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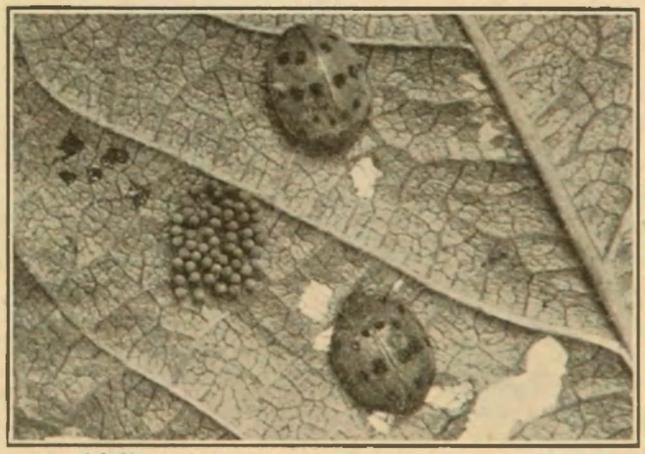
The Agricultural Experiment Station
OF THE
Colorado Agricultural College

THE MEXICAN BEAN-BEETLE

By GEO. M. LIST



Adults and eggs of the Mexican bean-beetle

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THE MEXICAN BEAN-BEETLE

(*Epilachna corrupta Muls*)

By GEO. M LIST

The Mexican bean-beetle is the only species of the highly beneficial lady-bird family in Colorado known to feed by choice upon vegetation. Other members of this family are among our most beneficial predatory insects, feeding almost exclusively upon plant lice, scale insects, soft-bodied larvae and insects eggs. This particular species has selected the bean as its food plant and has become a pest of major importance upon this crop. In Colorado it is more destructive to the bean crop than the Colorado potato-beetle. is to the potato, and is much more difficult to control due to the susceptibility of the bean plants to injury from the use of arsenical sprays.

In the infested regions, it is not uncommon to see garden and field beans a complete failure on account of the injuries of this pest and very few attempt to grow beans commercially.

The recent outbreak of this pest in the South and its ability to adapt itself in that region to the soy bean and cow pea as food plants, makes it a serious menace to the entire agriculture of the South as well as the bean crop of the semi-arid West.

DEFINITIONS

The Mexican bean-beetle passes thru four distinct stages of development, the egg, larva, pupa and adult. The term "generation" is used in reference to this complete cycle of development. The terms, "hibernated", and "spring brood", adults are used in reference to the adult beetles that have passed the winter in hibernation. They may be beetles from either the first or second generation of the previous year. The term "brood" is used to refer to the eggs, larvae, pupae or adults of any generation. The "hibernated" or "spring brood" of beetles deposit the "first-brood" eggs which develop into the "first-brood" larvae, pupae and adults. "Second-brood" refers to the eggs, larvae, pupae and adults forming the second generation.

COMMON NAMES

An insect may be known among a few entomologists by its scientific name but it is important, to avoid confusion, that a common name be accepted and uniformly used. In Colorado this pest is most generally known as the "spotted bean-beetle" or "bean beetle." In publications issued by other states and by the U. S. Department of Agriculture, it has been variously called "bean beetle," "bean lady-bird," "Mexican bean-beetle" and "bean-bug." It

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The investigations reported in this bulletin are the result of co-operative work supported jointly by the Experiment Station and the Office of State Entomologist of Colorado.

would seem that the names "spotted bean-beetle" or "bean beetle" are sufficiently descriptive and distinctive to be appropriate, and apparently have priority, but as a number of official, state and federal, quarantine regulations have been issued in which the name "Mexican bean-beetle" has been taken, this will be used in this paper.

HISTORY AND DISTRIBUTION

The Mexican bean-beetle has been a serious pest of the beans in certain sections of Colorado since reliable entomological records have been taken. Dr. C. P. Gillette, in Colorado Agriculural Experiment Station Bulletin 19, in reporting conditions for the season of 1891, says: "This beetle out-does all other insect pests that the bean crop has to contend with in the West." The older settlers report injury to beans during the early development of the oldest sections of the State. Native food plants have never been found in Colorado This would indicate that it is not a native of this State but has migrated to the beans from other sections of the semi-arid region, possibly from as far south as Mexico where it undoubtedly has native food plants.

Its distribution in Colorado has been confined largely to the foothill regions of the Eastern Slope of the Rocky Mountains and to the southern portion of the State. The infested section east of the mountain range is made up of the following counties: Larimer, Boulder, Weld, Adams, Arapahoe, Jefferson, Denver, Douglass, El Paso, Fremont, Pueblo, Crowley, Otero, Custer, Huerfano and Las Animas.

In Weld county they extend only a short distance east of Greeley and it is only recently that they have been injurious in the Greeley section. Only the western portions of Adams and Arapahoe Counties are known to be infested and the infestation in Crowley and Otero Counties is of comparatively recent origin.

In the southwest portion of the State, the counties of La Plata, Montezuma, Dolores, and the western part of Montrose, known as Paradox Valley, are known to be infested.* It is reporteed as a serious pest to beans in Arizona, New Mexico and parts of Texas, and a serious infestation is reported in several counties in Alabama, Georgia, Tennessee, South Carolina and Kentucky.

IMPORTANCE AS A PEST

The Mexican bean-beetle has practically destroyed commercial bean growing in the infested sections of Colorado, and in many localities has even made the successful growing of beans in the home gardens very difficult. The latter is especially true in the cities

Since writing the above infestations have been found in the Uncompahgre Valley, Montrose County, and as far east in Delta County as Cory. (July 23, 1920.)

where many fail to apply remedial measures and where conditions are favorable for the hibernation of beetles. Since its attacks have been confined almost entirely to the bean, which is not a crop of major importance in the infested region of a rather limited area of the West and the pest has not spread rapidly into new territory, it has not caused much concern only in the states infested. The recent serious outbreak in the South which shows that it readily adapts itself to the humid conditions and also its change in food to the cow pea and soy bean of that section, makes it a most serious menace to the agriculture of the entire country. Its possibilities of damage are much greater than those of the Colorado potato-beetle, the spread of which caused such consternation over the entire country a few years ago. If it does as serious damage to the cow peas and soy beans as well as garden and field beans in the South as it does to the beans of Colorado, it will be a menace to their entire agricultural system by limiting the use of their greatest soil-building and forage-producing crops, as well as by reducing an important food supply.

FOOD PLANTS

The writer has never, with one exception, found the larvae feeding upon any plants but the true beans. In a garden in 1918 some garden peas growing by some heavily infested beans were quite badly damgaed by larvae. No egg masses were found so it is thought the larvae migrated to the peas after the beans had been badly eaten.

The adults have never been observed to deposit eggs on any plants but the true beans. They deposit eggs freely upon only the kidney and lima types. The upright growing beans commonly called Broad or English Dwarf seem to be entirely free from the attacks of both the adults and larvae. The adults feed freely upon the soy beans but not until the present season were they observed to deposit eggs upon this type of bean. A number of egg masses have been found in a field of soy beans on the College Farm. The larvae are developing normally and are doing considerable damage to the individual plants infested.

The adults feed and deposit eggs quite freely upon the lima beans but as a rule they prefer beans of the kidney type. However, the limas may be seriously damaged.

The kidney type of beans, which includes all the varieties commonly called snap and shell beans, is the most preferred food plant. There is some difference in the susceptibility of the different varieties within this type but it is doubtful if this is great enough to be of value if the less susceptible varieties are the only ones grown within a section.

During the season of 1921 notes were taken, just after the period of maximum injury, on 242 varieties being grown in the College garden. The injury, based upon the percentage of foliage surface destroyed, varied with the different varieties from 20 to 95 per cent. The beetles had been hand-picked from all plots three times early in the season. The percentage of a crop produced ranged from nothing to 60 per cent. The best crops were produced by the early maturing varieties and in most cases they showed the greatest amount of injury but produced some beans before the plants were seriously damaged. Many of the varieties were not adapted to this locality.

The adults have been found feeding upon a number of other leguminous plants, such as a number of varieties of garden and field peas, vetch, clover and alfalfa. On one occasion a number of large alfalfa plants growing near some beans were defoliated. As a rule, even the adults prefer the true beans to any other plants.

NATURE AND EXTENT OF INJURY

The insect in both the adult and larval stages will feed upon the leaves, flowers and growing pods of the bean plant, but the greatest amount of injury is done to the leaves. The adult beetles are not responsible for as great an amount of injury as are the larvae, but are heavier eaters and feed for longer periods than do the adults of many insects. They usually feed by clinging to the under surface of the leaves and eating irregular holes entirely thru the leaves, leaving some of the larger veins crossing such holes, but in many cases they eat off only the lower epidermis. They will occasionally eat the blossoms and in many cases small pods will be entirely destroyed or so badly eaten that they drop from the plant. Irregular patches of epidermis may be eaten from the larger pods. Often when the

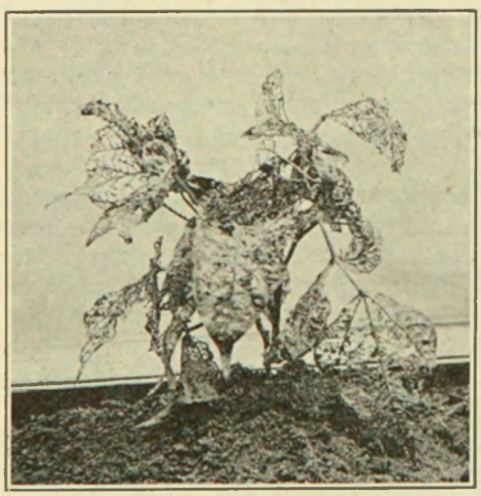

Fig. 2—A plant showing typical injury of the Mexican bean-beetle. The leaves are so badly skeletonized that they will soon drop.

first brood of beetles begins to emerge, the bean leaves have been so badly eaten by the overwintering adults and first-brood larvae that little food is left except the pods which may be attacked and riddled by the new adults. The bean seeds, if they have developed, may be partly eaten.

Fig. 3—Bean plants showing a late stage of Mexican bean-beetle injury. The few partly developed pods are badly eaten.

The adults have a roving disposition and do not concentrate their atack. At certain times of the day they may be seen flying from one part of the field to another or from one garden to another. They rather prefer feeding on the larger plants, probably on account of the protection, yet the writer has seen young beans entirely destroyed when only a few days old.

The larvae are voracious feeders. For a few days they feed in colonies near the egg cluster on the under surface of the leaves, but later scatter to other parts of the plant or to other plants. They feed by eating the lower epidermis and the central layers of the leaves, leaving the upper epidermis and veins. The leaves may be so badly eaten that only a whitish skeleton will remain. Such leaves will soon drop. The leaf surface may be entirely destroyed or so reduced that growth of the plant ceases. The larvae also eat irregular patches of epidermis from the pods.

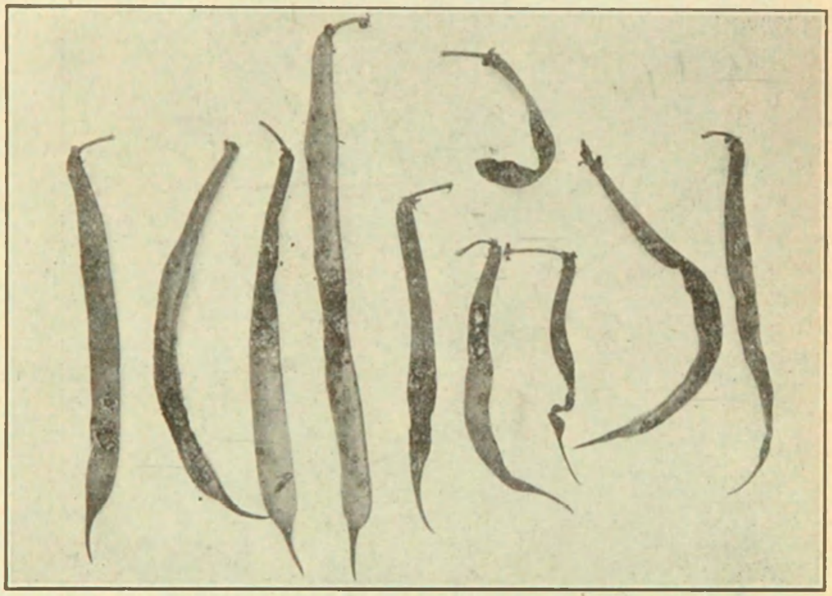

Fig. 4—Injury to bean pods caused by the feeding of larvae and adults of the Mexican bean-beetle.

The extent of the injury will depend upon the degree of infestation and the stage of development of the plants when attacked. It is seldom that the feeding of the adults entirely destroys the plants, altho this has been seen in a few cases. The larvae may so eat the leaves that they will wither as shown in Fig. 2 and later drop. A plant that loses only a few leaves may continue growth and make a fair crop, or if the attack does not come until the pods are formed, a partial crop may mature. In the heavier infested localities, the later-planted beans are usually a complete failure. The plants that lose their foliage may throw out some new leaves but if these are not destroyed by the larvae, they usually are by the first-brood adults.

The percentage of injury ranges from five or ten per cent to a complete crop failure. Most of the heavier infested sections have discontinued the growing of beans as a commercial crop. During the past season a number of fields in the Greeley section planted for seed production did not produce more than fifty per cent of a crop and one field of approximately twenty acres was visited that was not worth harvesting.

City gardens are usually very badly damaged, probably due to the continued growing of a considerable number of beans in a given locality and to the favorable conditions for the hibernation of the beetles. Most city gardeners who do not use control methods, plant only the earliest varieties of snap beans hoping to get a partial crop before the plants are destroyed.

GENERAL DESCRIPTION

ADULT

The adult (Page 13) is a stout "hard shelled" beetle, oval in outline, and about one-fourth of an inch in length. The newly emerged adult is of a straw or cream-yellow color. A few minutes after emergence, eight black spots of variable size appear on each wing cover. The adults darken with age until they become an orange brown with a bronze tinge, at which time the black spots are less conspicuous. The males are slightly smaller than the females. The adults are sluggish and when disturbed drop from the vines and secrete small drops of offensive yellow liquid from their knee joints.

EGGS

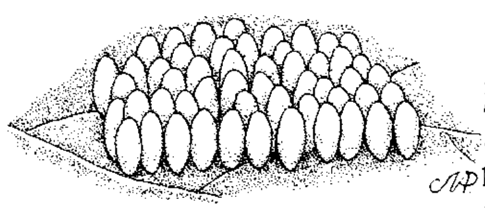

Fig. 5—Eggs of the Mexican bean-beetle. The eggs are light yellow in color and are placed on the under side of leaves in masses averaging about fifty. Enlarged seven times. M. A. Palmer, Delineator.

The eggs are light yellow in color and oval in shape. They are approximately one-twentieth of an inch in length and one-fortieth of an inch in width. They are placed on end in irregular masses on the underside of the leaves. The number in a mass ranges from four to eight-seven, the average being approximately fifty.

