BULLETIN NO. 221 JANUARY, 1924

Life History and Control
of the
Mexican Bean Beetle

By
F. L. THOMAS

In cooperation with
Bureau of Entomology, U. S. Department of Agriculture

AGRICULTURAL EXPERIMENT STATION
of the
ALABAMA POLYTECHNIC INSTITUTE
M. J. FUNCHESS, *Acting Director*
AUBURN

CONTENTS

FOREWORD

During 1921 the Alabama Experiment Station and the Bureau of Entomology of the United States Department of Agriculture conducted research work on the Mexican bean beetle under a cooperative agreement made the latter part of 1920.

The writer was assigned to the work for the Experiment Station and Mr. J. E. Graf and Mr. Neale F. Howard came from the Division of Truck Crop Insect Investigations to take charge for the Bureau.

At the end of June, 1922, the Experiment Station closed its share of the work and the data obtained have been prepared for earlier publication since the Bureau is continuing the work and will present a more exhaustive treatise on the subject in the near future.

ACKNOWLEDGEMENTS

The Department of Agronomy of this Station cooperated by supplying a collection of seed of leguminous plants and assisted in growing them.

Dr. W. E. Hinds, Entomologist for the Alabama Experiment Station, has at all times willingly and generously given valuable service and advice, contributing many notes which have been incorporated in the text of the bulletin. Practically all of the photographs were taken by him.

The City of Birmingham cooperated in 1921 by donating the use of land for experimental work and Mr. S. L. Brewster, farmer, cooperated in like manner.

The Tennessee Coal, Iron and Railroad Co. did all in their power through their representative, Mr. J. D. Pope, to further the investigations in 1920.

The Truck Growers in East Lake, Birmingham, were most generous in permitting their bean plantings to be used for experimental purposes.

Mr. J. P. Bell, formerly of the Department of Entomology of this Station, greatly assisted by taking observations and carrying on much of the routine work of the project. Mr. W. P. Whitlock, student, ably assisted in the control work and in observing results of application of insecticides.

To all of these and to many others thanks and acknowledgments are due and their services were invaluable in obtaining the results presented in the following pages.

INTRODUCTION

The Mexican bean beetle, after being in the Southwestern United States for about 75 years, suddenly became transported to the Southeastern part of the United States where it has become not only firmly established, but a menace that already threatens the bean growing industry of the entire eastern half of this country. The insect refuses to be quarantined and its remarkable spread is bidding fair to break all records.

SYNONYMY

The first description of typical specimens of *Epilachna corrupta* was made by Mulsant in 1850 (1, p. 815)* and printed under No. 90.

According to Coleopterists of the Federal Government, Bland in 1864 (2)* described the same species under the name *E. maculiventris.*

Crotch in 1874 (3, p. 62)* places *E. corrupta* in synonymy recognizing *E. varivestis* Muls. instead, although the latter name was described as No. 91, following *E. corrupta.*

Since 1874, all writers except Gorham have referred to this species as *E. corrupta.* Gorham in 1897 (8, pp. 242-243)* followed the lead of Crotch and not only placed *E. corrupta* in synonymy but also *E. varipes* Muls. and *E. murina* Muls., paying absolutely no attention to the law of priority, for of the four names *E. varivestis* was described last and *E. varipes* first by Mulsant in the original descriptions. According to Gorham that which constitutes the variety *E. varipes* is as follows: " . . and two subapical (spots) these latter sometimes united and forming an arcuate spot, this constituting the Var. *varipes* Muls."

Considerable variation occurs in this species. Beyond this it is not wise to go until opportunity of examining the type specimens provides the means for deciding positively the specific name to apply to the species under consideration. "*Epilachna corrupta* is (therefore) used to avoid further confusion, although *E. varipes* Muls. was described first and is acknowledged by Crotch and Gorham to be the same species. **(Chittenden. 24, p. 2)

*Figures in parentheses refer to Bibliography, page 98.

**In correspondence Dr. Chittenden has also written " . . it was finally decided to use *corrupta* until some real reason for changing the name was known, although *varipes* to me seems to be the proper name because first described."

HISTORY IN ALABAMA

Discovery of the Insect

The presence of the Mexican bean beetle (*Epilachna corrupta* Muls.) first became known in Alabama, June 30, 1920, when specimens from Blocton and Birmingham were received at the Experiment Station. They were identified as *Epilachna corrupta* and the occurrence was reported to the Bureau of Entomology, July 8, 1920. The identification was confirmed by Dr. F. H. Chittenden who expressed the opinion that the presence of the beetle in Alabama was the result of a commercial "jump."

