaining entrance, and once they are inside they remain until mature. Unlike the corn earworm, which may enter several pods, a full-grown pod borer seldom enters more than one pod. It is important, therefore, that the pods and the entire bean plant be thoroughly coated with an insecticide during the time the larvae are hatching.

Experiments in 1958

In the initial control experiment, new and older insecticides were tested in dusts or sprays against the pod borer in single-row plots 50 feet long. Each treatment and check were replicated five times. The beans were of the Fordhook variety and were planted later than usual, on July 1. Applications were made on August 8 at the time of blossoming, August 18, 28, and September 8. The effectiveness of the treatments was determined by picking 400 mature pods per treatment from September 10 to 29 and examining these for injury. Yield data were obtained.

As shown in table 13, none of the insecticides controlled the pod borer effectively. However, carbaryl, Telodrin,[5] and carbophenothion showed promise when judged by the percent reduction in damaged pods. All the materials except Monsanto 7769 and cryolite significantly reduced the number of infested

[5] See list of chemical names of proprietary materials at the end of this bulletin. Mention of these materials does not constitute their endorsement by the U.S. Department of Agriculture.

TABLE 13.—*Effectiveness of various insecticide dusts and sprays against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1958*

Insecticide[1]	Active ingredient per acre per application	Pods infested[2]	Reduction in damaged pods	Yield of dry beans per acre (100-lb. sacks)
Dusts	*Pounds*	*Number*	*Percent*	*Number*
Carbaryl 10	2.4	69	76	13.4
Endrin 2	.8	135	53	11.3
Endosulfan 4	1.8	136	53	8.5
Malathion 4	1.8	144	50	11.9
Methoxychlor 10	2.8	242	16	10.0
Cryolite 72	21.0	248	14	10.5
Sprays				
Telodrin 1.25	1.0	102	65	11.5
Carbophenothion 4	2.0	107	63	11.7
Phosphamidon 4	1.0	139	52	12.3
Ethion 4	2.0	143	51	10.7
Monsanto 8574 1	1.0	235	19	10.6
Monsanto 7769 2	1.0	262	10	9.4
Check		290		10.2
L.S.D. at 5-percent level		42		2.0

[1] Percent in dusts; pounds per gallon in sprays.
[2] Examined 400 pods per treatment.

pods. When judged by yields of dry beans, only carbaryl and phosphamidon gave significant increases over the check. Cryolite, which was recommended years ago for controlling this pest, was ineffective.

The beans in the untreated plots were damaged extensively by the pod borer—72-percent infested pods. 1958 proved to be one of the worst pod borer years.

In another experiment on Fordhook beans planted on June 18, a 72-percent cryolite dust was compared with DDT-toxaphene and with other materials. Plots were four rows (10 feet) wide by 138 feet long and replicated six times. The sprays were applied with the power sprayer at 30 gallons per acre. Applications were made on August 5, 14, and 25. Yield data were obtained by harvesting and threshing the beans in the four rows of each plot.

Infested pod counts showed that all materials were effective in reducing injury in some degree, as shown in table 14. Carbophenothion, endrin, and carbaryl were the most effective, reducing damaged pods from 74 to 83 percent. Ethion, cryolite, and DDT-toxaphene gave partial control. On a yield basis, carbaryl, ethion, and cryolite were superior, but all the beans were of poor quality because of the feeding of the pod borer. Endrin affected the bloom, caused a poor pod set, and thus accounted for the low yield obtained.

Experiments in 1959

Insecticides showing promise in 1958 were compared with other materials in single-row plots of Fordhook beans planted on April 17. Sprays were applied with hand sprayers at 60 gallons per acre per application and dusts at 40 pounds per acre. Applications were made on June 9, 16, 24, and 30. Data on injury were obtained by inspecting pods between July 13 and 22.

The results, as given in table 15, show that carbaryl was superior when applied in a spray at 1 and 2 pounds actual per acre and in a dust at 2 pounds. Carbaryl dust at 1 pound did not give adequate control. Malathion and endosulfan dusts and

TABLE 14.—*Effectiveness of various insecticide sprays and cryolite dust against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1958*

Insecticide [1] (pounds per acre per application)	Pods infested [2]	Reduction in damaged pods	Yield of dry beans per acre (100-lb. sacks)
	Number	*Percent*	*Number*
Carbophenothion 2	41	83	9.0
Endrin 1	53	78	4.5
Carbaryl 2	62	74	10.2
Ethion 2	95	61	10.2
Cryolite 25	99	59	9.9
DDT 2-toxaphene 4	137	43	8.5
Check	243		9.1
L.S.D. at 5-percent level	42		1.2

[1] Emulsifiable concentrates, except 72-percent cryolite dust.
[2] Examined 450 pods per treatment.