LARVA

The newly-hatched larvae are light yellow in color and not over one-sixteenth of an inch in length. Their bodies are covered with rows of stout branched spines. These spines are at first,

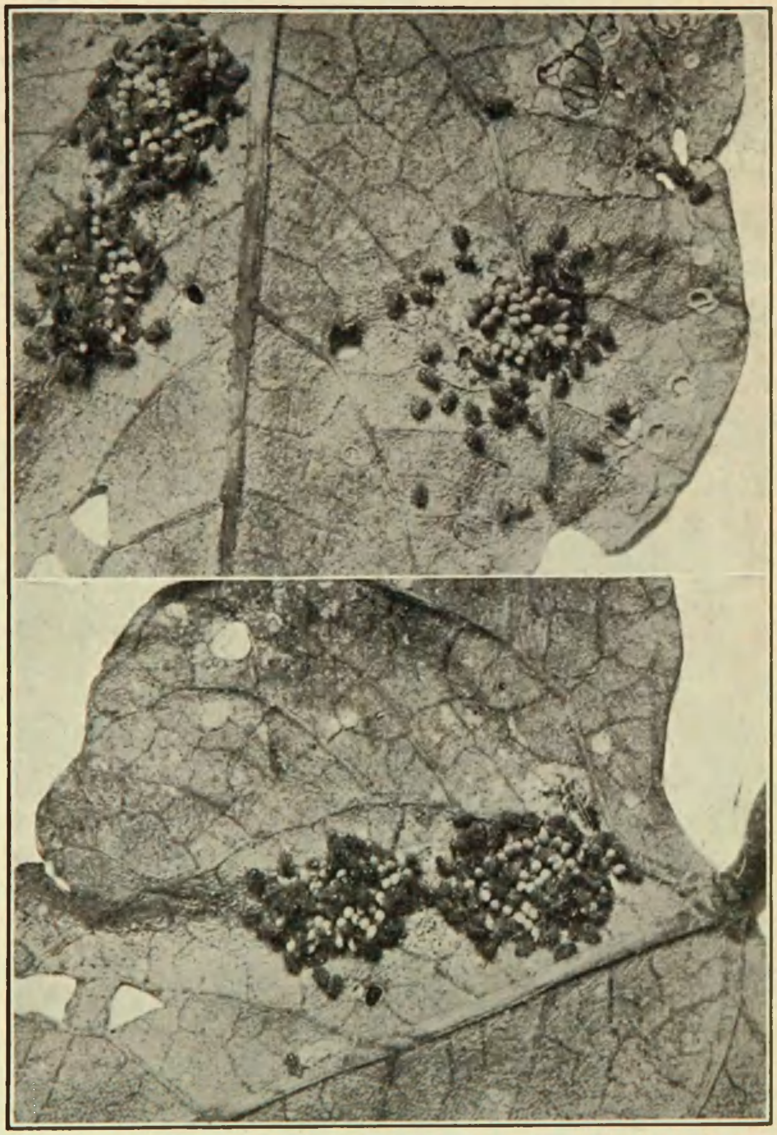

Fig. 6—Small larvae of the Mexican bean-beetle that have recently hatched and are still clustered about the egg mass. They begin to scatter on the third or fourth day, as shown in the upper right portion of the figure and feed singularly thereafter.

yellow in color, but later become darker at the tips and more conspicuous. The mature larvae are from one-quarter to three-eighths of an inch in length, and of a greenish yellow color. The body is heaviest in the center and tapers sharply posteriorly and anteriorly, and the spines on the central part of the body are longest, thus giving the larvae a humped back appearance. The larvae molt four times during the time of development. The last or pupation molt occurs after feeding has stopped and the larva has attached itself for pupation. After each molt, except the pupation molt, the larvae are pale yellow in color. A few hours after molting, the tips of the spines become darker, giving a general greenish or dirty, yellow color. For about twenty-four hours before attachment for pupation, the larvae do little feeding and move about, often going to other plants than beans for pupation. They apparently have a tendency to congregate in considerable numbers for pupation.

PUPA

The larvae, when mature, attach themselves by the rear end of the body, to the underside of leaves, stems or pods of the bean plants and often to parts of near-by plants. In this position, they pupate or transform to adults. After attaching themselves, the larvae go thru the last molt, the cast skin being pushed back from over the thorax to the abdomen where it remains in a whitish, wrinkled mass. The black tips of the spines remain conspicuous on the cast skin. The pupa is yellow in color, spineless and of about the size and shape of the adult.

GENERAL LIFE HISTORY

The Mexican bean-beetle passes the winter as an adult in hibernation. The hibernation is complete, the adults not showing any activities until after considerable warm weather has been experienced. In the Fort Collins section they usually begin to appear during the fore part of June. After feeding from seven to ten days, they begin to deposit their eggs. Egg laying of the over-wintering adults may continue as late as the middle of August, the maximum coming during July. These adults die after egg laying is completed.

The eggs hatch in from five to nine days, depending upon the weather conditions, the average being approximately seven days.

The larvae, on an average, feed for about twenty-three days. The maximum number of larvae usually appear the middle or latter part of July and fore part of August.

The pupation period, including the time from when the larvae attach themselves for pupation until adults emerge; is on the

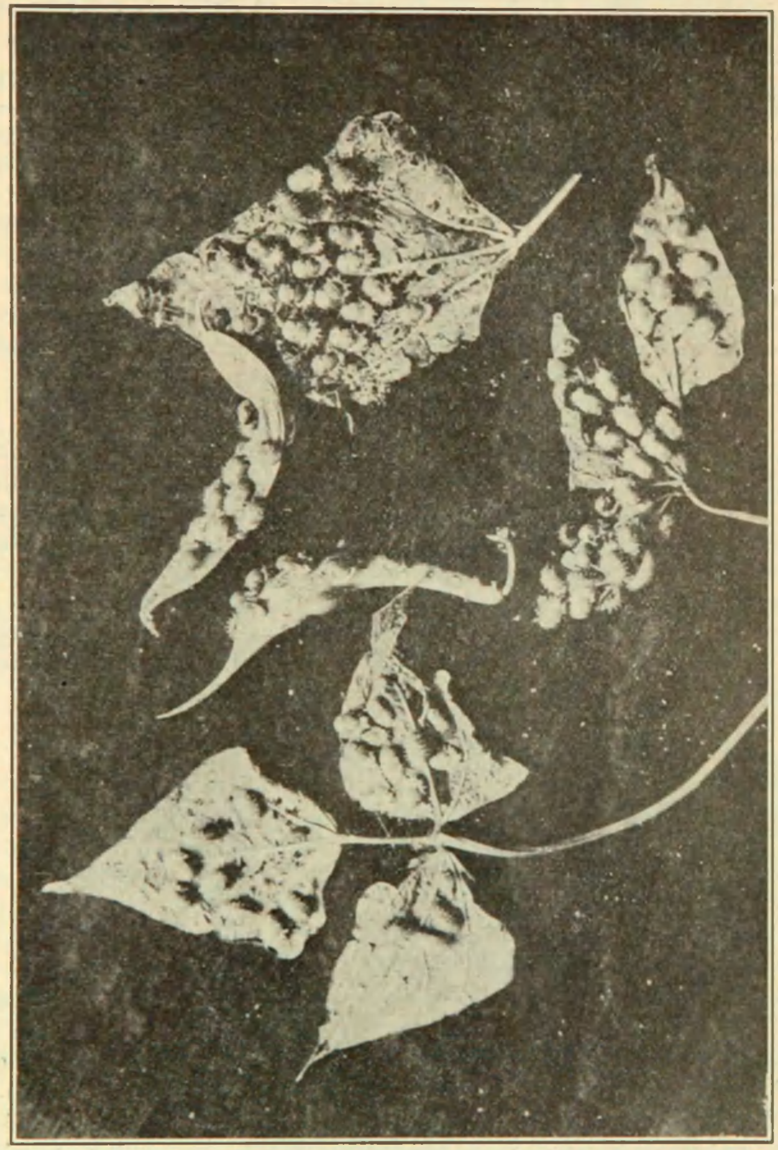

Fig. 7—Pupae of the Mexican bean-beetle on the under surface of bean leaves and pods.

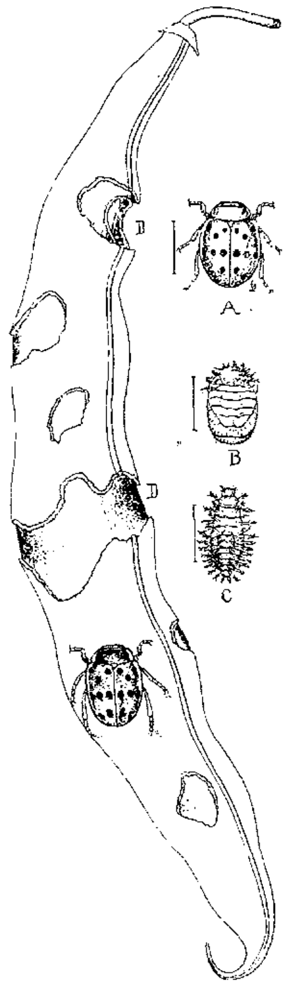

Fig. 8—The Mexican bean-beetle. A, mature beetle; B, pupa; C, larva; D, bean pod showing injuries. Original. Colorado Agricultural Experiment Station Bulletin No. 19.

average about eight and a half days.

This development completes a generation. The length of periods given is approximate for the first generation. In the Fort Collins section a portion of the first-brood beetles deposit eggs and a second generation is begun. In many cases, on account of cold weather and scarcity of food, the second generation is not completed. The percentage of the first-brood beetles that deposit eggs of a second generation varies with the different seasons. The periods of development of the second generation are all longer than the corresponding periods in the first generation. As the expression is generally used, there is one complete generation and a partial second. The numbers of the first generation far exceed those of the second. The greatest injury is done by the first. It is not known whether any of the first-brood adults that deposit second-brood eggs live over winter to deposit eggs in the spring or not. In sections of the State where the temperature is higher and the season longer there is a larger percentage of a second generation. This is true in the Arkansas Valley and in portions of the infested counties in the southern part of the State.

LIFE-HISTORY STUDIES

More or less detailed life-history studies of the Mexican bean-beetle were carried out in the Fort Collins sections during the seasons of 1917, 1918, 1919 and 1920. Most of this work was done in an open air laboratory where conditions were made as near those of the field as possible. Some data were taken from breeding cages placed in the field. These data were supplemented by numerous field notes. The writer is indebted to the following workers for much of the life-history and control data herein given: Wm. P. Yetter, Jr., A. Granovsky, Miriam A. Palmer, F. J. Brinley and John L. Hoerner. The writer has also had the free use of numerous field and laboratory notes made by Dr. C. P. Gillette and S. Arthur Johnson, and the helpful suggestions of Dr. C. P. Gillette, who has observed the Mexican bean-beetle in this State for thirty years.

HIBERNATION

The bean beetles pass the winter in only the adult stage. Their hibernation is complete. They begin to disappear for hibernation in the fall as soon as frosts injure their food plants and no more activity is shown until in June when they suddenly appear. It is rather unusual that they remain in hibernation until so late as many days of high temperature are experienced and early beans are often in bloom before they are seen.

We have been able to collect very little data as to the conditions under which they hibernate in this locality. It is supposed that they hibernate under vines, grasses and rubbish in and about the gardens, but the writer has never taken one in hibernation even though rather diligent search has been made in and about gardens that were heavily infested. Dr. C. P. Gillette reports that, during his thirty years of experience as Entomologist at the Colorado Agriculural Experiment Station, he has never found but one in hibernation, and that one was under a stone in the foothills west of Fort Collins.

We have had difficulty in carrying them thru successfully in the insectary. The methods ordinarily used for wintering other species of the lady-beetle family have been a failure. During the fall of 1920 some two thousand beetles were liberated in a screened, natural-temperature insectary and a large variety of hibernating places provided. No live beetles could be found in the spring. A number of dead ones were found under boxes, under and in excelsior and straw, and in a number of other apparently desirable places. It is possible that the conditions were too dry for the best results. Conditions were favorable for hibernation outside, as the beetles have appeared in large numbers and many garden beans are being badly damaged by the adults and little will remain after the larvae are thru feeding.

A. E. Mallory reports finding the beetles in December, 1918, under bean vines at Greeley, Colorado. D. E. Merrill, in Bulletin 106, of the New Mexico Agricultural Experiment Station, says: "If bunches of old vines, weeds, rubbish, or such, be left in the field, the beetles will crawl down under them and perhaps partly bury themselves in the soft soil beneath."

The Fort Collins section lies on the northern boundary of the bean-beetle infestation. It is possible that the hibernation habits are somewhat different than in the sections farther south and they bury themselves deeper in the soil or seek hiding places that we have not found with a limited amount of searching.

During the past four seasons, the first beetles have appeared on the beans from hibernation on the following dates: 1918, June 7; 1919, June 10; 1920, June 12; and 1921, June 8. Each season they were found in large numbers within two or three days' time.

EGG LAYING OF HIBERNATED BEETLES

Eggs have been found in the field in from six to ten days after the first beetles appear from hibernation. Egg laying may continue over a period of several weeks. In 1919, eggs were deposited by hibernated beetles as late as August 26.

On June 25, 1919, twenty-four pairs of beetles were collected in the field and placed in breeding cages, one pair to each cage. Fresh bean leaves were given daily and all eggs removed and counted. A few egg masses were noted in the field when the beetles were collected. Table 1 gives a tabulation and summary of the results.

Table I. Individual egg record of twenty-four hibernated females, 1919.

Cage No.	Date first eggs deposited	Date last eggs deposited	Length of egg-laying period	No. egg masses	Total eggs
1	June 27	Aug. 5	40 das.	12	634
2	June 28	Aug. 5	39 das.	11	583
3	June 29	July 31	33 das.	10	668
4	June 28	Aug. 7	41 das.	11	584
5	July 1	July 10	10 das.	4	95
6	June 26	July 19	24 das.	10	580
7	June 27	July 26	30 das.	11	669
8	June 27	July 25	29 das.	9	447
9					
10	July 1	Aug. 26	57 das.	17	913
11	June 27	July 22	26 das.	9	421
12	June 29	July 26	28 das.	9	597
13	June 29	July 15	17 das.	5	291
14	June 26	Aug. 10	46 das.	13	665
15	June 26	Aug. 4	40 das.	12	680
16	June 26	July 27	22 das.	11	578
17	June 26	July 15	20 das.	6	315
18					
19	June 26	Aug. 14	50 das.	18	1,036
20					
21					
22	June 29	July 31	33 das.	12	631
23	June 30	July 26	27 das.	9	486
24	June 27	July 28	32 das.	12	619
Totals			646 das.	211	11,482

Four females laid no eggs. Twenty females averaged 574.1 eggs. Minimum eggs by one female 95. Maximum eggs by one female 1036. Average egg masses for twenty females 10.5. Egg laying period, Max. 57 days, Min. 10 days Avg. 32.3 days. Number of eggs per egg mass, Max. 78, Min. 4, Avg. 54.4. Period of maximum egg laying, July 5 to 25. Last date of egg deposition, Aug. 26.

On June 25, 1919, 100 beetles were collected in the field and twenty were placed in each of five cages to secure an average egg record. The beetles were collected at random regardless of sex. Fresh bean leaves were given daily and all eggs removed and counted. An occasional egg mass was found in the field at the time the beetles were collected. When confined in numbers in a cage, the beetles would sometimes eat the eggs. The egg record has been somewhat interfered with on this account, altho no large percentage of the eggs was destroyed.

Table II gives a summary of the egg record.

Table II. Average egg record of 100 hibernated beetles, 1919.
Average Egg Record of 100 Hibernated Beetles.

Cage No.	Date first eggs deposited	Date last eggs deposited	Egg laying period	No. Egg Masses	Total eggs	Average eggs per egg mass	Average eggs per beetle
1	June 26	July 14	19 das.	27	1208	44.7	64
2	June 26	July 17	22 das.	42	2304	54.8	115.2
3	June 26	Aug. 23	59 das.	98	5651	57.6	282.5
4	June 26	Aug. 4	40 das.	75	3970	52.9	198.5
5	June 26	July 25	30 das.	69	3692	53.5	184.6
T'tls				311	16825	54.1	168.2

Average eggs per beetle, 168.2. Average eggs per egg mass, 54.1. Egg-laying period, 59 days. Last date of egg deposition, Aug. 23.