Preliminary Investigations

As soon as possible a survey of the situation was made to determine the distribution of the insect and any other pertinent facts which would have a bearing upon it. This survey was only begun when beetles and larvae were found destroying cowpeas, a new food plant and one which is extremely important to the diversified agriculture of the South. The beetles were also observed feeding on soy beans.

Four Counties, Jefferson, Shelby, St. Clair, and Etowah, were found to be wholly infested and nine others surrounding these to be partly infested. An early frost occurring the last of September put an end to further spread in 1920.

Shortly after the frost a supplemental inspection was made by two federal men from the Bureau of Entomology. They spent nineteen man days looking for traces of the insect in seven counties in Alabama and one in Georgia, covering territory just north and east of the known infested area. The only finding was made at Jasper in Walker County, already known to be partly infested.

Previous Occurrence

Another fact that developed in the course of the survey was that the longest and heaviest infestations occurred in mining communities. From what is considered reliable information, the first observation of the occurrence of the beetle in Alabama was "in the pole bean season (late summer) of 1918" at Blocton in the northern part of Bibb County. This observation was made by a miner who was also an expert gardener. He remembered seeing the characteristic "yellow bugs" at that time. The insect was noticed by a number of bean growers in Jefferson County in 1919, but not realizing the seriousness of the occurrence the pest was not reported until 1920. The majority of the growers in this county did not see the insect until the year 1920.

Manner of Reaching Alabama

Those mining communities which had the heaviest infestation are made up of families which raise a large share of their own food supply, especially vegetables and milk. The alfalfa hay fed to cows is obtained without exception from the commissary of the mining company. The origin of this hay was traced to sections of Colorado and New Mexico infested with the bean beetle, and it was learned also that one large mining company alone had received regularly direct from those sections for several years as many as ten carloads of alfalfa hay each month during early summer.

The transportation of adult bean beetles in such hay shipments was rendered possible and more probable in 1918 because of the fact that the demand and war time prices for dried beans had greatly extended their culture in the West and for the first time brought the bean plantings into close proximity with extensive alfalfa-growing areas. In this way, or by what is known as a commercial "jump," the Mexican bean beetle is believed to have reached Alabama.

Up to that time the species seems to have been restricted in its spread by surrounding desert and semi-arid range country wherein the necessary food plants did not occur through long distances.

Biology and Control Work in 1920

In the control investigations during late summer of 1920, preliminary experiments on snap beans with several proprietary insecticides as well as arsenate of lead, arsenate of calcium, Bordeaux mixture, sulphur, lime, and pyrethrum were productive of the following results:

1. Tobacco decoctions were not effective.
2. Sweetened preparations and bean decoctions did not prove attractive.

3. Calcium arsenate burned the plants.
4. Best control was obtained from use of Pyrethrum, calcium arsenate, and arsenate of lead.

Mr. J. D. Pope, Supervisor of Gardening for the Tennessee Coal, Iron and Railroad Co., contributed the following notes of biologic interest:

> "Cowpea.—During August and September, 1920, only two examples of feeding on cowpea noticed. Injury very slight. Injury serious on pole and lima beans within 5 to 20 feet of cowpeas.
>
> Flowering Beans.—August 30, 1920, observed characteristic injury on flowering beans (Dolichos sp.)
>
> Kudzu.—August 30 and subsequent dates in September, several specimens of Kudzu vine examined in neighborhoods where bean beetle was prevalent. No characteristic injury by bean beetle noted. On September 18, 1920 . . . confined 2 adults, 2 larvae, and 4 batches of eggs of bean ladybird on a portion of kudzu vine. The beetles were enclosed in a cheese cloth fastened tightly to the vine. Examination 26 days later showed feeding on the leaves of the plant and at least 12 adult beetles and 6 larvae resulting from the specimens confined.
>
> Peanut.—September 22, confined 5 adults and 10 larvae to peanut plant growing in garden . . September 29, 3 adults alive, no feeding noticed."

During the early fall large numbers of beetles were observed on late beans and more than 7,000 were collected for the hibernation cage. Because of the unusual abundance of the insects occurring late it was naturally believed that many would remain in the gardens for hibernation. Therefore, a winter clean-up campaign was inaugurated, the object of which was to destroy trash piles and shelter that would be most favorable to keeping beetles alive and to bury as many of the beetles as possible by early winter plowing in gardens and fields where infestation occurred. This campaign was well carried out and followed with advice to plant early the coming spring.