TABLE 15.—*Effectiveness of various insecticide dusts and sprays and* Bacillus thuringiensis *wettable powder against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1959*

Insecticide[1]	Active ingredient per acre per application	Pods infested[2]	Reduction in damaged pods
Dusts	*Pounds*	*Number*	*Percent*
Carbaryl 10	1	16 (6)	68
	2	4 (7)	92
Malathion 4	1.5	5 (8)	90
Endosulfan 3	1	8 (5)	84
Sprays			
Carbaryl 4	1	6 (4)	88
	2	5 (0)	90
Dieldrin 1.5	1	6 (6)	88
Ethion 4	1	22 (17)	56
Heptachlor 2	1	34 (11)	32
Kepone 2	1	43 (21)	40
Wettable powder			
B. thuringiensis[3]	1	32 (12)	36
Check	----------	50 (13)	----------
L.S.D. at 5-percent level	----------	15 (11)	----------

[1] Percent in dusts; pounds per gallon in sprays.
[2] Examined 300 pods per treatment. Figures in parentheses indicate number of earworms.
[3] 70 billion bacillus spores per gram (Merck).

a dieldrin spray were also highly effective. Ethion, heptachlor, Kepone, and *Bacillus thuringiensis* were ineffective.

As carbaryl showed superiority in the 1958 experiments, an experiment was conducted to determine the effect of varying the time and number of applications. Fordhook beans planted on April 17 were used. Plots were single rows arranged in randomized blocks with five replicates. Carbaryl was applied in a spray on three dates. The results, as given in table 16, show no significant difference in the effectiveness of dates or number of applications of carbaryl. Applications on June 9 and 24 reduced pod borer damage the most.

A May 25 planting of Fordhook beans was used for comparing a *Bacillus thuringiensis* dust and spray with five insecticide sprays. Plots were four rows (10 feet) wide by 136 feet long and were replicated six times. Applications were made on July 13, 21, 28, and August 4. The effectiveness of the materials was determined by inspecting green pods and threshed beans. Yields were also obtained.

Pod inspections, as given in table 17, showed that in comparison with the check all materials except *B. thuringiensis* significantly reduced pod injury. Endrin and Telodrin at 2 pounds per acre were especially effective. Carbaryl, carbophenothion, and phosphamidon at 1 pound and both formulations of *B.*

TABLE 16.—*Effectiveness of time and number of applications of carbaryl spray against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1959*

Date of applications[1] in June	Pods infested[2]	Reduction in damaged pods
	Number	*Percent*
9	15	56
16	22	35
24	13	62
9 and 16	21	38
16 and 24	11	68
9 and 24	8	76
9, 16, and 24	12	65
Check	34	--------
L.S.D. at 5-percent level	N.S.	--------

[1] 1 pound per acre per application.
[2] Examined 300 pods per treatment.

thuringiensis gave poor control. Telodrin and endrin were also superior in reducing damage to the threshed beans. The high percent injury to the threshed beans indicated that the pod borer continued to feed on the beans after they had been cut and while drying prior to threshing. When judged on the basis of yield, only Telodrin significantly increased the yield of Fordhook beans. Yields in the endrin plots were exceptionally poor, because repeated applications caused excessive blossom drop and poor pod set. In 1958 another brand of endrin also reduced pod set similarly.

A combination dust of carbaryl, DDT, and Kelthane was compared with a DDT-carbophenothion dust against pod borers on Ventura lima beans. Plots were eight rows (20 feet) wide by 600 feet long, with six replicates of each treatment and check. Applications were made with an eight-row power duster on July 15, 23, 30, and August 7. Examination of pods showed that the carbaryl-DDT-Kelthane dust significantly reduced injury to pods, but it was far from being effective commercially. Yields were about the same, averaging 10 sacks per acre in the dusted and untreated plots, as shown in table 18.

Experiments in 1960

New materials were compared with carbaryl in toxicity in a field of Ventura limas planted on May 11. Applications were made on July 6, 13, 21, and August 1 and there were six replicates. The results of the individual treatments are shown in table 19. All materials except dimethoate reduced damage to pods. Guthion resulted in the least pod damage. General Chemical GC-4072 and GC-3583 gave slightly better control than carbaryl. The remaining materials gave inadequate control—from 38- to 64-percent reduction in damaged pods. Pod borers were less destructive in 1960 than in the previous 2 years.