Plate I shows a graph of the egg deposition of the twenty-four pairs of beetles represented in Table I and the one hundred beetles represented in Table II. The dotted portion of the graph is an estimate of the eggs deposited in the field before the beetles were collected. The first eggs were found in the field June 18th and the last deposited in the breeding cages August 26th, showing a maximum egg-laying period of 69 days. Eggs were deposited freely from June 26 to July 28, a period of thirty-three days, with the maximum deposition occurring July 10th. The egg-laying period no doubt varies with the different seasons.

During the season of 1920 seven rows of beans thirty-five feet long were planted in a somewhat isolated place for use in studying the bean beetle. No beans were on the ground the year before. None were growing, nor had been grown the previous year closer than four hundred yards. Beginning June 30th, the plants were gone over each second day and all beetles and egg masses observed were removed and recorded. The first beetles were noted on the vines June 12th. We were unable to start the handpicking until June 30th, at which time three hundred and fifty beetles and ten egg masses totalling five hundred fifty-six eggs were found. It was impossible to collect all beetles and eggs. Enough larvae hatched from eggs that remained in the field to seriously damage the beans.

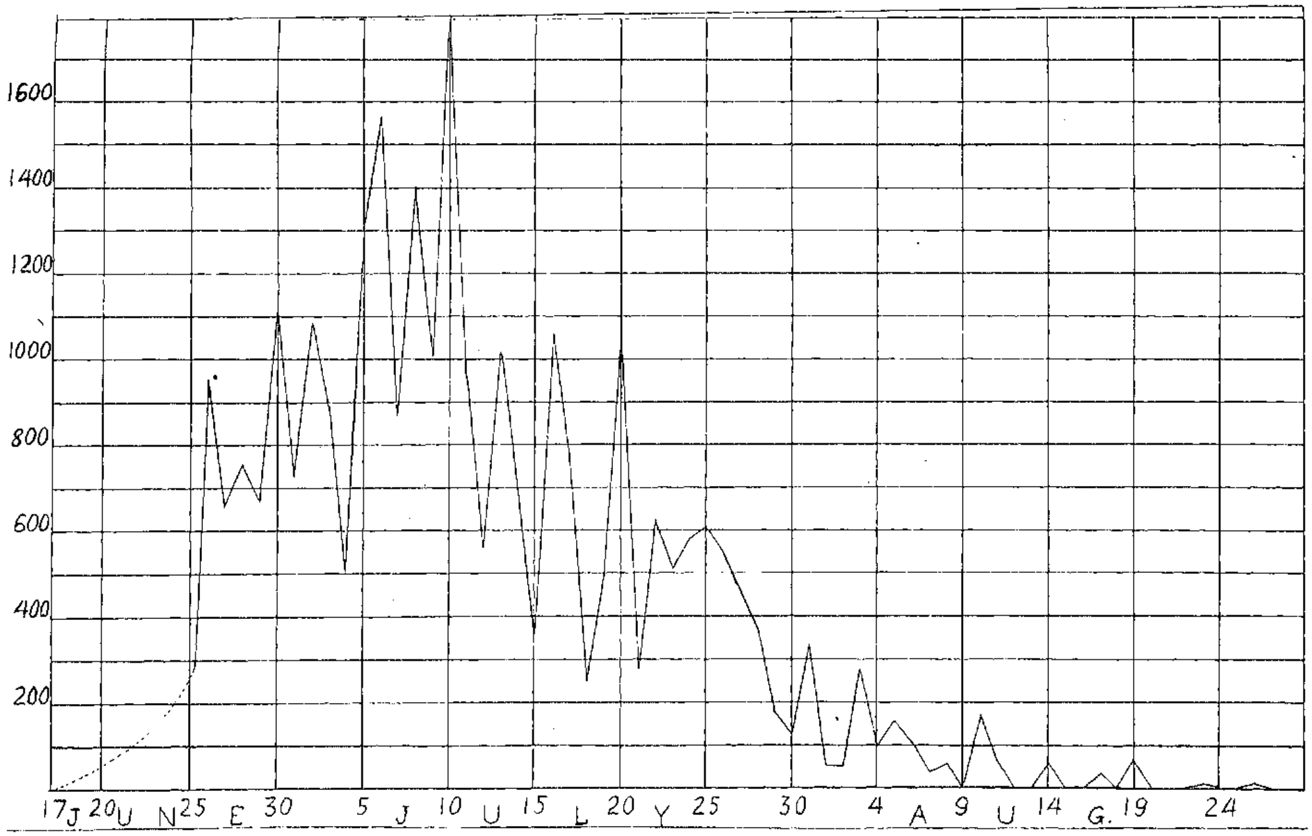

Plate I. A graph of the deposition of first-brood eggs by 148 hibernated beetles, season of 1919. The dotted portion represents the eggs deposited in field before the beetles were collected on June 25. The first eggs were deposited June 18 and the last, August 26. The maximum deposition occurred July 10. The period of heavy egg laying extended from June 26 until July 28, a period of 33 days.

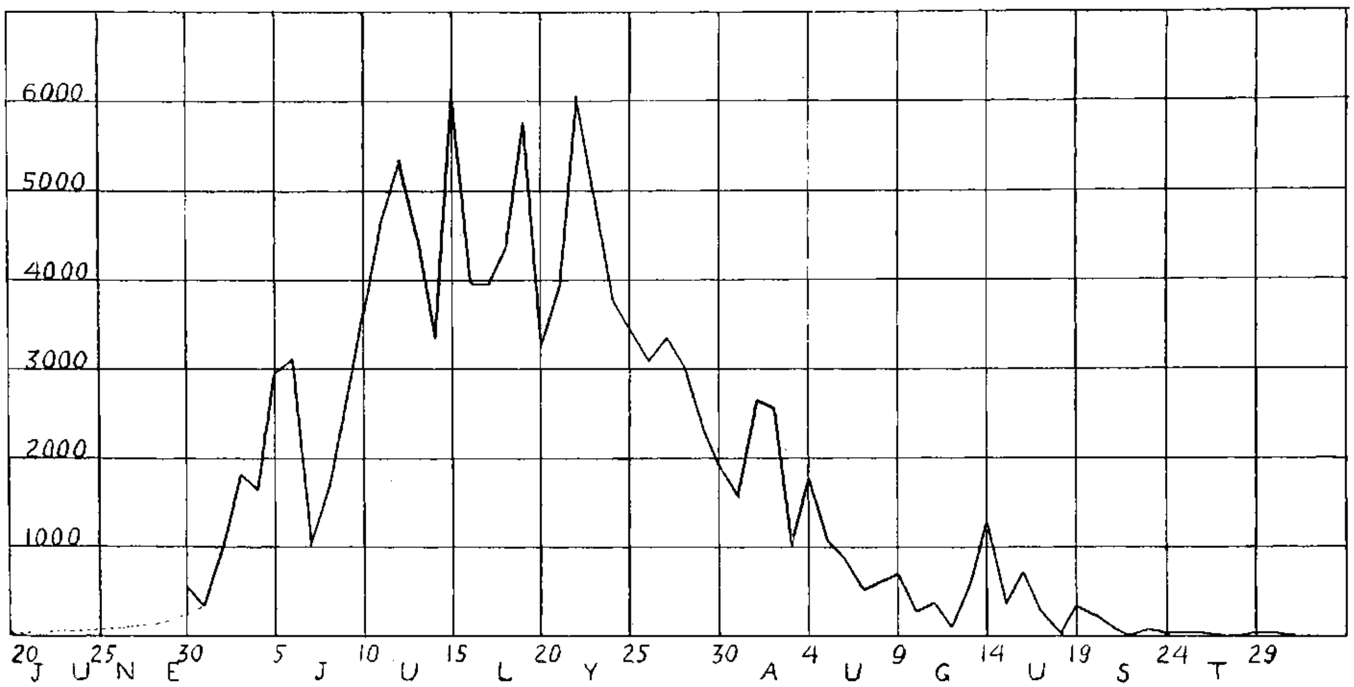

Plate II. A graph of the first-brood eggs deposited by the hibernated beetles that were collected during the season 1920 from seven rows of beans thirty-five feet long. The first eggs were deposited June 20, and the last, August 30. The period of heavy egg laying extended from July 1 to August 5.

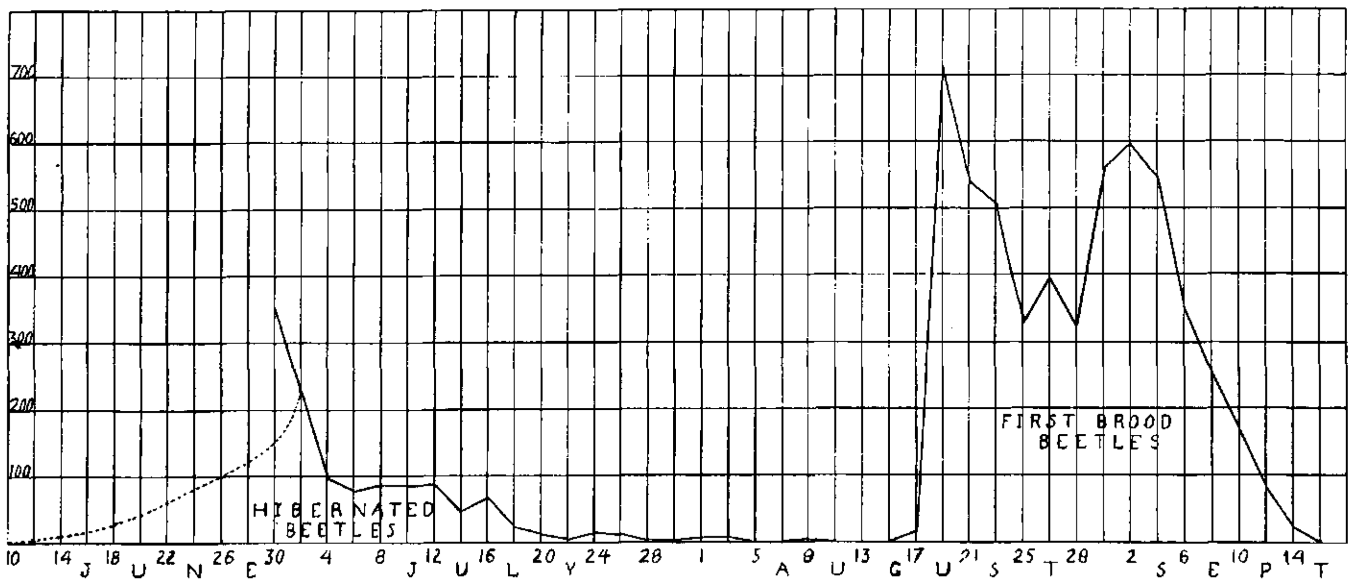

Plate III. The appearance of beetles in a plot of beans consisting of seven rows, thirty-five feet long. The first beetles appeared in the field June 12. The first collection was made June 30; the dotted portion estimates the appearance of those first collected. The appearance of the first-brood beetles is not normal on account of the removal of the hibernated beetles and the first-brood eggs.

The beetles collected were placed in breeding cages and allowed to complete their egg laying. Plate II shows graphically the total eggs collected in the field and deposited by the beetles in the breeding cages. A very small percentage was collected in the field. The five hundred and fifty-six eggs collected with the first collection of beetles are represented by the dotted portion of the graph. They were deposited some time between June 20th when the first eggs were found in the field and June 30th. The remainder of the eggs collected in the field were credited one-half to the date of collection and one-half to the preceding date. It is probable that the total egg record is somewhat higher than it naturally would have been in the field as no doubt many beetles from which we have almost a complete egg record would have migrated. The data should represent fairly accurately the egg deposition for the season. A total of 1,216 beetles were collected and a total of 119,996 eggs were recorded. This is an average of 98 per beetle. Overwintered beetles were collected as late as August 9th. Plate III represents the appearance of the beetles. This would indicate that there is a constant migration of the beetles, or they appear from hibernation over an extended period. From observing the flight of the beetles and a study of the egg record, it would seem that it is the former. The beetles of the first collection overaged 102.5 eggs, while those collected July 24th and later averaged only 19.7, indicating that they migrated into the garden well towards the end of the egg-laying period.

The maximum egg deposition occurred between July 5th and 28th. The maximum was not reached quite as eariy as in 1919. The season in general was later.

Accurate counts were made on 119 egg masses collected in the field. These totalled 6,098 eggs or an average of 51.2 per mass. The maximum for one mass was 73 and the minimum 17. Counts were made on 1,798 masses deposited in breeding cages. These totalled 96,517 eggs with an evarage of 53.6. The maximum for one mass was 87, minimum 4. The eggs are all deposited on the under side of the leaves. Usually the lower or central leaves of a plant are selected. With one female observed, the rate of deposition was one egg per minute, with another five eggs in four minutes. Occasionally a female will deposit egg masses two days in succession. In such cases the masses contain fewer than the average number of eggs. In the case of the twenty-four females used in collecting the data shown in Table I, the minimum interval between the deposition of egg masses was one day, maximum thirteen days, average 3.1 days.

INCUBATION PERIOD OF FIRST-BROOD EGGS

In 1919, beginning June 27th and continuing until August 3rd, from three to five egg masses were selected daily to determine the incubation period. Table III shows the hatching of these on specified days. In all cases the hatching of a mass was completed in a one-day period. The hatching usually occurred during the warm part of the day. Eggs failed to hatch in five masses, all other masses hatched practically 100 per cent. The incubation period of 169 masses is recorded. The minimum was six days, maximum nine days and average 7.19 days. The incubation period of a limited

Table III. Incubation period of first-brood eggs.

Date Deposited	Number of masses	Specified days of Hatching						Masses failing to hatch
		5	6	7	8	9		
June 27	5			5				
June 28	5			4	1			
June 29	4			3				1
June 30	5			5				
July 1	5			5				
July 2	5			5				
July 3	5			5				
July 4	5			5				
July 5	5			3				2
July 6	5			5				
July 7	5			5				
July 8	5			4				1
July 9	5			5				
July 10	5			4				1
July 11	5			3	2			
July 12	5			3	2			
July 13	5			3	2			
July 14	5				5			
July 15	5			2	3			
July 16	5				4	1		
July 17	5			1	4			
July 18	4			4				
July 19	5			5				
July 20	5			5				
July 21	5			5				
July 22	5			5				
July 23	5		5					
July 24	5		4	1				
July 25	5			5				
July 26	5				5			
July 27	5			5				
July 28	5			5				
July 29	3				3			
July 30	3				3			
July 31	5			5				
Aug. 3	5				5			
Totals	174		9	120	39	1		5

Average Incubation Period, 7.19 days. Minimum Incubation Period, 6 days. Maximum Incubation Period, 9 days.

number of egg masses selected the latter part of July, 1918, was as follows: Minimum 6 days, maximum 7 days, average 6.5 days.

FEEDING PERIOD OF FIRST-BROOD LARVAE

During the principal hatching period of first-brood eggs in 1919, from five to ten larvae were taken daily and data kept as to the larval stage or feeding period. The larval stage is taken as the time from the hatching until the last or the pupation moult. Feeding may be discontinued from one to three days before the pupation moult.

Table IV. Development period of first-brood larvae, 1919, including the time until the pupation moult.