Attempts to Prevent Spread

In August, 1920, several pupae were found in a bunch of mustard greens offered for sale on the public market at Birmingham. And upon examination of a nursery where cowpeas were suffering from attack by the beetle, pupae were also found on the trunks of growing trees. Such occurrences as these at once suggested the possibility that infested products might be shipped outside the area already infested by the insect and become sources of new infestations.

These facts were placed before a meeting of state and government entomologists and quarantine officials held at Birmingham, September 21-23, 1920, to consider the situation created by the presence of this insect. It was determined that the situation was so critical that a joint attempt at eradication by the State and Federal Government was warranted, provided the insect was not found to be too firmly established or too widely distributed. At the same time a request was made of the Federal Horticultural Board to impose a federal quarantine upon the shipment of dangerous material from the infested areas.

As a result of this meeting efforts were made to secure the passage of an appropriation bill by the State Legislature, then in special session, providing $250,000 for eradication of the Mexican bean beetle from the infested area in Alabama. This bill failed to get the necessary vote. The Alabama State Board of Horticulture placed a quarantine on the infested area November 20, 1920. Following a public hearing held in Washington, D. C., October 11, 1920, quarantine No. 50 was issued by the Secretary of Agriculture through the Federal Horticultural Board and became effective May 1, 1921.

It soon became evident, however, that on account of its habits the Mexican bean beetle was not amenable to successful control by quarantine methods and on July 22, 1921, the Federal Quarantine was repealed. Shortly afterward the Alabama Quarantine was suspended.

Plans for Further Investigation

As the distribution of the beetle became apparent the importance of obtaining outside help for properly carrying on investigation of this new enemy was realized. Accordingly, Dr. W. E. Hinds, Entomologist for the Experiment Station, requested cooperation of officials of the Bureau of Entomology. Plans were made for cooperation to study and determine the biology, food plants, distribution in the United States, and methods of possible control, including native and imported parasites.

Quarters were established at Birmingham, Ala., in November, 1920, with Mr. J. E. Graf in charge of field control and Mr. Neale F. Howard in charge of research. The writer represented the Alabama Experiment Station and is responsible for the results presented in this bulletin.

DISTRIBUTION AND SPREAD

Epilachna corrupta Muls. is a native North American insect having been known in the United States since 1864 and as a serious pest in Colorado as early as 1883. Until the year 1920 only four States, Arizona, New Mexico, Colorado, and Texas, in addition to Mexico and Guatemala were known to be infested.

That year in early summer it was found in Alabama acquiring new habits and appearing far more serious as a pest than in the Southwest where it was previously known. Although its presence in Alabama was not known until 1920 a few growers in Bibb and Jefferson Counties had experience with this insect in 1919, and it is now believed that the infestation did not extend beyond these two counties at that time. At the end of 1920 beetles were found in 13 counties, of which 4 were wholly and 9 partly infested, covering an area of approximately 4500 square miles.

WHOLLY INFESTED	1920	PARTLY INFESTED	
Etowah		Bibb	De Kalb
Jefferson		Blount	Talladega
Shelby		Calhoun	Tuscaloosa
St. Clair		Cherokee	Walker
		Chilton	

Scouting to determine the extent and rapidity of spread by the insect in 1921 began in April under the direction of J. E. Graf of the Bureau of Entomology. By June 4, when the first generation adults were beginning to mature, 3 counties had been added to the list of 13 in Alabama; 8 were found infested in Georgia, (6 of these bordered upon Alabama) and in Tennessee the beetles were found in 2 counties near Chattanooga. The number of infested counties at this time was double the number known to be infested in 1920. By June 26, Mr. Graf reported the total area infested as 23,505 square miles of which 13,178 square miles were in Alabama. From June 4 to 26 there were added 8 counties in Alabama, 12 in Georgia, and 12 in Tennessee. In the next two months, June 26-August 27, 1921, the infested area was increased by 45 counties extending into 6 states and comprising 38,959 square miles of which 18,827 were in Alabama. For the remainder of the year only 8 new counties were reported. A summary of Mr. Graf's weekly reports appears below in brief tabulated form:

TABLE I.—*The number of counties and States added to the infested area in the South, 1921*

Date	Alabama	Georgia	Tennessee	S. Carolina	N. Carolina	Kentucky	Counties added, 1921	Entire area, square miles
1920								
December	13 (4500)*	0	0	0	0	0	----	4,500
1921								
June 4	3	8	2	0	0	0	13	------
(3 weeks)								
June 26	8 (13178)*	12	12	0	0	0	32	23,505
(2 months)								
August 27	9 (18827)*	12	18	3	2	1	45	38,959
October 22	1	4	2	0	0	1	8	------
Total	34	36	34	3	2	2	98	------