A large-scale field experiment was conducted to compare carbaryl with Telodrin, endosulfan, and malathion. Plots were 16 rows (40 feet) wide by 107 feet long. Ventura limas were planted on May 9. An eight-row power sprayer was used to apply the sprays at 25 gallons per acre. Applications were made on July 15, 25, and August 4. When two applications were used, the August 4 application was omitted. Two applications of carbaryl at 1 and 2 pounds per acre and Telodrin at 1 pound gave significantly higher yields than the check or the other materials, as shown in table 20. Examination of the threshed beans indicated no differences in the degree of borer injury due to the treatments. In some instances there was

TABLE 17.—*Effectiveness of various insecticide sprays and* Bacillus thuringiensis *dust and spray against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1959*

Insecticide (pounds per gallon)	Active ingredient per acre per application	Pods infested[1]	Reduction in damaged pods	Threshed beans damaged[2]	Reduction in damaged beans	Yield of dry beans per acre (100-lb. sacks)
	Pounds	*Number*	*Percent*	*Number*	*Percent*	*Number*
Endrin 1.6	1	25	85	56	75	7.7
	2	10	94	48	79	5.1
Telodrin 1.25	1	51	70	107	53	14.4
	2	13	92	37	84	15.1
Carbaryl 4	1	103	39	133	41	13.1
	2	27	84	75	67	13.3
Carbophenothion 4	1	110	35	169	26	13.0
	2	66	61	109	52	13.8
Phosphamidon 4	1	95	44	162	29	12.8
B. thuringiensis (dust)[3]	1	124	27	141	38	12.5
B. thuringiensis (spray)[4]	1	160	6	200	12	13.3
Check		170		227		12.0
L.S.D. at 5-percent level		40		75		2.0

[1] Examined 450 pods per treatment.
[2] Examined 600 beans per treatment.
[3] Merck's Agritrol, 5-percent dust, 5 billion bacillus spores per gram.
[4] Merck's Agritrol, wettable powder, 70 billion bacillus spores per gram.

TABLE 18.—*Effectiveness of insecticide dust combinations against lima-bean pod borer on Ventura lima beans, South Coast Field Station, Irvine, Calif., 1959*

Insecticide (percent)	Amount per acre per application	Pods infested[1]	Reduction in damaged pods	Yield of dry beans per acre (100-lb. sacks)
	Pounds	*Number*	*Percent*	*Number*
Carbaryl 5+DDT 5+Kelthane 3	30	13	79	10.1
DDT 5+carbophenothion 3	32	25	60	9.6
Check		62		10.0
L.S.D. at 5-percent level		39		N.S.

[1] Examined 450 pods per treatment.

TABLE 19.—*Effectiveness of various insecticide sprays against lima-bean pod borer on Ventura lima beans, South Coast Field Station, Irvine, Calif., 1960*

Insecticide[1] (pounds per acre)	Pods infested[2]	Reduction in damaged pods
	Number	*Percent*
Guthion 1	10	88
General Chemical GC-4072 1	12	85
General Chemical GC-3583 1	18	78
Carbaryl 2	22	73
Bayer 22408 1	29	64
Naled 2	30	63
Geigy G-30492 1	31	61
Bayer 29493 1	32	60
Phosphamidon 1	34	58
Trichlorfon 1	41	49
Dimethoate 1	50	38
Check	80	----------
L.S.D. at 5-percent level	35	----------

[1] Emulsifiable concentrates, except carbaryl and trichlorfon, 85- and 50-percent wettable powder, respectively.
[2] Examined 600 pods per treatment.

TABLE 20.—*Effectiveness of various insecticide sprays against lima-bean pod borer on Ventura lima beans, Scott Field, Irvine, Calif, 1960*

Insecticide (pounds per acre per application)	Applications	Threshed beans damaged[1]	Reduction in damaged beans	Yield of dry beans per acre (100-lb. sacks)
	Number	*Number*	*Percent*	*Number*
Telodrin 1	3	20	47	14.6
Carbaryl:	2	32	16	14.2
1	3	46	----------	13.0
	1, 3	19	50	13.9
2	2	59	----------	14.3
	3	15	61	12.8
Endosulfan 1	2	40	----------	13.9
	3	25	34	12.3
Malathion 1.5	2	57	----------	10.9
	3	35	8	13.0
Check	----------	38	----------	12.1
L.S.D. at 5-percent level	----------	24	----------	2.0

[1] Examined 1,200 beans per treatment.

more pod injury in the treated than in the untreated plots. Plots treated with three applications of carbaryl at 2 pounds per acre had the least injury.

Experiments in 1961

Tests were continued on Ventura limas to evaluate the effectiveness of different insecticide sprays against the pod borer. Plots were four rows wide (10 feet) by 93 feet long, with six replicates. Applications were made with the power sprayer on July 5, 19, and August 2. Yield data were obtained by threshing the beans in the two center rows. The results of this experiment are shown in table 21.

Pod borer injury in untreated plots in 1961 was unusually light—only 7-percent infested pods as compared with 72- and 40-percent injury in the 1958 and 1959 experiments. Judging by the results of the pod inspections, there was no significant difference between treatments and check in pod injury. Both dosages of Guthion and endosulfan at 2 pounds per acre gave the best control. In reducing pod borer injury to the threshed beans, Guthion at both dosages and endosulfan and Zectran at 2 pounds were significantly better than the check. Naled was the least effective. When compared on a yield basis, Zectran at 2 pounds, Guthion at both dosages, and carbaryl and diazinon at 1 pound per acre were superior.