Date Hatched	Total Larvae	Larvae Pupating on Specified Days													
		19	20	21	22	23	24	25	26	27	28	29	30	31	Total Days
July 4	3			1	2										65
July 5	3			3											63
July 7	2				1					1					49
July 9	5		2	3											103
July 10	5			2			3								114
July 11	4		2	2											82
July 12	5			3	1		1								109
July 13	5	1	4												99
July 14	4			1	3										87
July 15	5	1	2	2											101
July 16	3		1		1		1								66
July 17	5		1	2	2										106
July 18	5			1	2	2									111
July 19	5						3	2							122
July 20	3						3								72
July 21	5			1	2	2									111
July 22	1				1										22
July 23	5	1	1	3											102
July 24	3		2	1											61
July 25	6	1				1	2		2						142
July 26	3							2		1					77
July 27	3						1	1			1				77
July 28	1												1		30
July 29	2					1		1							48
Aug. 1	6				1	1	1	1	1	1					147
Aug. 2	2									1	1				56
Aug. 3	5									1	1	2	1		143
Aug. 4	6										4	1		1	172
Aug. 6	4						2		1			1			103
Aug. 7	7									2	5				194
Totals	121	4	15	25	16	7	17	7	4	7	12	4	2	1	2,833

Average, 23.41 days. Minimum, 19 days. Maximum, 31 days.

Table IV gives the time in specified days from the hatching until the pupation moult of 121 larvae that matured in the breeding cages under observation. The minimum length of larval stage was 19 days, maximum 31, with an average of 23.41 days. It will be noted that the period was extended the later part of July and the fore part of August when the nights began to be cooler and the mean temperature lower. No doubt the average larval period is shorter in some of the warmer sections of the State.

On July 12, 1918, approximately 100 larvae that had just hatched were placed in breeding cages. The pupation moult occurred on July 29, 30 and 31, giving an average larval period of approximately 18 days.

Table V. A detailed development record of first-brood larvae, 1919.

Larval No.	Date Hatched	1st Moult		2nd Moult		3rd Moult		4th Moult		Larval Period
		Date	Time days	Date	Time days	Date	Time days	Date	Time days	
1	8-4	8-9	5	8-14	5	8-20	6	8-28	8	24
2	8-4	8-10	6	8-14	4	8-22	8	9-4	13	31
3	8-4	8-10	6	8-16	6	8-22	6	9-3	12	30
4	8-4	8-10	6	8-15	5	8-20	5	9-3	14	30
5	8-4	8-11	7	8-16	5	8-22	6	9-1	10	28
6	8-6	8-11	5	8-16	5	8-23	7	9-2	10	27
7	8-6	8-13	7	8-17	4	8-23	6	9-1	9	26
8	8-6	8-12	6	8-18	6	8-23	5	9-2	10	27
9	8-6	died								
10	8-7	8-13	6	8-18	5	8-25	7	9-4	10	28
11	8-7	died								
12	8-7	8-12	5	8-17	5	8-24	7	9-3	10	27
13	8-7	8-14	7	8-18	4	8-24	6	9-2	9	26
14	8-7	8-12	5	8-17	5	8-23	6	9-1	9	25
14	8-7	8-13	6	8-17	4	8-24	7	9-2	9	26
Totals			77		63		82		133	355
Averages			5.92		4.84		6.3		10.23	27.3

Table V gives a detailed record of the development of fifteen first-brood larvae These were under observation during August when the larval stage was somewhat longer than the average. It will be noted that there are four distinct stages (instars) of development, each terminating by the larva moulting its old skin.

Before moulting, the larvae attach themselves by the tips of their abdomens. A longitudinal split is formed in the old skin on the under side of the thoracic region. The head and first pair of feet are worked out. With the aid of the front feet, the larva then pulls the abdomen from the skin, leaving the cast skin attached. The skin is very thin and light in color, not showing any of the yellow color of the larva. The skin is shed from the entire surface of the body and the outline of the body even to the small branches of the spines can be distinguished. The tips of the spines may carry the dark color shown by the larvae.

During most of the first stage, the larvae feed in a group near the egg mass but before the first moult, they usually scatter. Their feeding during this stage is hardly noticeable.

The second stage is the shortest of the four. The injury at this time is also quite small. They feed singularly and move often.

The third stage shows little change over the second. The larva is larger and more food is taken. The injured portions of the leaves are larger and become more noticeable.

The fourth stage is the longest and it is during this period that the greatest development takes place. The larvae are larger and demand more food. It is when the larvae reach this stage that the most injury is done to the plants. During the last day or so of this stage, the larvae may wander about and feed very little. They then glue the tip of the abdomen to the under surface of some part of the plant where they will have protection and here

Table VI. Pupation period of first-brood individuals, 1919, given in specified days.

Date of Pupation Moult	No. of Pupae	Emergence on Specified Days						
		7	8	9	10	11	12	Total Days
July 25	1	1						7
July 26	5		5					40
July 29	3	1	2					23
July 30	3		3					24
July 31	4		4					32
Aug. 1	2		2					16
Aug. 2	6		6					48
Aug. 3	6	1	5					47
Aug. 4	3	3						21
Aug. 5	4	1	3					31
Aug. 6	1		1					8
Aug. 7	2	1	1					15
Aug. 8	3		3					24
Aug. 9	2	2						14
Aug. 10	2		2					16
Aug. 11	2		2					16
Aug. 12	3		2	1				25
Aug. 13	7		4	1	1		1	63
Aug. 16	1	1						7
Aug. 20	4		4					32
Aug. 21	2		2					16
Aug. 22	1			1				9
Aug. 23	1			1				9
Aug. 24	1				1			10
Aug. 25	1				1			10
Aug. 26	1			1				9
Aug. 27	2			1		1		20
Aug. 28	2			1	1			19
Aug. 30	4			4				36
Sept. 1	9			6	3			84
Sept. 2	7			6	1			64
Sept. 3	1				1			10
Sept. 4	8			6	2			74
Totals	104	11	51	29	11	1	1	879

Average Pupation Period, 8.45 days. Minimum Pupation Period, 7 days. Maximum Pupation Period, 12 days.

the pupation moult and later the pupation takes place. They have a tendency to collect in groups for pupation. As many as seventy-five or one hundred may be found on the lower surface of a single leaf or a pod may be covered. They may collect on other plants.

PUPATION PERIOD—FIRST BROOD

The pupation period is taken as the time from the fourth or pupation moult until the beetle emerges. Table VI gives the length of this period in specified days for one hundred and four first-brood individuals under observation in 1918. They were taken so as to represent the time between July 25th and September 4th, when the first brood was pupating in largest numbers. The average pupation period was 8.45 days, minimum 7 days and maximum 12 days. It will be noted by the table that the period was longer during the latter part of the season when the mean daily temperature was lower.

After each of the first three moults, the larva has a brighter yellow color and apparently feeds with renewed vigor. After an hour or so the tips of the spines begin to darken and the larva takes on a dirty yellow appearance.

The fourth and last moult is known as the pupation moult. The cast skin is pushed back and remains as a partial protection of the abdomen of the pupa while the transformation to the beetle takes place.

It will be noted that the average larval stage of the fifteen larvae was 27.3 days and the average length of the four stages were as follows: first, 5.92 days; second, 4.84 days; third, 6.3 days; fourth, 10.23 days.

During 1918, approximately 100 individuals that had gone thru the pupation moult July 29 to 31 inclusive were observed. The adults emerged August 3rd to 6th inclusive, giving a pupation period of approximately six days. This as well as the feeding period of the larvae forming these pupae is shorter than the corresponding periods of the same season of the year of 1919. The season of 1918 was warmer than that of 1919.

SUMMARY OF DEVELOPMENT OF FIRST GENERATION

Table VII gives a summary of the lengths of the development periods of the first generation, 1919. The average total time taken

Table VII. Length of the development period of first generation, season 1919.

	Average.	Minimum.	Maximum.
Egg	7.19 days	6 days	9 days
Larva	23.41 days	19 days	31 days
Pupa	8.45 days	7 days	12 days
Totals	39.05 days	32 days	52 days

for the egg, larval and pupal stages is 39.05 days. The total time for the same stages in 1918 was 30.5. Only a limited number of individuals were observed in 1918 and these represented only the warmer part of the season.

LIFE OF HIBERNATED BEETLES

Plate IV represents the life of 707 hibernated adults. These were collected between the dates of June 30 and August 9, 1920, and are a part of the beetles used in securing the egg record given in Plate II.

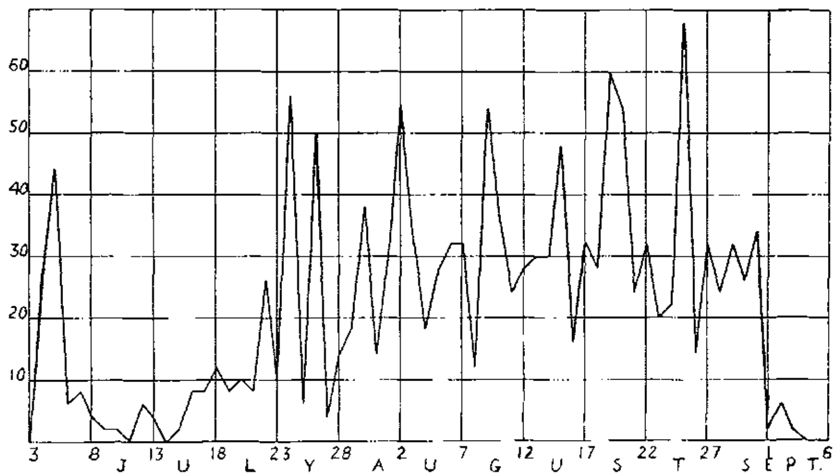

Plate IV. A graph of the death of 707 hibernated beetles collected in the field, season of 1920. Beetles lived until September 3. The highest mortality occurred between July 23 and September 1.

The beetles died in largest numbers in the period between July 23 and Sept. 1. Beetles lived until Sept. 3rd. The large number dying July 4 and 5 is probably due to injury in collection. Large numbers were collected June 30th and July 2nd.

FIRST-BROOD BEETLES

The first of the first-brood beetles emerged in the laboratory in 1920, on August 3rd. The first taken in the field was on August 4th. Plate III shows graphically the appearance of these beetles as was indicated by handpicking seven rows of beans thirty-five feet in length. The beetles did not appear in numbers until August 18th. They appeared in large numbers from this date until Sept. 10th. The handpicking was discontinued Sept. 14th. At this time the plants, due to the injury of the insect and frost, were practically devoid of foliage. Beetles emerged in considerable numbers after this date. The appearance of the first-brood beetles as shown in

Plate III may not be entirely normal due to the fact that a considerable portion of the first brood had been removed by hand-picking and many of the individuals represented migrated into the plot.

In 1919 the first individuals of the first brood of beetles emerged July 16th from pupae collected in the field. They increased in numbers rapidly from this date. In 1918 the first individuals emerged in the laboratory July 23rd from material collected in the field.

SECOND GENERATION

The percentage of a second generation of the bean beetle in the Fort Collins section varies a great deal with the different seasons. In 1920 there was practically no indication of a second generation. Only a very few egg masses were found in the field and none were deposited in breeding cages. During 1918 and 1919 there were considerable portions of a second generation. Eggs were deposited freely during August and early September and second-brood larvae in connection with the first-brood beetles destroyed practically all late beans.

EGG LAYING OF FIRST-BROOD BEETLES

In 1919 the first of the first brood of beetles emerged July 16. The first, second-brood eggs were deposited in the laboratory August 5th.

During the period of July 16 to 21, a number of first-brood pupae were collected in the field. All second-brood egg records are

Table VIII. Individual egg record of ten first-brood females, season 1919.

Cage Number	Date Beetles Emerged	Date First Eggs Deposited	Date Last Eggs Deposited	Length of Egg Laying Period	No. Egg Masses	Total Eggs
1	7-25	Aug. 7	Sept. 10	35 das.	10	330
2	7-25	Aug. 8	Sept. 24	48 das.	11	526
3	7-25	Aug. 9	Sept. 1	24 das.	8	265
4	7-27	Aug. 12	Sept. 19	39 das.	10	386
5	7-26	Aug. 8	Sept. 2	26 das.	6	266
6*	7-26	Aug. 8	Sept.		2	54
7	7-26	Aug. 9	Sept. 18	41 das.	10	494
8	7-27	Aug. 11	Sept. 17	35 das.	8	489
9	7-27	Aug. 9	Sept. 26	49 das.	10	600
10	7-27	Aug. 8	Aug. 23	15 das.	4	186
Total				312 das.	77	3596

Nine females averaged 393.5 eggs. Minimum eggs by one female, 186, maximum 600. Average egg masses per female, 8.5; minimum, 4; maximum, 11. Egg-laying period, average 34.5 days; minimum, 15 days; maximum, 49 days. Number of eggs per mass, maximum, 76; minimum, 3; average 46.7. Period of maximum egg laying, Aug. 10 to Sept. 10. Last date of egg deposition, Sept. 26.

* Beetles escaped. Record not considered.

from beetles bred from this material. All beetles used emerged during the period of July 25 to 27 inclusive.

Table VIII gives a summary of the individual egg record of ten first-brood females. The pairs were selected while in copulation and placed in breeding cages. Fresh food was given daily. All females deposited eggs. The average per female was 393.5. The period of maximum egg laying was August 10 to September 10. The date of last egg deposition was Sept. 26th.

Table IX gives a summary of the egg record of thirty-one first-brood beetles carried in two cages. These beetles emerged July 25 and 26. They were selected regardless of sex.

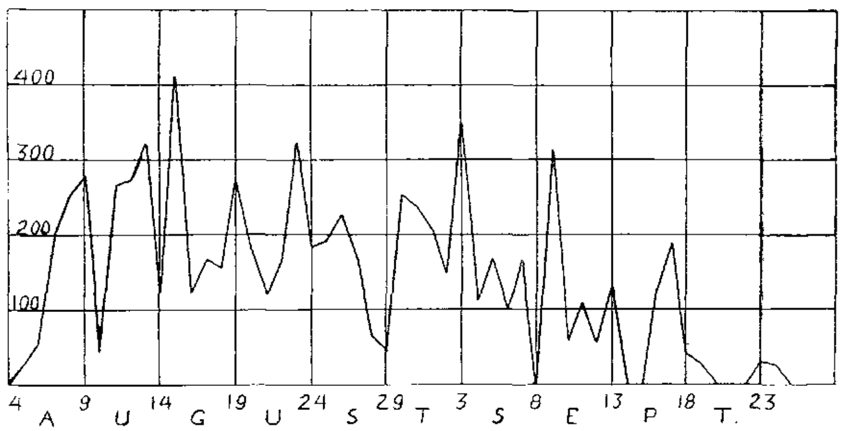

Plate V. A graph of the deposition of second-brood eggs by fifty-one first-brood beetles, season of 1919. Second-brood eggs were deposited in considerable numbers during August and the fore part of September.

Plate V shows graphically the egg deposition of the ten pairs of beetles and the thirty-one individuals used in securing the data given in Tables VIII and IX. It should represent in a general way the deposition of second-brood eggs. The exact percentage of the first-brood beetles that deposited second-brood eggs is not known.

Table IX. Average egg record of thirty-one first-brood beetles, season 1919.

Cage No.	Beetles Emerged	Date First Eggs Deposited	Date Last Eggs Deposited	Length of Egg-Laying Period	No of Egg Masses	Total Eggs
1	7-25	Aug. 7	Sept. 26	51 das.	37	1878
2	7-26	Aug. 5	Sept. 9	36 das.	50	2121
Total				87 das.	87	3999

Average eggs per beetle, 126.7. Average eggs per egg mass, 45.9. Egg-laying period, 51 days. Last date of egg deposition, Sept. 26.