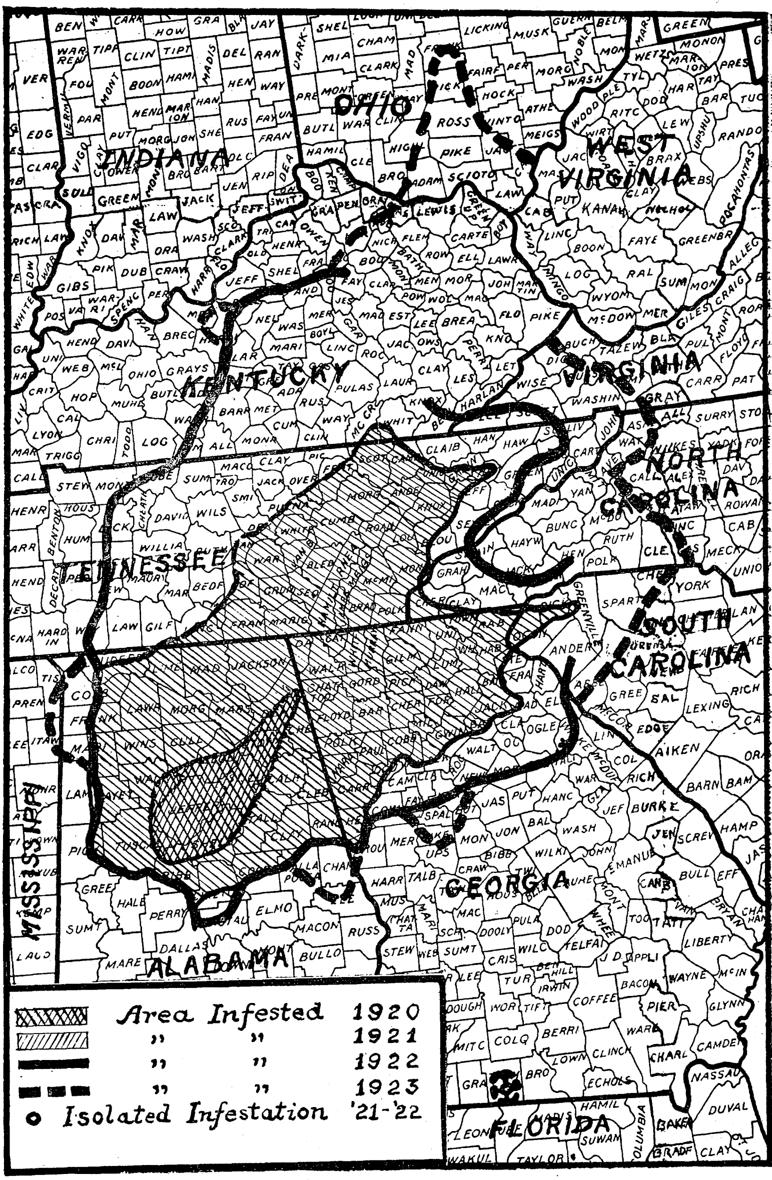
Total number of counties infested, 111.
*Figures in parenthesis denote total area infested in Alabama.

The Counties in Alabama were as follows:

WHOLLY INFESTED		1921	PARTLY INFESTED	
Bibb	Cullman	Marshall	Colbert	Limestone
Blount	DeKalb	Morgan	Dallas	Marion
Calhoun	Etowah	St. Clair	Franklin	Pickens
Cherokee	Fayette	Shelby	Hale	Randolph
Chilton	Jackson	Talladega	Lauderdale	Tallapoosa
Clay	Jefferson	Tuscaloosa		
Cleburne	Lawrence	Walker		
Coosa	Madison	Winston		

At the end of 1922 Mr. N. F. Howard of the Bureau of Entomology reported as follows:

> " . . . the only spread southward in Alabama occurred in Autauga County. It is worthy of note that the insect was not present where scouting was done in several localities where it was found in 1921; notably in Tallapoosa, Coosa, Dallas, and Bibb Counties."



Map showing spread of the Mexican Bean Beetle in S. E. United States. After Bureau of Entomology, U. S. Department of Agriculture.

The greatest spread for the year was recorded in Kentucky where the infestation extended 110 miles beyond the nearest point in 1921 and was found only 30 miles from the Ohio River and Indiana.

The progress of the infestation in the South by the Mexican bean beetle is shown by the map on page 13. A glance at this map is sufficient to see that there has been a decided tendency to spread in a northerly and easterly direction at a very alarming rate. An examination of the meteorological records shows that during spring and summer when the adults of *E. corrupta* are in flight, the prevailing winds are from the south and southwest and this may be the decisive factor in influencing the direction of the spread.