An experiment was conducted to evaluate the effectiveness of Guthion, carbaryl, and endosulfan when applied at the same dosages in sprays and dusts. Fordhook beans

TABLE 21.—*Effectiveness of various insecticide sprays against lima-bean pod borer on Ventura lima beans, South Coast Field Station, Irvine, Calif., 1961*

Insecticide (pounds per acre per application)	Pods infested [1]	Reduction in damaged pods	Threshed beans damaged [2]	Reduction in damaged beans	Yield of dry beans per acre (100-lb. sacks)
	Number	*Percent*	*Number*	*Percent*	*Number*
Endosulfan:					
1	11	48	18	40	12
2	7	67	8	73	11
Guthion:					
0.75	8	62	7	77	13
1.5	9	57	10	67	13
Diazinon 1	16	24	20	33	13
Carbaryl:					
1	21	0	22	27	13
2	17	19	19	37	12
Trichlorfon 2	18	14	30		12
Zectran:					
1	27	0	19	37	11
2	16	24	13	57	14
Naled 2	31	0	33		12
Check	21		30		11
L.S.D. at 5-percent level	15		14		1.8

[1] Examined 300 green pods per treatment.
[2] Examined 1,200 beans per treatment.

were planted on May 31. Sprays were applied at 62 gallons per acre with knapsack sprayers and the dusts at 35 pounds per acre with rotary hand dusters. Applications were made on June 28, July 10, and 21. Yield data were obtained by picking and weighing the dry-bean pods on 10 plants per plot at harvesttime. The results, as given in table 22, show that there was no significant difference between treatments and check in pod borer damage to the bean pods. Guthion applied either in a spray or dust caused the least pod injury. Sprays were more effective than dusts in reducing injury.

Leaves on the Fordhook plants treated with endosulfan spray at 1 and 2 pounds per acre turned yellowish after the second application. Pod set appeared to have been affected, as the numbers and weight of the pods were reduced significantly by one-half when compared with the check and other materials. The 4-percent endosulfan dust applied at the same rates reduced the number of pods per plant from 9 to 13 percent, but did not discolor the foliage.

In another experiment new materials were applied in sprays in single-row plots of Fordhook beans planted on May 1. Applications were made on June 27, July 7, and 17. The results are shown in table 23. Telodrin, Guthion, and Shell SD-3562, each applied at 1 pound per acre, gave significant reductions in damaged pods. Plots treated

TABLE 22.—*Effectiveness of various insecticide sprays and dusts against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1961*

Insecticide (pounds per acre per application)	Reduction in damaged pods [1]	Pods per plant	Weight of pods per plant
Sprays			
Guthion:	*Percent*	*Number*	*Ounces*
1	79	12	1.5
2	96	14	1.8
Carbaryl:			
1	54	14	1.7
2	63	14	1.7
Endosulfan:			
1	33	7	.9
2	33	6	.8
Dusts			
Guthion:			
1	63	15	1.8
2	75	14	1.8
Carbaryl:			
1	29	14	1.6
2	17	14	1.7
Endosulfan:			
1	25	11	1.3
2	25	11	1.4
Check	----	12	1.4
L.S.D. at 5-percent level	N.S.	2	.3

[1] Examined 300 green and 125 dry pods per treatment.

TABLE 23.—*Effectiveness of various insecticide sprays against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1961*

Insecticide (pounds per acre per application)	Pods infested [1]	Reduction in damaged pods	Pods per plant [2]	Weight of pods per plant [2]
Experiment A	*Number*	*Percent*	*Number*	*Ounces*
Telodrin 1	5	74	11	15
Guthion 1	7	63	12	14
Shell SD-3562 1	8	58	13	14
Shell SD-4294 1	10	47	12	14
Bayer 29493 1	11	42	12	14
Dimethoate 1	15	21	13	17
Geigy G-30494 1	23		11	13
Endosulfan 2	24		6	10
Check	19		13	18
L.S.D. at 5-percent level	11		2.2	2.6
Experiment B				
Zectran:				
0.5	11	48		
1	6	71		
2	6	71		
Carbaryl 2	4	81		
Trichlorfon 2	13	38		
Stauffer ASP-51 1	16	24		
Check	21			
L.S.D. at 5-percent level	N.S.			

[1] Examined 300 green and 125 dry pods per treatment.
[2] Based on 60 plants per treatment.

with endosulfan and Geigy G-30494 had more infested pods than the check. Endosulfan discolored the leaves and reduced pod set and yields as in the previous experiment.