All females used in breeding cages deposited eggs but they represented the first beetles to emerge. It is known that many of the later beetles laid no eggs. Probably not more than 25 per cent deposited eggs. Egg laying in the field was discontinued a few days earlier than in the laboratory. This was probably due to scarcity of food.

In 1918 the first, second-brood eggs were deposited in the laboratory August 4th. Approximately 100 beetles that had emerged on August 4 and 5 were placed in breeding cages. Only egg masses were counted. The first were deposited August 12 and the last October 12. A total of 202 egg masses were deposited. The period of maximum egg laying was from August 14 to September 14.

Table X gives a summary of the egg-deposition record of ten pairs of first brood beetles, 1918. Those in cage 1 emerged July 26, cages 2 to 7 inclusive, August 4 and 5, cages 9 and 10, August

Table X. Individual egg record of ten first-brood females, season 1918.

Cage No.	Date Taken in Copulation	Date First Eggs Deposited	Date Last Eggs Deposited	Length of Egg Laying Period	No. of Egg Masses	Total Eggs
1	July 31	Aug. 6	Aug. 14	9 das.	3	151
2	Aug. 6	No egg				
3	Aug. 6	Aug. 8	Sept. 14	35 das.	10	510
3	Aug. 7	Aug. 27	Sept. 15	10 das.	3	160
4	Aug. 7	Aug. 8	Aug. 13	6 das.	3	169
5	Aug. 8	Aug. 13	Sept. 2	21 das.	7	232
6	Aug. 8	Aug. 13	Oct. 16	65 das.	12	505
7	Aug. 10	Aug. 14	Sept. 9	27 das.	8	287
8	Aug. 10	Aug. 13	Sept. 19	38 das.	9	342
9	Aug. 30	Sept. 3	Sept. 3	1 da.	1	58
10	Sept. 4	No eggs				
Total				212 das.	56	2414

Two females laid no eggs. One female laid only one mass, 58 eggs. Average for all 10 females, 241.4. Maximum for one female, 510. Last date of egg deposition, Oct. 16. Maximum egg-laying period, 65 days. Eggs per egg mass. Minimum, 3; Maximum, 66; Average, 43.1.

20. The average egg deposition per female was 241.4. Two deposited no eggs. The last eggs were laid October 16.

The egg laying of the first-brood beetles and to some extent the time of hibernation, may depend upon the food supply available. The beetles rapidly disapear for hibernation as soon as their natural food is killed by frosts or is entirely eaten. Beetles in the natural temperature laboratory fed on protected plants will continue depositing eggs for several days after all beetles have disappeared from the field.

In 1918, approximately 100 beetles were placed in cages and given food for two days only. No eggs were deposited. Beetles emerging on the same dates and given food daily deposited eggs freely. The unfed beetles were active until cold nights came on when they went into hibernation apparently in a normal condition.

Both the fed and unfed lot of beetles perished in the cages during hibernation.

It is believed that in the field second-brood egg deposition is often limited to some extent at least by the lack of food, and the hibernation of the beetles may be hastened by the same cause.

Table XI. Incubation period of second-brood eggs, season 1919.

Date Deposited	Number of Masses	Specified days of hatching				
		8	9	10	11	Masses Failing to Hatch
Aug. 8	4	3				1
Aug. 9	5	3				2
Aug. 10	1		1			
Aug. 12	2		2			
Aug. 15	1		1			
Aug. 17	1	1				
Aug. 18	3	3				
Aug. 19	3	3				
Aug. 20	2	1	1			
Aug. 21	1		1			
Aug. 22	2	2				
Aug. 23	2	2				
Aug. 24	3			3		
Aug. 25	1		1			
Aug. 27	3	3				
Aug. 29	4			4		
Sept. 1	5		5			
Sept. 2	3		3			
Sept. 3	4		4			
Total	50	21	19	7		3

Average Incubation Period, 8.7 days. Minimum Incubation Period, 8 days. Maximum Incubation Period, 10 days.

Table XI gives a summary of data on the incubation of second-brood eggs, 1918. Eggs were taken daily thruout the egg-laying period. A total of 207 masses or 9,594 eggs were observed. Only 12.8 per cent of the eggs hatched. About 50 per cent of those not hatching were infertile and shrivelled while the embryo developed in the remainder but did not emerge. In many cases the larvae were able to force their heads and fore legs from the shells but were unable to withdraw their bodies.

The low percentage of fertility and hatching of the eggs was probably due to the cool weather and possibly to some extent to laboratory conditions. In all other work, even with the second-brood eggs, the eggs of a mass have either all been infertile or have hatched practically 100 per cent and a very small percentage of the egg masses have been infertile. In all first-brood data, it will be noted that all eggs of a mass hatched during a one-day period and in most cases all eggs deposited on the same date did the same. In Table XII it will be seen that hatching occurred over a period

Table XII. Incubation period of second-brood eggs, season 1918.

Date of deposition	Number Egg masses	Number eggs	Number eggs hatching	Number eggs not hatching	Date hatching begun	Date hatching completed	Incubation period
Aug. 4	1	63	2	61	Aug. 13	Aug. 13	9- 9 days
Aug. 5	3	133	15	118	Aug. 13	Aug. 18	8-13 days
Aug. 8	5	270	104	166	Aug. 14	Aug. 16	6- 8 days
Aug. 9	4	211	42	169	Aug. 15	Aug. 16	6- 7 days
Aug. 10	2	107	61	46	Aug. 17	Aug. 18	7- 8 days
Aug. 11	4	214	78	136	Aug. 17	Aug. 19	6- 8 days
Aug. 12	3	162	70	92	Aug. 18	Aug. 20	6- 8 days
Aug. 13	5	273	146	127	Aug. 19	Aug. 20	6- 7 days
Aug. 14	5	240	128	112	Aug. 20	Aug. 21	6- 7 days
Aug. 15	6	309	34	275	Aug. 21	Aug. 22	6- 7 days
Aug. 16	5	260	40	220	Aug. 21	Aug. 24	5- 8 days
Aug. 17	3	134	7	127	Aug. 23	Aug. 25	6- 8 days
Aug. 18	4	189	4	185	Aug. 25	Aug. 25	7- 7 days
Aug. 19	1	9	0	9			
Aug. 20	4	39	0	39			
Aug. 21	2	11	0	11			
Aug. 22	1	47	0	11			
Aug. 23	4	192	0	192			
Aug. 24	3	116	1	115	Aug. 31	Aug. 31	7- 7 days
Aug. 25	5	190	0	190			
Aug. 26	5	260	0	260			
Aug. 27	5	214	39	175	Sept. 3	Sept. 6	7-10 days
Aug. 28	5	286	8	278	Sept. 5	Sept. 5	8- 8 days
Aug. 29	6	254	37	217	Sept. 7	Sept. 9	9-11 days
Aug. 30	5	249	26	223	Sept. 9	Sept. 9	10-10 days
Aug. 31	5	224	60	164	Sept. 10	Sept. 11	10-11 days
Sept. 1	6	278	19	259	Sept. 11	Sept. 13	10-12 days
Sept. 2	5	256	76	180	Sept. 14	Sept. 15	12-13 days
Sept. 3	3	168	40	128	Sept. 15	Sept. 16	12-13 days
Sept. 4	5	290	40	250	Sept. 16	Sept. 18	12-14 days
Sept. 5	5	250	0	250			
Sept. 6	5	245	2	243	Sept. 18	Sept. 18	12-12 days
Sept. 7	5	263	14	249	Sept. 19	Sept. 22	12-15 days
Sept. 9	5	260	2	258	Sept. 21	Sept. 22	12-13 days
Sept. 10	5	206	16	190	Sept. 22	Sept. 23	12-13 days
Sept. 11	5	270	11	259	Sept. 23	Sept. 24	12-13 days
Sept. 12	5	257	1	256	Sept. 25	Sept. 25	12-12 days
Sept. 13	3	113	31	82	Sept. 24	Sept. 26	11-13 days
Sept. 14	6	193	11	182	Sept. 25	Sept. 28	11-14 days
Sept. 15	1	10	0	10			
Sept. 16	2	63	4	59	Oct. 1	Oct. 2	15-16 days
Sept. 17	1	39	0	39			
Sept. 18	1	22	2	20	Oct. 2	Oct. 2	14-14 days
Sept. 19	5	265	23	242	Oct. 2	Oct. 2	13-13 days
Sept. 20	2	97	7	90	Oct. 4	Oct. 5	14-15 days
Sept. 21	1	50	2	48	Oct. 5	Oct. 5	14-14 days
Sept. 22	2	87	0	87			
Sept. 23	2	106	13	93	Oct. 6	Oct. 7	13-14 days

TABLE XII—(Continued)

Date of deposition	Number Egg masses	Number eggs	Number eggs hatching	Number eggs not hatching	Date hatching begun	Date hatching completed	Incubation period
Sept. 24	2	46	3	43	Oct. 8	Oct. 11	14-17 days
Sept. 25	2	129	2	127	Oct. 9	Oct. 10	14-15 days
Oct. 1	2	95	6	89	Oct. 16	Oct. 18	15-17 days
Oct. 3	1	57	3	54	Oct. 22	Oct. 22	19-19 days
Oct. 4	3	100	5	95	Oct. 19	Oct. 22	15-18 days
Oct. 5	3	126	0	126			
Oct. 6	2	58	0	58			
Oct. 7	1	61	0	61			
Oct. 9	1	28	0	28			
Oct. 10	2	67	0	67			
Oct. 11	2	58	0	58			
Oct. 12	4	186	0	186			
Oct. 14	2	62	0	62			
Oct. 16	1	59	0	59			
Total	207	9576	1235	8341			10.3-11.6

of from one to five days. The maximum incubation period was 19 days. The 207 masses averaged 46.3 eggs per mass. The last eggs were deposited October 16 which was considerably later than they were deposited in the field.

FEEDING PERIOD OF SECOND-BROOD LARVAE

Beginning August 17, 1919, a few larvae were selected at in-

Table XIII. Development period of second-brood larvae, season 1910, including the time until the pupation moult.

Date Hatched	Total Larvae	Larvae pupating on specified days													Total Days
		24	25	26	27	28	29	30	31	32	33	34	35	48	
Aug. 17	6	2	2	2											150
Aug. 18	6			2	1	1		1	1						168
Aug. 24	4				1	2					1				116
Aug. 25	6						1	1		3		1			189
Aug. 26	4						1		1	1	1				125
Aug. 27	4											2	2		138
Aug. 28	4										2	1	1		135
Aug. 30	1													1	48
Total	35	2	2	4	2	3	2	2	2	4	4	4	3	1	1,069

Average Larval Period, 30.5 days. Minimum Larval Period, 24 days. Maximum Larval Period, 48 days.

tervals thruout the hatching period for observation. Table XIII gives a summary of the feeding period of these. All larvae that hatched after August 30 died before maturity. The average length of the larval stage was 30.5 days, minimum 24 days and maximum 48 days.

Table XIV. Development period of second-brood larvae, season 1918, including the time until the pupation moult.

Date Hatched	Total Larvae	Larvae pupating on specified days																									Total Eggs
		20	21	22	23	24	25	26	27	28	29	30	31	32	36	37	38	39	40	41	42	45	47	48	51	55	
Aug. 13	13				1	2	1	2	1		1	2	1	2													359
Aug. 15	13						2	2	1	1		2	3	1			1										380
Aug. 17	16	1	4	2	2	1	2	1	1	2																	353
Aug. 19	22		1		1	3	4	6	5	1				1													567
Aug. 21	18			1	6	7	2	2																			430
Aug. 23	8								1		3		3		1												248
Aug. 25	2																				1			1			90
Sept. 3	3																			1		1	1				131
Sept. 5	3														1				1							1	131
Sept. 7	1															1											37
Sept. 9	6																	1	1	3					1		253
Sept. 11	3															2	1										112
Total	108	1	5	3	10	13	11	13	9	4	4	4	7	4	2	3	2	1	2	4	1	1	1	1	1	1	3088

Average Larval Period, 28.6 days. Minimum Larval Period, 20 days. Maxi mum Larval Period, 55 days

Table XIV gives a summary of the larval period of one hundred and eight second-brood larvae under observation, 1918. All larvae hatching after Sept. 11 died before maturity. There was a low mortality among those hatching before that date. The average larval period was 28.6 days, minimum 20 days and maximum 55 days.

PUPATION PERIOD OF SECOND BROOD

Table XV gives in specified days the pupation record of thir-

Table XV. Pupation period of second-brood individuals, season 1919, given in specified days.

Pupation began	No. of Pupae	No. Pupae died	Emergence on specified days					Total Days
			13	14	16	20	26	
Sept. 10	2		2					26
Sept. 11	2			2				28
Sept. 12	2			1	1			30
Sept. 13	2	2						
Sept. 17	1					1		20
Sept. 18	1						1	26
Sept. 20	1	1						
Sept. 21	2	2						
Sept. 23	1	1						
Sept. 24	2	2						
Sept. 26	5	5						
Sept. 27	1	1						
Sept. 28	2	2						
Sept. 30	4	4						
Oct. 1	3	3						
Total	31	23	2	3	1	1	1	130

Average Pupation Period, 16.25 days. Minimum Pupation Period, 13 days. Maximum Pupation Period, 26 days. Pupae died, 23, or 74.2 per cent.

ty-one second-brood pupae that began pupation between September 9 and October 3, 1919. It will be noted that 74.2 per cent or all that began their pupation after September 18 died. The average pupation period was 16.25 days, minimum 13 days and maximum 26 days.

Table XVI gives in specified days the pupation record of ninety-one individuals, starting their pupation between September

Table XVI. Pupation period of second-brood individuals, season 1918, given in specified days.

Putation began	No. of Pupae	No. of Pupae died	Emergence on specified days							Total Days
			11	12	13	14	15	16	17	
Sept. 5	16		1	4	4		3	3	1	221
Sept. 9	3		1		2					37
Sept. 10	2				2					26
Sept. 11	5				5					65
Sept. 12	6			5	1					73
Sept. 13	10		5	5						115
Sept. 14	17		10	7						194
Sept. 15	10	4		3	3					75
Sept. 16	7			1	2	1	3			97
Sept. 18	1			1						12
Sept. 20	2			2						24
Sept. 22	3			3						36
Sept. 27	4	3		1						12
Oct. 6	5	5								
Totals	91	12	17	32	19	1	6	3	1	987

Average pupation period, 12.5 days. Minimum pupation period, 11 days. Maximum pupation period, 17 days.

4 and October 7, 1918. All individuals beginning their pupation on and after October 6 died.

The average pupation period was 12.5 days, minimum 11 days, and maximum 17 days.

SECOND-BROOD BEETLES

Due to the heavy mortality in all stages of development of the second generation, second-brood beetles are rather limited in numbers under field conditions. Those reared in the laboratory in 1919 emerged between the dates of September 22 and October 14. Those reared in 1918 emerged between the dates of September 15 and October 10. All second-brood beetles fed for two or three days and began to seek places for hibernation. None were seen copulating and no eggs were deposited.

LIFE OF THE FIRST-BROOD BEETLES

A certain portion of the first-brood beetles deposit second-brood eggs. Some deposit a large part, if not all, of their entire quota of eggs. It is not known whether those that deposit eggs in the fall live thru the winter and continue egg laying in the spring or not. The first-brood beetles form a large percentage of the beetles that hibernate.

Of the twenty first-brood beetles whose egg record is given in Table VIII, thirteen died and seven went into hibernation. Of the thirty-one represented in Table IX, twenty died and eleven went into hibernation.