FOOD PLANTS

The foliage of garden and field beans constitutes the chief food of adults and larvae of the Mexican bean beetle. The beans commonly known as string, snap, pole, kidney, cornfield, corn hill, bunch, navy, and shell beans (*Phaseolus vulgaris*) are preferred, but lima or butter beans (*Phaseolus lunatus*) are also attacked and destroyed. Young beans, especially of late plantings, are quickly injured.

Upon the destruction of beans, and in badly infested areas, the insect will attack other leguminous crops, namely, cowpeas and soybeans. The writer has observed instances of complete destruction of cowpeas, but up to the present time such observations have occurred only where cowpeas were in the immediate vicinity or adjacent to destroyed bean plantings. It is rare that soy beans are seriously attacked.

During the season of 1921, 38 leguminous plants, including several varieties, were planted in a heavily infested area for observation of the feeding habits of the insect and the amount of injury produced. The following plants are those on which complete development from egg to adult was found to take place and are arranged with regard to their preference by the beetle.

Hosts Upon Which Complete Development Occurs

	Common Name	Scientific Name
1.	Beans (string, snap, etc.)	*Phaseolus vulgaris*
2.	Beans (lima, butterbeans)	*Phaseolus lunatus*
3.	Beggarweed	*Meibomia sp.*
4.	Cowpea	*Vigna sinensis*
5.	Hyacinth bean	*Dolichos lablab*
6.	Soy beans	*Glycine hispida*
7.	Adsuki bean	*Phaseolus angulatus*
8.	Similar to hemp	*Crotolaria juncea*
9.	*Alfalfa	*Medicago sativa*
10.	**Kudzu	*Pueraria Thunbergiana*

*Reared in confinement.
**Record from J. D. Pope, T. C. I. and RR. Co.

Sweet Clover (*Melilotus*) is included by N. F. Howard in a similar list (28, p. 23), but the writer was unsuccessful in getting complete development on this plant although larvae in all the different stages, as well as adults, fed slightly when confined with it.

Velvet beans, crimson clover, yellow clover, peanuts, lespedeza, hairy vetch, garden peas, horse beans (*Vicia*), coffee weed, Urd bean, Mung bean, and Jack bean were practically immune from injury at the time they were tested. However, cases of accidental feeding have been found upon Jack bean, corn, and velvet beans, resulting from intermingling of these with host plants. Velvet beans and okra have been attacked by third and fourth stage larvae following the destruction of the host plants in adjacent rows. Leaves of white clover (*Trifolium repens*) were eaten considerably by adults in confinement and in one case even carpet grass was eaten by beetles when no other food was present.

CHARACTER AND EXTENT OF INJURY

Adult Injury

Both the adult and larval stages of this insect feed chiefly on the leaves of beans which soon become skeletonized and drop off. The adults when feeding cut irregular holes through the leaf, leaving portions of the upper epidermis, the larger veins, and a network of tissue which resembles veins. This network of leaf tissue may appear within the freshly made holes and on the lower surface of leaves where this insect has been at work. The vein-like network is very characteristic of feeding by this species. Although the network soon disappears from the larger holes as a result of wind and rain, enough of the fragments remain to quickly distinguish the work of *E. corrupta* from that of the bean leaf beetle (*Ceratoma trifurcata*) and from the work of *Diabrotica 12-punctata*. The adults may also be found feeding on the blossoms, pods, and even on the stems of bean plants.

First Instar Larvae Beginning to Feed.

Larval Injury

The larvae are voracious feeders and do more harm than the adults. At first they feed in colonies near the egg mass on the lower surface of the leaf, but soon become scattered as they crawl to other leaves in search of more food. The larvae consume the lower layers of the leaf, leaving the upper epidermis, the larger veins and a vein-like network of leaf tissue which is so characteristic of the work of this insect. The injured leaves present a whitish skeletonized appearance and at the beginning of larval feeding characteristic whitish areas can be seen on the upper surfaces. When not completely skeletonized, the leaves may be so eaten that growth is checked and they dry up without dropping off.

Extent of Injury

The Mexican bean beetle is the most injurious pest of beans in the United States. Injury develops slowly in the early stages of the attack but increases with great rapidity with the development of the larvae. The extent of injury depends upon the degree of infestation and the size of the plants attacked. The smaller varieties of bush beans were destroyed much quicker than the larger varieties.

Foliage of Snap Beans Destroyed by the Bean Beetle.