When carbaryl, trichlorfon, and Stauffer ASP-51 were compared with Zectran at varying rates per acre (table 23), there was no significant difference between these materials and the check in the degree of injury to pods. Zectran at 1 and 2 pounds per acre and carbaryl gave good control of the pod borer, whereas trichlorfon and Stauffer ASP-51 gave fair control.

Experiments in 1962

In the 1962 experiments against the pod borer, 22 new materials applied in sprays were compared in toxicity with carbaryl, Zectran, and Guthion in a field of Fordhook beans planted on May 1. Plots were single rows, 48 feet long, and replicated six times. Applications were made with hand sprayers on June 21, July 7, and 17 in experiments A, B, and C, but were delayed until July 10, 17, and August 2 in experiment D. The results are given in table 24.

Of the eight materials tested in experiment A, only Zectran gave a significant reduction in damaged pods. The Bayer materials 25141, 44646, and 37344, with reductions in injury from 52 to 58 percent, gave partial control. Plots treated with dimethoate and with some Bayer materials had more pod injury than the check.

TABLE 24.—*Effectiveness of various insecticide sprays against lima-bean pod borer on Fordhook lima beans, South Coast Field Station, Irvine, Calif., 1962*

Insecticide (pounds per acre per application)	Pods infested[1]	Reduction in damaged pods
Experiment A	*Number*	*Percent*
Zectran 2	8	76
Bayer 25141 1	14	58
Bayer 44646 1	15	55
Bayer 37344 1	16	52
General Chemical GC–3707 .5	29	12
Bayer 32651 1	31	6
Bayer 36205 .5	37	----------
Dimethoate 1	53	----------
Check	33	----------
L.S.D. at 5-percent level	21	----------
Experiment B		
General Chemical GC–4072 1	2	91
Carbaryl 2	3	87
Bayer 47940 1	3	87
Bayer 46676 1	4	83
Bayer 41831 1	14	39
Pyramat (Geigy) 1	15	35
Bayer 39007 1	18	22
Isolan 1	19	17
Dimetilan 1	20	13
Endosulfan 2	31	----------
Check	23	----------
L.S.D. at 5-percent level	12	----------
Experiment C		
Stauffer R–1504 1	5	81
Zectran 2	7	73
American Cyanamid 43064 1	8	69
Shell SD–3562 .5	9	65
Famophos 1	13	50
Union Carbide UC–10854 1	13	50
Stauffer N–2788 1	18	31
Union Carbide UC–8305 1	22	15
Trichlorfon[2] 1.5	31	----------
Dimethoate 1	33	----------
Check	26	----------
L.S.D. at 5-percent level	12	----------
Experiment D		
Zectran 2	3	86
Guthion 1	4	82
Ortho 5305 1	7	68
Phorate 1	15	32
General Chemical GC–3707 1	15	32
Di-Syston 1	16	27
Dimethoate 1	18	18
Check	22	----------
L.S.D. at 5-percent level	11	----------

[1] Examined 600 pods per treatment.
[2] 50-percent wettable powder.

In experiment B, General Chemical GC–4072, carbaryl, and Bayer 47940 and 46676 reduced pod injury from 83 to 91 percent. The other materials gave poor control, with 39-percent or less reductions in injury. Endosulfan not only was ineffective but caused a yellowing of the foliage, which reduced pod set and yields in the same manner as in 1961.

In experiment C, Stauffer R–1504, Zectran, American Cyanamid 43064, and Shell SD–3562 showed promise by reducing pod injury from 65 to 81 percent. The six other materials gave reductions in injury of 50 percent or less.

Of the seven materials tested in experiment D, only Zectran, Guthion, and Ortho 5305 reduced injury significantly, with reductions from 68 to 86 percent. Phorate, General Chemical GC–3707, Di-Syston, and dimethoate were ineffective.

Discussion

Of the insecticides tested in 1958, fair to good control was obtained with carbaryl, Telodrin, and carbophenothion. Endrin showed promise, but affected bloom and reduced yields. Cryolite, long recommended for the control of the pod borer, gave partial control.

In 1959, carbaryl applied either in a dust or spray gave good control in one experiment and fair in another. Carbophenothion was also inconsistent. *Bacillus thuringiensis* applied in a dust or spray was ineffective. Other materials failed to give commercial control.

Experiments in 1960 showed Guthion, General Chemical GC–4072 and GC–3583, and carbaryl superior. In another experiment carbaryl applied at different dosages and times and Telodrin gave fair control, but they increased bean production significantly in some instances.

In 1961, endosulfan, Guthion, and Telodrin were the most effective in reducing pod injury. Endosulfan, however, discolored the leaves and reduced pod set and yields. Zectran used for the first time showed promise.

In experiments in 1962, the best control was obtained with General Chemical GC–4072, Zectran, carbaryl, Bayer 47940, Bayer 46676, Stauffer R–1504, and Guthion. Three applications of these materials gave 81- to 91-percent reduction in pod injury.