SUMMARY OF DEVELOPMENT OF SECOND GENERATION

Table XVII gives a summary of the lengths of the development periods of the second generation, 1919 and 1918. The total of the average of the egg, larval and pupal stages in 1919 was 55.45 days; 1918, 51.4 days.

Table XVII. Length of the development period of the second generation, seasons 1919 and 1918.

SECOND GENERATION, 1919

	Average.	Minimum.	Maximum
Egg	8.7 days	8 days	10 days
Larvae	30.5 days	24 days	48 days
Pupae	16.25 days	13 days	26 days
Totals	55.45 days	45 days	84 days

SECOND GENERATION, 1918

	Average.	Minimum.	Maximum
Egg	10.3 days	5 days	19 days
Larvae	28.6 days	20 days	55 days
Pupae	12.5 days	11 days	17 days
Totals	51.4 days	36 days	91 days

GENERAL SUMMARY OF THE LIFE HISTORY

In the Fort Collins section there is one complete generation and a portion of the insects form a second generation. The numbers in the second generation are not as large as in the first. The mortality of the second generation is much greater than of the first.

The percentage forming a second generation varies with the different seasons. In 1920, when the season was rather short, there was little indication of a second generation. In 1918 and 1919, probably 25 per cent of the first-brood beetles deposited second-brood eggs. Many of the first beetles of the brood deposited a large portion, if not all, of their quota of eggs. There is a larger percentage of infertile eggs among the second-brood than among the first-brood eggs. Also a larger percentage of the second-brood larvae die as embryos in the egg. Many die in the field on account of the scarcity of food and cold weather. The second generation does little damage and is, therefore, of little importance economically. The percentage of a second generation is greater in some warmer sections of the State. In a few localities, there may be a full second generation. On account of the high mortality of the second generation, which comes from adverse weather conditions, and from scarcity of food, a second generation may be a detriment to the insect. In Colorado the insect is apparently as serious a pest where there is only a small, second generation as where there is practically a full, second generation.

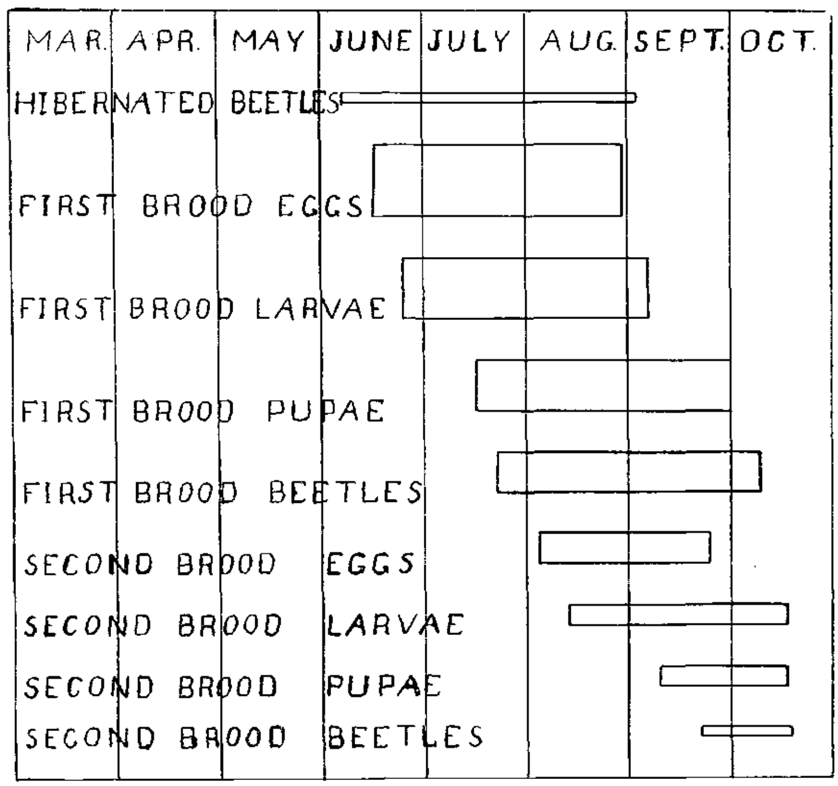

Plate VI. A graph showing approximately the periods of the year that the different broods of the two generations of the Mexican bean-beetle are present in the field. The figures may represent in a very general way the comparative numbers of individuals of the different broods.

Plate VI shows graphically the occurrence of the different broods in the Fort Collins section. The dates for the appearance or completion of a brood are only approximate as they may vary with the different years. No effort has been made to have the different figures represent accurately the number of individuals of a brood. They may give a general comparison of the numbers making up the broods of the two generations and of the mortality of the second generation.

It will be noted that there is a period including the last of July and most of the month of August when some hibernated beetles, the maximum number of first-brood larvae, considerable numbers of first-brood beetles, and a slight overlapping of the second brood larvae are all at work in the field. It is at this season of the year that the maximum injury to the bean crop occurs. The first-brood larvae in their third and fourth instars, or stages of development, are responsible for the greatest amount of this injury. The first-brood beetles may do considerable injury. Usually this is greater than the injury from the second-brood larvae.

NATURAL ENEMIES

The bean beetle is especially free from natural enemies. During the handling of large numbers of all stages of the insect during the past four years, no parasitic or predaceous insect enemies have been observed. The adult bean-beetles have, in a few cases, eaten a limited number of their own eggs in breeding cages. Occasionally a partially eaten egg mass has been found in the field. This may have been eaten by the bean beetle or by other species of the lady-beetle family that have been reported as feeding upon the eggs of this species.

Dr. Morrill reports observing an undetermined ant feeding upon the eggs.

Dr. F. H. Chittenden reports: "In one case the larva of a lace-wing fly (*Chrysopa* sp.) was observed sucking the juices from a partially grown larva."

The numerous spines over the body of the larva apparently afford almost perfect protection. The beetles are protected by the hard, wing covers and by an offensive, yellow liquid which is secreted in small drops from the knee joints when the insects are disturbed. Birds have never been observed feeding upon any stages of the insect. Poultry, even when confined in close quarters, will not eat larvae or adults.

PREVENTIVE AND CONTROL MEASURES

It is good agricultural practice to destroy, as soon as crops are removed, all useless material in and around the field or garden. Such practice may be of benefit in keeping the bean beetle in check by destroying individuals in hibernation or by destroying hibernating places and causing a lessening of the infestation in the immediate locality. Judging from the difficulty in finding hibernating beetles in the Fort Collins section, much hope cannot be held out for such practice being of material help in keeping the pest under control under Colorado conditions.

Often the bean crop will be ready to harvest, or so badly eaten that it is of no value, while large numbers of larvae and pupae are present. Such a crop should be harvested or pulled and burned for the destruction of the insects.

CROP ROTATION

Crop rotation, if practiced on large enough units of land, will undoubtedly be of material benefit. The beetles fly freely at hibernation time and also as they come from hibernation, so much protection could not be expected from this practice in city-garden sections and in truck-garden sections. For the general farmer who has a larger unit of land available and will separate the new field as far as possible from the old, such a practice should lessen the number of adults that will find the planting.

PLANTING TIME

In the heavily infested sections, early planting has been by far the most successful. It will be noted from Plate VI that hibernating beetles do not appear until well into June and the first-brood larvae late in June. The hibernating beetles do not, as a rule, seriously damage a bean crop if the plants are well started when they appear, and the first-brood larvae are not numerous enough to do serious damage before the latter part of July. Early planted beans of early maturing varieties will often be in bloom when the adults appear and have pods well formed when the larval injury becomes serious. In this way a good crop of snap beans can be produced and often a fair crop of dry beans will mature. The success of this practice will depend upon geting the crop planted at the earliest, possible date that will avoid spring frosts. This date will vary in different localities and must be determined for each. Early planting makes control by spraying more practical. If plants are practically fully developed by the time injury begins, one application of spray will keep the foliage well covered during this entire period, while if the plants are growing rapidly, the insects go to the new, unprotected leaves and a number of applications may be necessary.

Late planting, if practiced over an entire community, would undoubtedly have the effect of starving and reducing the numbers of the first generation. Late planting, in a community where only a small portion of the beans are of such planting, is useless as the plants will be small while the maximum injury is occurring and if they are not destroyed by the first-brood larvae, they will be by the first-brood beetles and second-brood larvae.

In sections of considerable size, if community co-operation could be developed to the point that beans would be planted only on alternate years, the infestation could probably be kept to a point where serious injury would not result. Such a practice is practical with an insect that is limited to a single food plant that is an annual and grows only under cultivation.

VARIETIES TO PLANT

Success will depend to a considerable extent upon the variety of bean planted. Early planting is of value only when early maturing varieties are used. The success of spraying depends upon keeping the foliage covered with an arsenical compound during the period of possible injury. With late maturing varieties it takes a number of applications of spray to do this. Beans of vining type should be avoided as they have a long growing season and it is almost impossible to effectively spray the large mass of foliage produced. The strictly bunch beans are usually early maturing and are much more easily sprayed. They should be grown exclusively in a bean-beetle, infested section.

The writer has had an opportunity to make notes on 242 varieties of the kidney type of beans being grown by the Botany Department of the Colorado Agricultural Experiment Station. Of the 26 most successful varieties, all are early maturing, 21 have the bunch or bush type of growth, 4 have only a slight tendency to vine and one has a marked tendency to vine but would not be classified as a vining or pole bean.

TRAP CROPS

Under certain conditions, a combination of a trap crop with delayed planting of a portion of the field, might be used to advantage. During the season of 1919, the writer visited a 20-acre field of beans in western Weld county that had been planted early in the season but the soil was so dry that they did not come up until irrigated. In the meantime an irrigation ditch broke and wet about one-half acre of the field. The beans in this portion came up about three weeks earlier than in the remainder of the field. The bean beetles concentrated here and destroyed the crop while little damage resulted upon the remainder of the field. From what we could learn of the planting time, these had come up after the beetles had deposited a greater portion of their eggs upon the few, early plants. There were no other beans closer than a half mile. The insects might have been effectively destroyed upon the small infested area.

First-brood beetles often collect in large numbers on late planted beans after the earlier crops have been harvested or destroyed. The general infestation could be reduced by destroying these, while congregated, by burning the plants or by spraying with a strong kerosene emulsion.

BRUSHING

If the larvae are brushed from the vines to a dry soil during the warmest part of the day, those that are in the direct sun will be destroyed by the heat. Some protection can be secured in this way. The small larvae are not as easily brushed from the plant as the larger ones.

HAND-PICKING

During the season of 1920, seven rows of bunch beans thirty-five feet long were hand-picked, each second day from June 30 until the end of the season. Eggs were beginning to be deposited freely when the work was started but none had hatched. All adults and eggs were removed. No attempt was made to hand-pick the larvae hatching from the few eggs that were missed. Plate III shows graphically the appearance of the hibernated and first-brood beetles. A record was kept of the time taken for the hand-picking. The total time until September 14, when the work was discontinued, was 20 hours and 54 minutes. It will be noted from Plate III that hibernated beetles were collected in considerable numbers until July 28th. The greatest benefits from hand-picking undoubtedly come from the removal of these beetles and the first-brood eggs. The total time taken for the hand-picking until July 28 was 5 hours and 27 minutes. The time was increased somewhat by the fact that the beetles and eggs were collected and handled in such a way that they could be used for breeding-cage work. If a shallow pan containing oil or a small amount of water with a film of oil, had been used for the collection work some time could have been saved.

At a wage of 40 cents per hour, the cost per acre would have been approximately $245.00. The beans were drilled in the row and averaged six plants to the foot.

Regardless of the care taken, quite a few eggs hatched in the field. The injury caused by the beetles and the larvae caused much of the foliage to drop and not more than half a crop of beans was produced.

As a preventive measure, the hand-picking is only partially effective. As a commercial proposition, it is impractical. When time is not considered, hand-picking of the hibernated beetles and the first-brood eggs can be used to advantage, especially in protecting the early crops of snap beans.

SPRAYING

Spraying experiments for the control of the bean beetles have been carried on for four seasons. For the most part these have been confined to tests of the arsenical insecticides. In all of this work the spraying on small plots was done with a bucket pump or a hand pump on wheels. A right-angle, mist-producing nozzle, placed on a four-foot rod was used. An effort was made to cover the under surfaces of the foliage, especially. In the field experiments a large hand pump that had been used in spraying sugar beets was used. It would carry a pressure of from 125 to 160 pounds with 9 mist nozzles spraying three rows. In this work each row was sprayed by three nozzles, one from each side spraying somewhat upward and one from above. In spraying small plants some liquid was wasted but little was wasted on larger plants when the size of the opening in the disc of the nozzle was adjusted to the pressure of the pump and gait of the team.

The dusting was done with a hand-power duster.

In some cases, beetles and larvae were placed in cages and fed foliage from the sprayed plots in order to determine the killing effect of the material.

Extracts from Unpublished Notes by Johnson and Gillette

The results obtained in some preliminary experiments carried on during previous years by S. Arthur Johnson and Dr. C. P. Gillette were a guide in selecting the materials used. For the most part the materials they had tested had been used on individual plants in cages or on small plots, with the object in view of determining the safety in using the materials on the plants as well as their effect on the insects.

Ortho zinc arsenite powder was used at the rate of 1, 2, 4 and 6 pounds to 100 gallons of water. With the 1-pound strength, 5 of 30 larvae confined on the sprayed plant were alive on the tenth day. The leaves were quite badly eaten and showed a slight burning. A second test of this strength showed no burning. On the tenth day 3 of 14 larvae were alive on the plant sprayed with the 2-pound strength. There was little injury from the larvae and no more burning than with the 1-pound strength. All larvae were killed with the 4-pound strength and there was only a slight amount of burning. All larvae were killed with the 6-pound strength. The lower leaves of the plant were burned in spots. The same amount in summer-strength Bordeaux mixture showed about the same results.

The plant sprayed with Bordeaux mixture with paste arsenate of lead (Sherwin-Williams), 6 pounds of paste to 100 gallons, 27 larvae placed on plant. All larvae dead at end of fifth day. There was no injury to the plant from the spray.

Small plots in the field were sprayed with the following strengths of paste arsenates:

Ortho (California Spray Co.)	1 oz. to 1 gal. of water
Sherwin-Williams	1 oz. to 1 gal. of water
Grasselli	½ oz. to 1 gal. of water
Hemingway	½ oz. to 1 gal. of water

The plants sprayed with Sherwin-Williams lead were killed, the others were only slightly burned. Those sprayed with Ortho and Grasselli showed very little injury from the insect, while those sprayed with Heminway's were quite badly injured.

One plant in cage was sprayed with pyrethrum, 1 ounce to 1 gallon of water. There were 15 larvae on the plant and none were killed. The plant was badly eaten, but there was no injury from the pyrethrum. The test was repeated with the same results.

Another plant was sprayed with commercial lime-sulfur solution, 1 part to 40 parts of water containing paste lead arsenate, 1 ounce to 1 gallon. Six larvae were placed on the plant but left without breeding and the plant was killed.

One plant containing four larvae was sprayed with lime sulfur, 1 part to 30 parts of water. All larvae were alive at the end of 24 hours; 2 died on the ninth day and the other pupated. The plant was uninjured.

One plant, containing 17 larvae, was sprayed with Black-Leaf tobacco product, 1 part to 75 parts of water. Many larvae fell from the plant as if dead but later became active and all but six matured on the plant. The same material, 1 part to 60 parts of water failed to kill the larvae.

Twenty larvae on one plant were sprayed with white hellebore, 2 ounces to 1 gallon of water. Six larvae died and all others matured. The plant was not injured by the spray.