In 1922 complete destruction of early planted beans, grown by a trucker in the East Lake district, first occurred by June 1, or about the time that the first generation of adults began to reach maturity. Another instance of early destruction, observed in a city garden, occurred 46 days after the beans came up, or about the time picking began. In a few of the city gardens beans were grown and harvested without loss, having only a very slight infestation. The degree of infestation depends on the proximity of previously infested plantings and favorable conditions for the hibernation of the beetles. Complete defoliation usually results in a few weeks following attack where nothing is done to prevent destruction.

One truck grower picked 60 baskets from a patch where he had planted 4 gallons of seed, gathering 15 baskets for each gallon planted. Previous to the arrival of the bean beetle he picked 300 baskets from the same piece of land and only planted 2 gallons of beans, harvesting 150 baskets for each gallon planted. This was a loss of 80 percent in yield.

The earliest observation of feeding upon cowpeas was May 13. On June 9, 16 percent of 100 hills were infested with larvae and eggs. Picking began June 20, 66 days after coming up. In a little over a month the peas were 100 percent infested and injury had become serious. In this case the cowpeas were adjacent to beans which were destroyed by the bean beetle. Cowpeas are not usually injured except where near bean plantings thus destroyed.

Three varieties of soy beans (Virginia, Tarheel, and Hollybrook) were planted in the same half acre and at the same time as several varieties of beans. The beans were destroyed by the beetles. The Virginia soy bean was the first of the three to mature and the Tarheel was second. Both dropped their foliage without noticeable injury. The Hollybrook soy bean, being the last to mature, may have had a slightly greater amount of feeding injury, but the average farmer never would have suspected the presence of an injurious insect from the general appearance and development of any of the soy bean varieties.

The percentage of loss for beans and cowpeas ranges from nothing to a complete crop failure, averaging around 70 percent for beans and a very small percent for cowpeas. It is rare that soy beans are injured enough to attract attention.

OUTLOOK FOR THE FUTURE

The Mexican bean beetle is a pest of major importance. But the fact that it practically failed to spread south and west in Alabama in 1922 has given encouragement to the thought that possibly, after all, this insect may not prove to be as serious to southern agriculture, at least in the Gulf States, as was supposed three years ago when its presence was discovered.

Forecasts regarding injury by this pest must be based on its accomplishments in the past. In the vicinity of Birmingham the destruction of beans was greatest in the fall of 1920; it was noticeably less in the fall of 1921, and in 1922 late beans suffered very little damage. The isolated infestation at Thomasville, Georgia, is barely holding its own after two years. Personal observations supplemented by diligent inquiries have led to the belief that cowpeas and soy beans have not been severely injured except in extenuating circumstances.

The following average yields of cowpeas in 21 of the heaviest infested counties are compared with the average for the entire State for the years 1919-1922, inclusive. The figures are taken from the latest and revised estimate of F. W. Gist, Statistician, and are the official records of the crop reporting service.

TABLE II

Yield per Acre of Cowpeas

District	1919 bu.	1920 bu.	1921 bu.	1922 bu.
Tennessee Valley 6 Counties	6	10	9	7
Mineral 9 Counties	6	10	9	8.3
Northeast 6 Counties	6	10	9	6.8
Average, 21 Counties (Infested area)	6	10	9	7.54
Average, Entire State	5.6	9.7	8.5	7.31

In its new location the beetle is in a different environment and under different climatic conditions than it has normally been accustomed, heretofore. It is impossible at this time to foretell the injury that may take place under these new conditions.

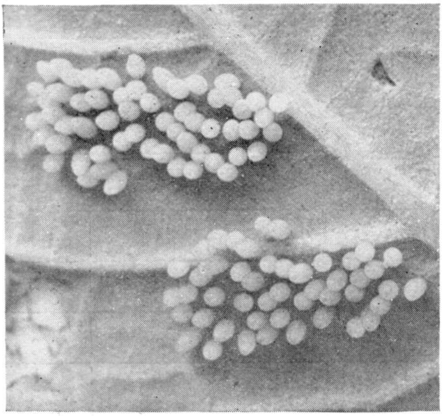
J. E. Graf, of the Bureau of Entomology, stated in a paper read at a meeting in Memphis of the Cotton States Entomologists that the presence or absence of suitable hibernating quarters will have a greater influence on the existence of the Mexican bean beetle than any temperatures that may be involved. He reported that the pest has been found in Colorado at an altitude exceeding 8000 feet where the temperature went 30 degrees F. below zero.