None of the 54 insecticides tested against the pod borer on lima beans from 1958 to 1962 gave outstanding commercial control. In repeated tests carbaryl at 2 pounds actual per acre per application (3 or 4 applications) was the most effective, averaging 80-percent reduction in pod injury. Carbaryl was also effective against the corn earworm and gave fair to good control of lygus bugs. However, it caused excessive buildup of the two-spotted spider mite (*Tetranychus telarius* (*L.*)) on beans. Guthion and Zectran applied at 1½ or 2 pounds actual per acre per application (3 or 4 applications) gave good control of both the pod borer and lygus bugs, but owing to the lack of residue information neither has been registered for use on beans. Both endrin and endosulfan showed considerable promise, but tests with these materials were discontinued because they affected pod set and reduced yields. Other promising materials that should undergo further testing are Telodrin, General Chemical GC–4072, Bayer 47940 and 46676, and Stauffer R–1504.

Because of cost, bean growers have been reluctant to apply more than two applications of insecticides to control insects on beans. Nevertheless, in years such as 1958 and 1959, when pod borers were extremely destructive (72-percent damaged pods), failure to make additional applications meant that growers experienced losses far in excess of the cost of the insecticides.

Summary

The lima-bean pod borer (*Etiella zinckenella* (Treitschke)) is one of the most serious insect pests of lima beans in California. It was first reported damaging lima beans in the United States during 1885 in El Dorado County, Calif. It occurs in several States from the Pacific to the Atlantic Ocean and is widely distributed throughout the world.

The lima-bean pod borer is primarily a pest of lima beans, but it has been reported damaging other varieties of beans and reproducing on several wild host plants, especially species of lupine (*Lupinus*), wild pea (*Lathyrus*), and locoweed (*Astragalus*).

The larva is the only stage that injures lima beans. It feeds only on immature beans after eating an entrance hole through the pod. Economic loss is caused by dropping of immature pods, which reduces yield, loss of beans from larval feeding, and cost of separating undamaged from damaged beans.

There are several insects in the larval stage that feed on lima beans and are often confused with the lima-bean pod borer, although the larvae are not similar and each has characteristic feeding habits by which it can be identified.

The life history of the lima-bean pod borer showed a wide range in length of different periods, as determined by rearing the various stages in a screen-wire insectary outdoors, supplemented by observations in the field from 1931 to 1935 at Ventura, Calif. Higher temperatures from June to September decrease the length of different development periods and lower temperatures during the other months increase the length of each period.

The adult lives from 1 to 69 days. During an average lifespan of 19 days, a female will deposit on an average 33 eggs. Eggs are deposited on or near pods of wild or cultivated host plants. The incubation period ranges from 5 to 33 days and averages 15. From 13 to 65 days is required for the newly hatched larvae to enter pods and feed until mature. When mature, the larvae leave the pods and enter the soil to a depth of one-half to 2 inches, where they spin cocoons in which they later transform to pupae. The pupal period lasts from 16 to 101 days. The total life cycle from egg to adult requires from 2 to 9.8 months. One brood develops on annual wild host plants from March to June, and from two to four broods develop on lima beans and perennial lupines from June to December. They overwinter as larvae in cocoons in the soil of old bean fields.

The relationship between the lima-bean pod borer infestation on wild and cultivated host plants is correlated with the seasonal life history and habits of the insect.

Varieties of beans that set their pods high on the plant, such as the bush type, usually have the largest percentage of wormy pods, whereas the vine type or varieties that set pods low on the plant have the lowest percentage of wormy pods. This difference of infestation is due apparently to the normal phototropic response of the pod borer lar-

vae that stimulates them to crawl toward the stronger light or peripheral of the plant in search of food.

The lima-bean pod borer was found to have several native parasites, none of which were effective in reducing the abundance of the species. Six species of parasites of the pod borer in foreign countries were introduced and liberated as adults in southern California.

Experiments in which mature overwintering larvae were covered with different depths of soil showed that a large percentage of the resulting adults could be prevented from emerging when the larvae were covered with 6 or more inches of soil.

Surveys conducted over many years show that late-planted beans have always had more pod borer injury than early-planted beans, but field experiments to substantiate this trend have been contradictory.

Numerous aromatic chemicals were tested in bait traps in the field from 1934 to 1936, but none of the baits used were sufficiently attractive to adult pod borers to be of any value as a control remedy.

A series of laboratory tests showed that the pod borer adult was positively phototropic, with a high selectivity for monochromatic blue light. In field tests conducted for 3 years pod borer adults were attracted to colored light and killed with an electrocuting device. However, the cost of installing light traps, the high ratio of males to females attracted, the small number of moths captured, and the uncertainty of infestation made this method of control impracticable.