Plants were sprayed with Vreeland's Electro Lead Arsenate, 3 pounds to 100 gallons of water and 3 pounds to 100 gallons of Bordeaux mixture. There was a little burning when used with Bordeaux mixture and very severe burning when used in water. Plants were also slightly burned when sprayed with the same material at the rate of 1 1-2 pounds to 100 gallons of water.

A plant was sprayed with Devoe and Reynold's paste lead arsenate, 3 pounds to 100 gallons of water. Ten larvae were placed on the plant. Three days later both plant and larvae were dead.

Six adults on another plant were sprayed with Ortho Lead Arsenate paste, 6 pounds to 100 gallons of water. All were alive on the fourth day; one died on the twelfth day, and the remainder were alive on the eighteenth day. They fed quite freely on the plant.

Four adults were confined on a plant sprayed with iron arsenate, 6 pounds to 100 gallons of water. The beetles fed freely and all were alive on the fourth day. One died on the twelfth day. No injury to the plant was recorded.

Another plant was sprayed with arsenic sulphide, 3-4 pound to 100 gallons of water. The beetles were not killed and no spray injury to the plant was recorded.

Arsenic sulphide was later used, 3 pounds to 100 gallons of water. The water was heated to dissolve the material. Thirteen of the 14 larvae on the sprayed plant died. The plant also died.

Another plant sprayed with the same material and strength, with lime at the rate of 6 pounds to 100 gallons added, was also killed.

One plant was sprayed with Paris green, 1 pound to 100 gallons of water. On the sixth day, three of nine larvae were dead. The plant was also dead.

Another plant was sprayed with Paris green, 1 pound to 150 gallons of water to which was added lime at the rate of 6 pounds to 100 gallons. On the fourth day, 6 of 10 larvae were dead. The plant was killed by the spray.

Cooper's V2 tree spray, 1 part to 100 gallons of water, killed all plants sprayed.

Arsenite of lime, prepared according to the Kedzie formula, killed all plants in all strengths used. The same was true when it was used with an excess of lime and with lime-sulfur solution.

Soap, used as a spreader with different arsenicals, increased the burning.

SPRAYING EXPERIMENTS

SEASON 1917

Experiment 1. July 21, a few plants were sprayed with zinc arsenite, 1 1-2 pounds of the powder to 100 gallons of water. Lime was slacked and added at the rate of 1 1-2 pounds to 100 gallons of spray. The plants showed no injury from the spray. Ten beetles were placed in a cage and fed foliage from sprayed plants. At the end of 24 hours, they were sluggish and were feeding very little. Five died on the third day, one on the fourth and 4 on the fifth day. No eggs were deposited. In a check cage fed on unsprayed foliage, two beetles died on the third day and the others were active and feeding normally at the end of 10 days. Several masses of eggs had been deposited.

Experiment 2. A few plants were sprayed July 24 with 2 pounds of powdered zinc arsenite and 6 pounds of lime to 100 gallons of water. No burning of the plants occurred. Seventeen beetles were placed in a cage and fed foliage from the sprayed plants. They fed very little and soon became inactive. Thirteen died on the second day and 4 on the third. The beetles in a check fed freely on unsprayed foliage and at the end of 10 days had deposited a number of egg masses.

Experiment 3. On July 21, a block of snap beans was sprayed with 1 pound of powdered zinc arsenite and 3 pounds of lime per 50 gallons of water. Larvae were very numerous and considerable injury was showing on the plants. A few larvae were mature. The plants were almost fully developed, many of the pods

Fig. 9—Breeding cages were maintained in the field as well as in the insectary. The illustration shows cages in which beetles and larvae were confined on plants that had been sprayed with different insecticides.

being 2 inches in length. On August 2, a few live larvae were present but a large percentage had disappeared. A number of dead ones could be found on the ground and clinging to the leaves. On August 3, the few live larvae had collected on the new or unsprayed foliage. Only a very few adults were found. As no dead adults were found it was thought they were repelled by the spray. There was a small amount of burning on the leaves, especially those that had been injured by the insect. Some leaves dropped early in the season but the plants produced a fair crop of beans.

Experiment 4. An adjoining block to Experiment 3 was sprayed on the same date with powdered lead arsenate, 1 pound to 50 gallons of water, with 3 pounds of lime addded. The killing effect on the insect was practically the same as in Experiment 3, but the foliage was injured much worse by burning, with the result that a large portion of it fell in a few days. Many small pods were burned and fell. The crop was considerably better than on the checks, but not as good as in Experiment 3.

Experiment 5. A block was dusted with "Insecto," 1 part to 4 parts of lime. Insecto was a combination insecticide and fungicide, consisting of calcium arsenate and Bordeaux mixture. It contained 14 per cent arsenic oxides. Only a few larvae were killed and serious burning resulted.

Experiment 6. A block was dusted with 1 part arsenate of lead and 4 parts lime. Very little benefit could be noticed. Only slight injury resulted.

Check: One check was used for Experiments 3, 4, 5, and 6. Practically all of the foliage dropped from the plants before the beans were mature. A very light crop of beans was harvested. Many pods were partly eaten by larvae and first-brood adults.

SEASON 1918

Experiment 1. Applications were made of powdered arsenate of lead, arsenate of calcium and arsenite of zinc at the strengths of 1 pound to 20, 40 and 60 gallons of water. The tests were repeated on adjoining blocks with lime added in amounts equal to the insecticide. The applications were made June 22. The beetles were beginning to appear in numbers but injury from them was not noticeable. The plants were from four to six inches tall and in a thrifty, growing condition. They had not begun to blossom. The check consisted of a block comprised of a portion of each row.

On July 28 very few beetles were present on any of the sprayed plants and very few eggs had been deposited. Beetles and eggs were quite abundant on the check.

All strengths of the arsenate of lead with and without lime caused a checking of the growth of the plants. Later observations showed there was little growth during a 10- or 15-day period. There was only a very slight burning. This was most apparent on leaves that had been injured by insects and on the plants sprayed with the 1-to-20 strength. Very little difference could be noted where the lime was added.

The arsenate of calcium, in all strengths, with and without lime, burned the foliage. The plants were practically destroyed where the 1-to-20 strength was used. The burning was somewhat less with the other two strengths but was very severe and all growth was stoppped for a 10- or 15-day period.

There was no injury from any application of the arsenite of zinc. The plants continued to grow and could not be detected from the checks until insect injury begun to be noticeable on the check.

All materials and strengths had the effect of preventing the beetles from depositing eggs on the sprayed plants. No dead beetles could be found so the sprays may have acted as repellants.

A second application of all materials was made on adjoining blocks July 19. At this time the plants were in bloom and a number of pods two inches in length were present. The injury from larvae was becoming quite severe.

The results from the different materials and strengths corresponded very closely with those from the first applications.

Checking of the growth was not noticeable as the plants were practically mature when sprayed. The arsenate of calcium in all strengths, with and without lime, burned severely. Most of the leaves and many of the blossoms and small pods dropped in a few days. Very few beans were produced.

The arsenate of lead in the 1-to-20 strength, with and without lime, burned the plants about the same as did the arsenate of calcium. The other strengths did not do so much injury although many blossoms failed to form pods and the insect-injured leaves were sufficiently burned to cause them to drop within a short time. There was very little difference where the lime was added to the spray. Th crop of beans was enough better to justify the expense of spraying.

The only injury from the arsenite of zinc in any of the strengths was an early dropping of some of the leaves. This was quite noticeable on the plot sprayed with the 1-to-20 strength. There apparently was some injury to blossoms on the 1-to-20 and 1-to-40 blocks which prevented them from forming pods. There was little, if any, benefit from the addition of lime. The plots sprayed with the arsenite of zinc produced a good crop of beans. The check was very badly eaten by the insect and produced only a very light crop.

Experiment 2: Aplications were made June 24 and 26 of the following materials and strengths: Zinc arsenite, 1 pound to 20 and 40 gallons of water, calcium arsenate, 1 pound to 20, 40 and 60 gallons of water, with and without lime. The lime was used in equal parts with the insecticide. Arsenate of lead, 1 pound to 20 and 40 gallons of water. Unfortunately the detail notes on this experiment were misplaced.

The results from the arsenate of calcium in all strengths, both with and without lime, were very unsatisfactory on account of burning. The results from the use of lead were somewhat better. The burning from the 1-to-20 strength was quite severe. The results from the 1-to-40 strength justified the expense.

Some injury to blossoms and leaves results from the use of the zinc, 1 pound to 20 gallons of water. The results from the 1-to-40 strength were satisfactory.

Experiment 3: On July 26 small blocks were sprayed with the following: Black Leaf 40, 1 part to 500, 750 and 1000 parts of water; kerosene emulsion carrying 4 and 8 per cent kerosene.

There apparently were no benefits from the Black Leaf 40.

Some preliminary tests made in the laboratory had indicated that the kerosene emulsion was very effective in destroying all stages of the insect. The laboratory data were not substantiated by the field tests as there was little, if any, benefit from any of the strengths. There was a small amount of injury to the plants from the 8 per cent emulsion.

The laboratory tests of the kerosene emulsion had indicated

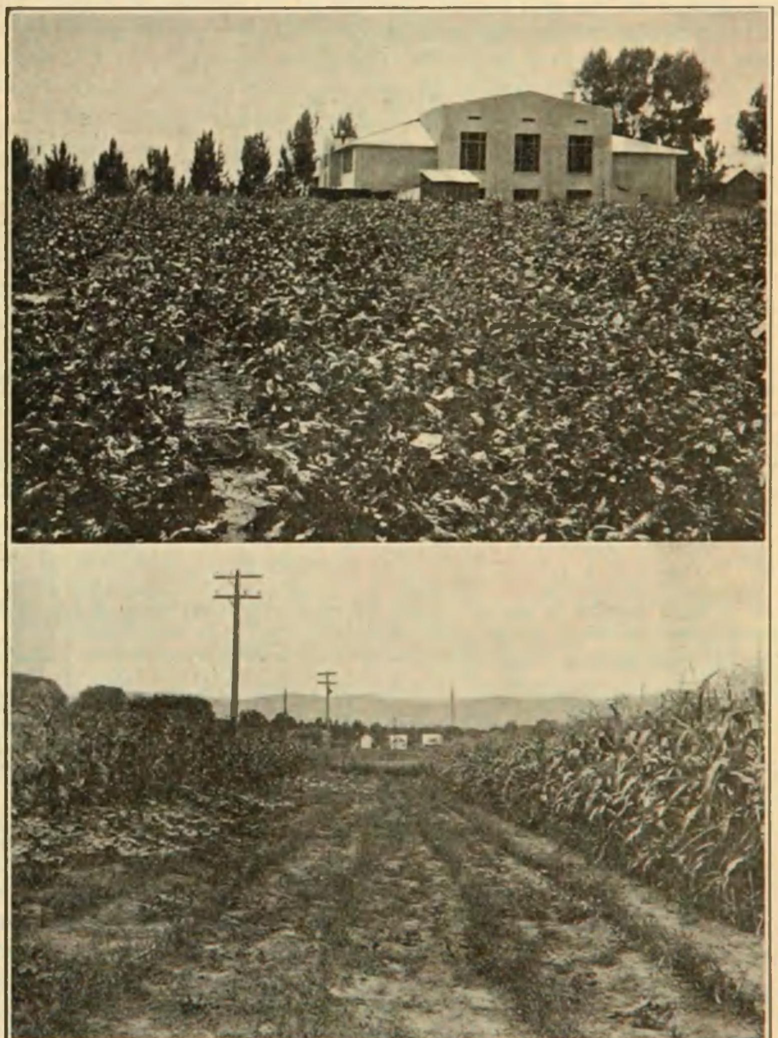

Fig. 10—(Upper) A view of a portion of the experimental field sprayed two times, season 1918, with arsenite of zinc, one pound of the powder to 40 gallons of water.

(Lower) The "check" or unsprayed plot in the same field.

that a 4 per cent emulsion was very effective on all stages of the insect and lower strengths were quite effective. The laboratory applications were made by dipping the specimens into the emulsion Regardless of the care taken there may have been a film of oil formed upon the surface of the emulsion and the results were influenced by this. In view of this uncertainty and the fact that later applications in the laboratory made by spraying did not show much benefit from kerosene emulsion, the laboratory data is not given in detail.

SEASON 1919

Experiment 1: On June 25 beetles were collected in the field and approximately 40 placed in each of three cages, designated as cages 1, 2 and 3. They were fed daily on foliage from fields 1, 2 and 3, sprayed on the same date with arsenite of zinc in the following strengths:

Field 1—one pound to 40 gallons of water.
Field 2—one pound to 50 gallons of water.
Field 3—one pound to 60 gallons of water.

Table XVIII shows in specified days the death of the beetles. Cage 3 shows a somewhat longer average life than the others. All beetles were dead at the end of the sixteenth day. The eggs deposited were as follows: Cage 1, 312; cage 2, 171; cage 3, 234. These were all deposited during the first four days and 65 per cent of them were deposited on the first day after being placed in cages.

Table. XVIII. Length of life of beetles fed on leaves taken from sprayed fields.

Cage No.	Death of beetles on specified days																	Average Life
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
1	2	1	5	1	2	3	4	5	2	5	4	2				3	39	7.7 days
2		1	1	7	7	6	3	3	2	4	2	1	3				40	7. days
3		2	3	4	1	2	3	3	6	1	4	3	3	2		1	38	8.3 days
Total	2	4	9	12	10	11	10	11	10	10	10	6	6	2		4		

On July 9, sixty beetles were placed in cages and fed foliage from a field sprayed with arsenite of zinc, one pound to 50 gallons of water, and 20 beetles were placed in other cages and fed unsprayed foliage. At the end of 12 days, all but one of the sixty beetles were dead. The last one died on the seventeenth day. During the first three days they deposited a total of 581 eggs. The average life in the cages was 6.7 days. They ate very little and those that were not dead after the second day were very sluggish. The 20 beetles that were fed unsprayed foliage deposited a total of 1133 eggs. The average life in the cages was 25.6 days. The last beetle died August 23 after being in the cage 46 days.

Experiment 2: Larvae were collected in the field and 30 placed in each of four cages, designated as cages 1, 2, 3 and 4. Cages 1, 2 and 3 were fed on foliage from fields 1, 2 and 3 mentioned in Experiment 1. Cage 4 was fed on foliage from unsprayed plants. Many of the larvae were mature when collected as is indicated by the fact that they began pupation within three days after being caged. In cage 2, 11 larvae pupated during the first two days and 14 died before the eighth day. In cage 3, seven pupated during the first two days and 27 died before the seventh day. In cage 4, six pupated during the first two days and 14 pupated between the fourth and fourteenth days. Two larvae died on the seventh day and one on the eleventh.

Experiment 3: A plot of beans comprising one city lot was divided into three blocks. Block 1 was sprayed June 21 with one application of arsenite of zinc, one pound to 50 gallons of water. This application was made as the beetles began to be numerous before they damaged the foliage and before eggs were hatching. The plants had attained almost their full growth. They were past the blooming period and pods were two inches in length. On the third day several dead beetles were found and others were sluggish. The beetles were much more numerous on the check. Very few eggs were deposited on the sprayed plants. The spray probably acted, to some extent, as a repellant.

As the beans were an early variety and had been planted very early, the check made a fair crop but the leaves had all dropped two weeks earlier than from Block 1.

Block 2 was sprayed July 12, just as injury from larvae was becoming apparent, with arsenite of zinc, one pound to 50 gallons of water. Beans were well formed in the pods. Larvae and adults were abundant. A few days later larvae were much less numerous and beetles were avoiding the sprayed plants. The injury was not as serious as on the check but slightly more than on Block 1.