No native enemies have been discovered that give promise of checking the multiplication of the bean beetle and practically all who would grow beans in the infested area must turn to methods of artificial control at present.

DESCRIPTION

In at least three stages, larva, pupa, and adult, the insect is conspicuous in appearance and easily distinguished from all other insects.

Eggs



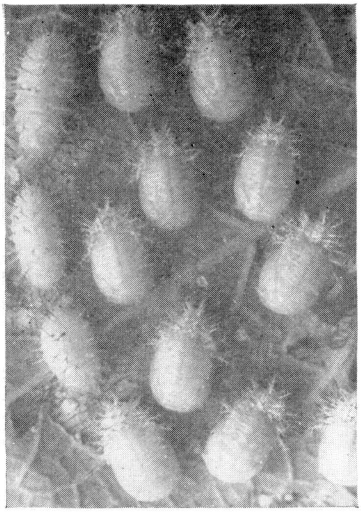
Two Typical Egg Masses.

The eggs are dull pale or orange yellow in color, nearly elliptical in outline, and about twice as long as wide. They are attached at one end and laid irregularly in groups on the underside of the leaves. There is an average of 52 eggs in each group, the number ranging from 4 to 76. Length of egg is 1.25 mm., width, 0.6 mm.

Larva

The first instar larva is about 1.5 mm. long, pale greenish-yellow in color, and its body is armed with spines. The larvae have four instars, molting three times previous to the pupation molt. The developing and mature larvae are yellow, with 6 rows of spines which become strongly branched and black at the tips, the dark color being due to cool temperatures and is more prominent in spring and fall. When over half grown the larva appears to be "humpbacked", the longest spines and the thickest portion of the body being in the middle. The abdomen in all instars tapers to the anal segment which is produced to form a sucker-like apparatus by which the larva is aided in clinging to the leaf and by which it fastens itself previous to molting. The fourth instar larva is 5.4 mm. to nearly 1 cm. in length and about half as wide. Larvae are illustrated on page 22.

Pupa

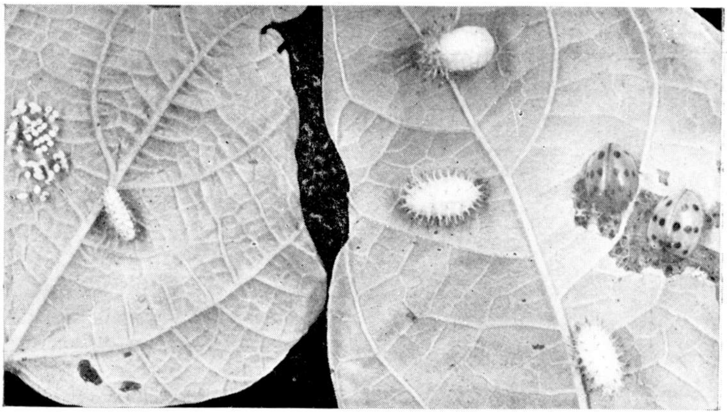


Pupae, and Larvae Preparing to Pupate

The pupa is light yellow in color, spineless and about the size of the adult. It hangs head downward when the leaf is not horizontal and is partly covered and protected by the shed larval skin which is attached by the posterior end to the surface on which it rests. Brown markings may occur on the pupa but these, like the black tipped spines of the larvae, are more evident in cool weather. The surface of the pupa is sparsely covered by short bristle-like setae. When larvae are preparing to pupate they seek the protection afforded by the lower surface of uninjured leaves and may congregate in numbers on the leaves of weeds or other plants growing near beans.

Adult

The adult is a robust, hemi-ovoid beetle with rather slender legs and is about one-fourth of an inch in length by about one-fifth of an inch in width. When newly developed the color is yellow, gradually darkening with age to bronze or brownish. Each wing cover or elytron is usually marked with eight small black spots. These spots vary in size, may coalesce or be connected with each other in the rows, and some of the spots may be entirely missing. Specimens were bred with the spots coalescing in each of the rows and one adult was found with three spots missing on one elytron. The length may vary from 5.5 to 8.3 mm. and the width from 4.0 to 6.0 mm. Chittenden (24, p. 3) gives the technical description of the adult as follows:



Eggs, Larvae, Pupa and Adults of Mexican Bean Beetle.

"Form oblong, more narrowly oval than *borealis* and distinctly smaller, dull in luster, densely pubescent and very closely, unequally punctate; color grayish brown; head and pronotum without spots. Each elytron ornamented with eight spots or dots of varying size in three rows; three small sub-basal spots in a broken row, median less basal; three in a transverse sub-parallel row just before the middle, usually larger than sub-basal, median usually a little larger, and two near apical fourth, placed near inner fourth and outer third. Lower surface darker or concolorous with legs, which are pale throughout. Length 6.5-7.8 mm.; width 4.8-5.4 mm."