Of the 54 insecticides tested against the pod borer on lima beans from 1958 to 1962, carbaryl at 2 pounds actual per acre per application (3 or 4 applications) was the most effective, with an average of 80-percent reduction in pod injury. Carbaryl was also effective against the corn earworm (*Heliothis zea* (Boddie)) and gave fair to good control of lygus bugs. Its main disadvantage was that it increased infestations of the two-spotted spider mite (*Tetranychus telarius* (L.)) on beans. Guthion and Zectran applied at 1½ or 2 pounds actual per acre per application (3 or 4 applications) gave good control of both the pod borer and lygus bugs. Other materials that should be investigated further are Telodrin, General Chemical GC-4072, Bayer 47940 and 46676, and Stauffer R-1504.

Literature Cited

(1) American Association of Economic Entomologists.
1931. COMMON NAMES OF INSECTS APPROVED FOR GENERAL USE BY THE AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS. Jour. Econ. Ent. 24: 1273–1310.

(2) Boas, F., and Merkenschlager, F.
1923. DIE LUPINE ALS OBJECT DER PLANZENFORSCHUNG. (Abstract) V. 8, 144 pp. Berlin.

(3) Chittenden, F. H.
1909. THE LIMA-BEAN POD-BORER. U.S. Bur. Ent. Bul. 82. pp. 25–28, illus.

(4) Clausen, C. P.
1931. INSECTS INJURIOUS TO AGRICULTURE IN JAPAN. U.S. Dept. Agr. Cir. 168. 62 pp.

(5) Essig, E. O.
1926. INSECTS OF WESTERN NORTH AMERICA. 1035 pp., illus. New York.

(6) FLANDERS, S. E.
1930. THE LIMA-BEAN POD-BORER IN CALIFORNIA. Calif. Dept. Agr. Bul. 19: 409–421, illus.

(7) ———
1932. OBSERVATIONS ON CERTAIN INSECTS IN AUSTRALIA IN 1931. Jour. Econ. Ent. 25: 1240–1241.

(8) FORBES, R. H.
1921. MOKI LIMA BEANS. Sultan. Agr. Soc., Tech. Sect. Bul. 9, 22 pp., illus.

(9) HULST, G. D.
1890. THE PHYCITIDAE OF NORTH AMERICA. Amer. Ent. Soc. Trans. 17: 1–135.

(10) HYSLOP, J. A.
1912. THE LEGUME POD MOTH. THE LEGUME POD MAGGOT. U.S. Bur. Ent. Bul. 95, pp. 89–104, illus.

(11) LARSON, A. O.
1926. OBSERVATIONS ON THE CHARACTERISTIC INJURY CAUSED BY LIMA BEAN POD BORER ETIELLA ZINCKENELLA TREIT., AND OTHER INSECTS WITH WHICH ITS INJURY IS CONFUSED IN CALIFORNIA. Jour. Econ. Ent. 19: 699–702.

(12) LEONARD, M. D., and MILLS, A. S.
1931. A PRELIMINARY REPORT ON THE LIMA BEAN POD BORER AND OTHER LEGUME POD BORERS IN PUERTO RICO. Jour. Econ. Ent. 24: 466–473.

(13) LIGHT, S. S.
1927. REPORT OF THE ENTOMOLOGISTS FOR 1926. Ceylon Tea Res. Inst. Bul. 1: 16–20.

(14) PIERCE, W. D.
1917. MANUAL OF DANGEROUS INSECTS. 256 pp., illus. U.S. Dept. Agr., Washington, D.C.

(15) SAKHAROV, N.
1923. REPORT OF THE ENTOMOLOGICAL DEPT. FOR THE YEARS 1916–1923. (Abstract) Saratov. Agr. Expt. Sta. Trans., 2 pp.

(16) SARATOVSKAYA AGRICULTURAL EXPERIMENT STATION.
1925. REPORT ON THE WORK OF THE ENTOMOLOGICAL DEPARTMENT FOR 1920–1925. (Abstract) Saratovsk. Oblastn. Selsk. Khoz. Opytn. Sta., 31 pp.

(17) SCHEGALER, V. N., and MAMONAV, B. A.
1929. THE SOY BEAN PESTS IN THE NORTHERN CAUCASUS. (Abstract) Byull. Severo-Kavazskaia Kraev Selsk. Khoz. Opytn. Sta. No. 287, 32 pp.

(18) SCOTT, L. B.
1940. THE BEAN POD BORERS IN PUERTO RICO. Puerto Rico Univ. Jour. Agr. 24 (No. 2), 12 pp.

(19) TREITSCHKE, G. F.
1832. DIE SCHMETTERLINGE VON EUROPA. Band 9, 272 pp.

(20) U.S. DEPARTMENT OF AGRICULTURE, PLANT QUARANTINE AND CONTROL ADMINISTRATION.
1929. ANNUAL LETTER OF INFORMATION NO. 41. PESTS COLLECTED FROM IMPORTED PLANTS AND PLANT PRODUCTS FROM JANUARY 1 TO DECEMBER 31, 1928, INCLUSIVE. Serv. and Regulat. Announc. No. 97 (Sup.), pp. 157–234.