Experiment 4: Different blocks were sprayed with arsenite of zinc, one pound to 40, 50 and 60 gallons of water. The applications were made when the plants were well developed and had pods two inches in length. Injury from larvae was becoming apparent. The check was practically destroyed before the crop was mature. More damage was done on the block sprayed with the 1-to-60 strength than on the others. The sprayed blocks all made a fair crop. There was no injury from burning by the arsenic in the insecticide.

Experiment 5: The object of this experiment was to see if it was practical to protect beans that were planted late and were small and growing rapidly during the period of most injury from the insect. The plot consisted of about one-quarter of an acre of pinto beans which had been planted on the college farm for an irrigation experiment. It was impossible to leave a check but unsprayed beans within a few hundred yards were very badly damaged and the crop on the same ground the year before had been destroyed.

Three applications of powdered arsenite of zinc at the rate of one pound to 40 gallons of water were made. The first application was made June 23. The beans had been up only a few days and no true leaves had been formed. Beetles were quite numerous and doing considerable damage. Two days later a number of dead beetles were found and many others were inactive. Very little additional damage had been done.

By July 8 many plants were six inches in height and beetles were feeding on the new growth. Egg masses were rather numerous. A second application was made. On July 11 a number of dead beetles were found and very few eggs were being deposited. Most of the larvae were being killed by the feeding they did on the leaves on which they hatched.

On July 25 newly hatched larvae were doing some damage to new leaves. A third application was made. Very little damage occurred after this. A casual observer would not have known the field was infested until later when the first-brood beetles began to come in from surrounding fields. As the plants were almost fully developed when the third application was made, the first-brood beetles and partial second brood of larvae did little damage. A good crop of beans was harvested. It is possible that the third application was not of enough benefit to justify the expense.

SEASON 1920

Experiment 1: The following materials were applied July 8 to various sized blocks in a field of navy beans:

Arsenite of zinc, one pound to 40 gallons of water.
Arsenite of zinc dust.
Lead-Bordeaux (Hexpo) 6 2-3 pounds to 50 gallons water.
Arsenate of magnesium, one pound to 40 gallons of water.
Arsenate of lead, one pound to 40 gallons of water.

The plants were well developed at the time the applications were made, beetles were quite numerous and eggs were being deposited freely. Little damage had been done by the adults.

The check was not severely injured, the foliage dropped earlier than on the sprayed plots but there was little difference in the crop.

All applications gave a fair protection. The dusting with the zinc probably was not as effective as spraying with the same material. There was no serious burning from any of the materials.

Experiment 2. A half-acre field of pinto beans was divided into two blocks and sprayed July 7 with arsenate of lead and arsenite of zinc at the rate of one pound to 40 gallons of water. The beans were about four inches high and were being badly injured by adults. Eggs were plentiful but no larvae were found.

There was a small amount of burning from both materials and apparently a stunting effect from the arsenate of lead. Larvae became quite numerous and a second application was made August 6. No burning from this was noticed. The field produced a good crop of beans.

Experiment 3: A 2-acre field was divided into equal parts and sprayed August 6 with the following materials, all used at the rate of one pound to forty gallons of water:

California Spray Chemical Co.—arsenite of zinc.
Grasselli Chemical Co.—arsenite of zinc.
General Chemical Co.—arsenite of zinc.
Magnesium arsenate and lead arsenate.

The beans were planted late and did not attract as many beetles as near-by fields planted earlier. The check plot was not seriously damaged.

All materials showed good protection with little burning of foliage. The greatest amount of burning was on the block sprayed with arsenite of zinc from the General Chemical Company.

Experiment 4: Small blocks of a very heavily infested garden were sprayed July 17, after injury from larvae was quite severe. Larvae and eggs were abundant. The plants were just past the blooming period. The following materials were used: lead arsenate, magnesium arsenate, General Chemical Company's zinc arsenite, California Spray Chemical Company's zinc arsenite, one pound to 40 gallons of water and California Spray Chemical Company's zinc arsenite applied as a dust.

The foliage was badly eaten on all blocks before the larvae were killed, yet a fair crop of beans was produced. The dust did not give as good results as the spray. There was little difference in the control on the other blocks. The General Chemical Company's arsenite of zinc caused quite severe burning. The check produced no beans.

Experiment 5: Table XIX gives the results of a number of tests of materials for the destruction of eggs. The materials were applied by spraying

Some tests of kerosene emulsion, made in 1918 by dipping, had indicated that this material was very effective on all stages of the bean beetle. These results were not substantiated by field tests nor by the laboratory spraying tests report in Table XIX. It will be noted that none of the materials, in strengths that would be safe to use on the plants, were effective.

A large number of other tests were made during the years of experimentation that cannot be reported on in detail. These com-

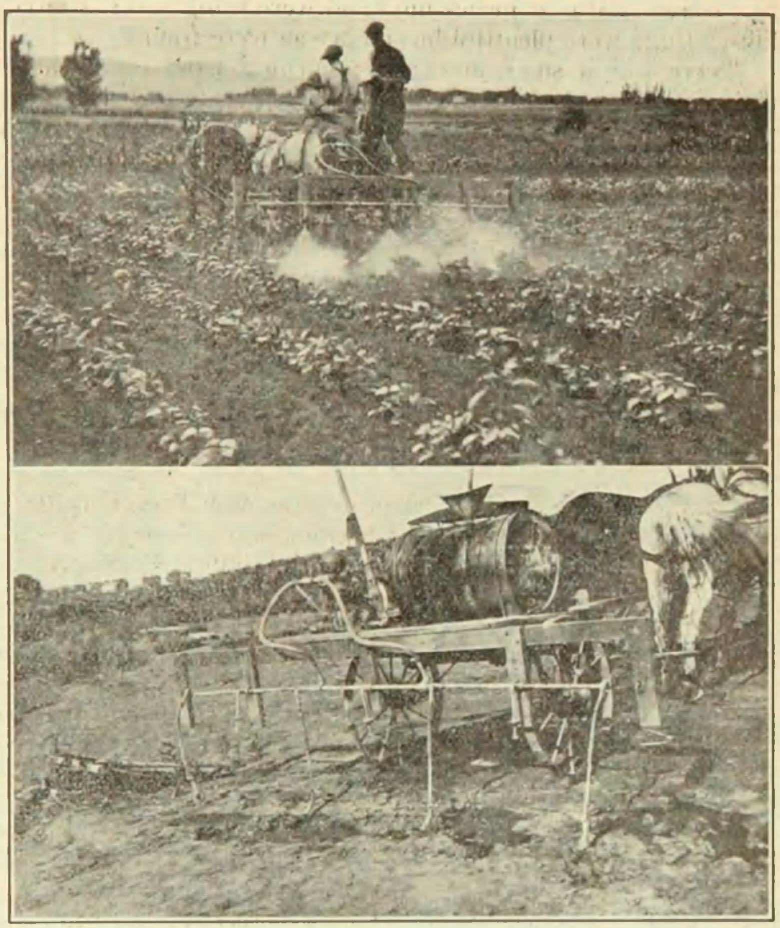

Fig. 11—(Upper) Spraying in the experimental field, season 1920. (Lower) A view of a hand-power sprayer equipped with a nozzle arrangement for spraying beans. Three nozzles are directed toward each row as shown in the upper view. The nozzles that spray from the side are lowered to within four inches of the ground by a rubber hose, and held steady and at a uniform height by another short piece of hose so attached that it drags on the ground and acts as a "shoe". A similar nozzle arrangement would give even better results on traction- and gasoline-power sprayers.

prised tests of the effectiveness of spraying and numbers of applications necessary under different conditions; tests on different varieties of beans; tests as to the burning effect of a number of arsenical insecticides; tests of different brands of arsenite of zinc and arsenate of lead, both with and without lime, and Bordeaux mixture added, and the effectiveness of materials applied as dust and in a liquid. The information gained from these tests is considered

Table XIX. Results of tests of materials for the destruction of bean-beetle eggs.

Material and strength used	No Eggs Treated	Eggs Hasched	Eggs not Hatched
Kerosene emulsion, 5 per cent kerosene	199	162	37
Kerosene emulsion, 7 per cent kerosene	194	167	27
Check	191	173	18
Black Leaf 40, 1 to 600	173	101	72
Black Leaf 40, 1 to 800	152	45	107
Black Leaf 40, 1 to 1000	251	133	118
Check	298	249	49
Target Brand Oil, 1 to 20	295	0	295
Target Brand Oil, 1 to 40	200	48	152
Scalecide, 1 to 40	170	48	122
Scalecide, 1 to 60	133	100	33
Black Leaf 40, 1 to 600 plus soap	156	65	91
Black Leaf 40, 1 to 800 plus soap	178	135	43
Black Leaf 40, 1 to 1000 plus soap	160	110	50
Black Leaf 40, 1 to 600 plus lime casenate	184	145	39
Black Leaf 40, 1 to 800 plus lime casenate	202	154	48
Black Leaf 40, 1 to 1000 plus lime casenate	158	128	30
Whale oil soap, 1 lb. to 10 gallons water	235	58	177
Whale oil soap, 1 lb. to 20 gallons water	218	156	62
Lime casenate, 3 lbs. to 100 gallons water	194	107	87
Lime sulphur, 1 part to 40 parts water	233	2	231
Lime sulphur, 1 part to 50 parts water	198	73	125
Kero (kerosene emulsion) 1 to 40	245	156	89
Kero (kerosene emulsion) 1 to 60	174	97	77
Kerosol (kerosene emulsion) 1 to 40	110	65	45
Kerosol (kerosene emulsion) 1 to 60	180	97	83
Check	228	186	42

in making the general summary of the spraying work.

GENERAL SUMMARY OF SPRAYING WORK FOR CONTROL OF THE BEAN BEETLE

The most effective means of controlling the bean beetle is by spraying with arsenical poisons. These materials are effective by poisoning both beetles and larvae. Beetles, however, may live for several days after feeding on poisoned leaves, but during this time they are inactive and deposit very few eggs. The arsenical insecticides act to some extent as repellants. The repelling effect is most noticeable on the adults and on larvae that are almost mature.

Bean plants are very susceptible to burning by the arsenical insecticides. Only certain ones of these have been found reasonably safe to use. All have, under certain conditions, caused some burning. Burning is more likely to occur during cloudy or rainy weather. Leaves that have been injured by insects are more susceptible to injury by burning. Blossoms and very small pods are very susceptible.

The burning on the leaves may take the form of a discoloration. Dark brown or almost black areas may appear on the edge or in spots on the leaf. Such leaves will drop prematurely. The leaves may not show discolored spots but turn yellow and drop. The injury to the blossoms is shown by a failure to form a pod. The injury to the small pods causes them to turn yellow and drop,

The addition of lime, in equal amounts with the insecticide, in some cases reduced the burning. The lime should be prepared as a milk of lime and added to the water before the insecticide is added, the mixture should then be thoroughly agitated. The burning was relieved to some extent by using the arsenical insecticide in summer-strength Bordeaux mixture.

The following materials were found unsafe to use: Paris green, arsenate of calcium, arsenite of calcium, arsenite of soda, and arsenate of iron.

Arsenite of zinc, arsenate of lead, and arsenate of magnesium were the most satisfactory arsenical insecticides. The arsenate of magnesium was used only one season.

The burning effect of the arsenate of lead varied a great deal. In some cases it was quite severe, while in others it was hardly noticeable. In some cases there was a very marked stunting effect from the arsenate of lead.

There was very little difference in results obtained from the use of different brands of this material.

During three of the four years that field experiments were carried on, there were cases where arsenate of lead caused quite severe burning. However, the burning effect under average conditions was not severe enough to discourage its use. Experiments indicate that an effective strength that is reasonably safe as regards burning is one pound of the powder to 40 gallons of water.

Arsenite of zinc has proved the most reliable insecticide. It caused burning of rather a serious nature in only two cases during the four years it was used. Three brands of this material were used. The tests indicate that the material is effective and reasonably safe when used at the rate of one pound of the powder to 40 or 50 gallons of water. The latter strength, apparently, is as effective as the former and should be less likely to burn and, under our present knowledge, is recommended as the most satisfactory spray for the bean beetle.

Better results were obtained when the arsenical insecticides were applied as a liquid spray than when applied as a dust.

The time and number of applications are important factors. These are determined by the degree of infestation, stage of development of the beans at the time of attack and the length of the growing period of the beans. If the beans have been planted early and are an early maturing variety and there is only a moderate infestation, one application may give good protection. In such a case the application should be made just before injury from the larvae becomes noticeable. Or if the crop is to be used as snap beans, so that poison on the pods would be objectionable, the application may be made just after the maximum blooming period and before the pods are two inches in length.

If the infestation is heavy and the indications are that considerable damage will be done by the hibernated beetles, even early beans should receive two applications. The first should be applied as soon as the beetles become numerous. This should, to a large extent, prevent injury from the beetles and prevent egg laying. The second application, if made as the larvae begin to do damage, should protect the crop during the remainder of the critical period.

There is less danger of burning from this system of spraying than from the one-spray system, as much of the burning occurs on leaves that have been injured by the insect and the system permits the applications to be made before the injury occurs, while a single spray must be delayed as much as possible in order to protect against the larvae, and consequently it is applied after the early feeding of the hibernated beetles.

Beans of the vining type that have a long growing period may be growing so rapidly during the period of maximum injury that two applications will not furnish protection. As a rule, the advantage of such beans does not justify the extra expense necessary to protect them.

Beans that come up during the period when the hibernated beetles are feeding and laying eggs freely, will need an application within a week, after they are up, to protect them from the injury of the adults. New foliage is formed so rapidly that a second application within ten days may be needed, and often a third applica-cation may be desirable.

There will be less danger of burning if the applications are made before serious injury by the insects occurs.

As a rule, the beans crop is sufficiently mature when the first brood of beetles appears in numbers, to make spraying for their control unnecessary. The same is true of the second-brood larvae.

At all times, applications during the maximum blooming period should be avoided, due to the danger of arsenical injury to the blossoms.

All contact sprays for the destruction of different stages of the bean beetle have been a failure when used in strengths that would be practical.

SUMMARY

The Mexican or spotted bean-beetle is a very serious pest to the bean crop in the infested sections of Colorado.

Its attacks are confined almost entirely to the true beans.

The insect winters as an adult.

The adults appear from hibernation during the middle and latter part of June.

In the Fort Collins section this insect passes thru one complete generation and, some seasons, probably 25 per cent of the first-brood adults deposit second-brood eggs, and second-brood larvae are often quite abundant. A few individuals pass thru a second, complete, life cycle emerging as beetles late in the fall.

The number of individuals of the second generation is small as compared with the first.

The number of individuals of the second generation is greater in warmer sections of the State.

The mortality of the second generation is high.

The second-generation larvae, as a rule, do little damage.

The larvae are responsible for a large percentage of the injury.

The period of maximum injury usually occurs during the latter part of July and during August.

Under certain conditions hand-picking of the hibernated adults and first-brood eggs may be used as a means of control.

The most satisfactory means of control is spraying with arsenite of zinc or arsenate of lead.

Beans are very susceptible to injury from arsenical sprays.

The least amount of injury has occurred from the use of arsenite of zinc.

The injury from arsenate of lead has not been serious enough to make its use impractical.

Arsenite of zinc should be used at the rate of one pound of the powder to forty or fifty gallons of water, preferably the latter.

Arsenate of lead should be used at the rate of one pound of the powder to forty gallons of water.

The spray should be applied to the under surface of the leaves.

One, two or three applications of spray may be necessary, depending upon conditions.

Only beans of the dwarf or bunch type should be grown.

Early planted beans of an early maturing variety are most easily protected and are generally most successful in badly infested sections.

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