(21) VAN HALL, C. J. J.
1924. ZIETEN EN PLAGEN DER CULTUURGEWASSEN IN NEDERLANSCH-INDIE IN 1923. (Abstract) Mededeelingen Inst. Plantenziektenkund. No. 64, 47 pp.

(22) WOLCOTT, G. N.
1933. THE LIMA BEAN POD BORER CATERPILLARS OF PUERTO RICO. Puerto Rico Dept. Agr. Jour. 19: 241–255, illus.

(23) ZELLER, P. C.
1881. HORAE SOCIETATIS ENTOMOLOGICAE ROSSICAE. V. 16, pp. 154–256, illus.

Chemical Names of Proprietary Materials Mentioned in This Bulletin

American Cyanamid 43064	2-cyclic ethylene (diethoxyphosphinothioyl) dithioimidocarbonate
Bayer 22408	*O,O*-diethyl *O*-naphthalimido phosphorothioate

Bayer 25141	*O,O*-diethyl *O-p*-methylsulfinylphenyl phosphorothioate
Bayer 29493	*O,O*-dimethyl *O*-[4-(methylthio)-*m*-tolyl] phosphorothioate
Bayer 32651	4-(methylthio)-*m*-tolyl methylcarbamate
Bayer 36205	6-methyl-2,3-quinoxalinedithiol cyclic *S,S*-dithiocarbonate
Bayer 37344	4-(methylthio)-3,5-xylyl methylcarbamate
Bayer 39007	*O*-isopropoxyphenyl methylcarbamate
Bayer 41831	*O,O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate
Bayer 44646	4-dimethylamino-*m*-tolyl methylcarbamate
Bayer 46676	*O*-ethyl *O*-(2-ethyl-6-methyl-4-pyrimidinyl) ethylphosphonothioate
Bayer 47940	*O*-(3-chloro-4-cyanophenyl) *O,O*-dimethyl phosphorothioate
Di-Syston	*O,O*-diethyl *S*-[2-(ethylthio)ethyl] phosphorodithioate
Famophos	*O-p*-(dimethylsulfamoyl) phenyl *O,O*-dimethyl phosphorothioate
Geigy G–30492	*O,O*-dimethyl S-[(phenylthio)methyl] phosphorodithioate
Geigy G–30494	*S*-(2,5-dichlorophenylthio)methyl *O,O*-dimethyl phosphorodithioate
General Chemical GC–3583	2-chloro-1-(2,5-dichlorophenyl)vinyl diethyl phosphate
General Chemical GC–3707	dimethyl 3-hydroxyglutaconate dimethyl phosphate
General Chemical GC–4072	2-chloro-1-(2,4-dichlorophenyl)vinyl diethyl phosphate
Guthion	*O,O*-dimethyl S-(4-oxo-1,2,3-benzotriazin-3-(4*H*)-ylmethyl) phosphorodithioate
Isolan	1-isopropyl-3-methyl-5-pyrazolyl dimethylcarbamate
Kelthane	1,1-bis(*p*-chlorophenyl)-2,2,2-trichloroethanol
Kepone	decachloroöctahydro-1,3,4-metheno-2*H*-cyclobuta[*cd*]pentalen-2-one
Monsanto 7769	hexaethyl [(ethylthio)methylidyne]triphosphonate
Monsanto 8574	tetramethyl (dithiodimethylene)diphosphonate
Ortho 5305	*m-sec*-butylphenyl methylcarbamate
Pyramat	4-methyl-2-propyl-6-pyrimidinyl dimethylcarbamate
Shell SD–3562	2-dimethylcarbamoyl-1-methylvinyl dimethyl phosphate
Shell SD–4294	dimethyl 2-(*alpha*-methylbenzyloxycarbonyl)-1-methylvinyl phosphate
Stauffer ASP–51	*O,O,O,O*-tetrapropyl pyrophosphorothioate
Stauffer N–2788	*O*-ethyl *S-p*-tolyl ethylphosphonodithioate

Stauffer R–1504	*O,O*-dimethyl *S*-phthalimidomethyl phosphorodithioate
Telodrin	1,3,4,5,6,7,8,8-octachloro-1,3,3a,4,7,7a-hexahydro-4,7-methanoisobenzofuran
Union Carbide UC–8305	3-chloro-5-methyl-3-thio-2,4-dioxa-3-phosphabicyclo[4.4.0]decane
Union Carbide UC–10854	*m*-isopropylphenyl methylcarbamate
Zectran	4-dimethylamino-3,5-xylyl methylcarbamate

U.S. GOVERNMENT PRINTING OFFICE: 1965 O—744-014

END