LIFE HISTORY AND DEVELOPMENT

Seasonal History

Mexican bean beetles pass the winter in the adult stage but in Alabama they do not remain in a completely dormant condition. Throughout the winter as the weather moderates and warm days occur there is a gradual movement and change of location. They prefer the shelter afforded by leaves and require a certain amount of moisture.

In 1921 spring opened earlier than usual and adults emerged from winter quarters and began feeding about the middle of March, or at least two weeks before the danger from the last killing frost was over. The following year, 1922, the first emerging beetle was found

April 6*. Emergence from hibernation continued until after the middle of May.

After feeding 8 to 15 days the beetles lay eggs. The eggs hatch in 15 days in early spring, the time shortening to 6 days in summer. In 1921, the first eggs found hatching in the field were discovered April 7.

Larval development usually requires 14 to 19 days, except in the case of the earliest of the first generation larvae which may require as long as 36 days.

The pupal stage lasts 5 to 18 days, the longer time occurring in the fall.

Total development from egg deposition to adult transformation requires, on an average, 30 days, the period ranging from 25 days in summer to 56 days in early spring.

The maximum injury by this pest usually occurs in July and August; fall beans, as a rule, having little chance to produce a crop.

Number of Generations

In addition to the over-wintering adults the Mexican bean beetle has two complete generations and a partial third.

Although many fourth generation beetles matured in the insectary in 1921 and a single fifth generation adult developed after the occurrence of a killing frost, these records must be considered exceptional because the beetles are descendants of the first adults maturing from the first eggs laid by the earliest emerging beetles in the spring of 1921. In other words the records are the result of "first selections." On the other hand it is equally true, and likewise exceptional, that a few beetles of the first generation entered hibernation in the fall of 1921.

How to Determine Number of Generations

To determine, theoretically, the average number of generations and the crest of each for a long-lived insect laying a large number of eggs and having several overlapping broods, the following "rules" were used.

1. The infestation for over-wintered adults begins with the first appearance in the field and ends with the death of the last hibernated beetle.

2. Determine the date when one-half of the over-wintered beetles have emerged and allow an average

*Record by N. F. Howard.

female emerging on that date to deposit one-half her eggs.

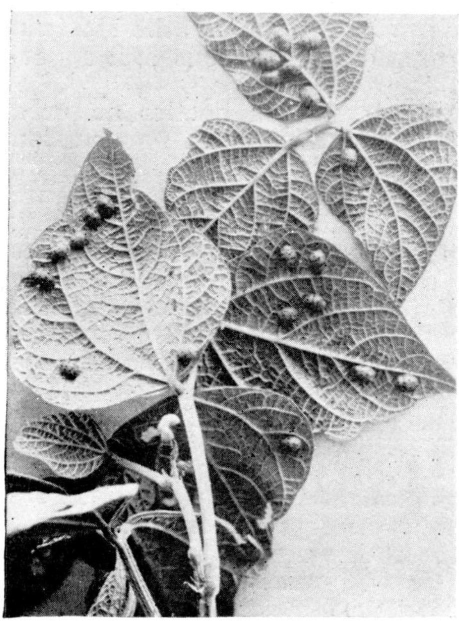
3. The crest of the infestation for over-wintered beetles and first generation larvae will be the date when half the eggs have been laid by the average female in No. 2.

4. The infestation for first generation adults begins with first occurrence and ends with death of the last of the first generation beetles.

5. The date of the crest of infestation by first generation adults and larvae of the second generation occurs when an average female which matures from an egg laid on date of crest of hibernated beetles has laid one-half her eggs.

Crest of other generations found in same manner. A summary of generations is recorded in Table XX and graphically shown in Table XXI.

Hibernation



Adults on Late Beans in October. Little Food is Taken but Mating is Common.

Entrance of the Mexican bean beetle into hibernation seems to be a gradual process extending over a varying length of time. Some beetles stopped feeding in September; others laid eggs as late as October 29, were observed mating on the same day, and took food as late as November 2, 1921. Graf, in his paper*, stated that in the East the beetles began to disappear from the fields during August, in 1922.

The beetles do not hibernate among the bean vines in the garden except possibly a few late developed

*Read at a meeting in Memphis of the Cotton States Entomologists.

adults. In many gardens examined during the winter of 1920-21, 25 living and 12 dead adults constituted the largest number found at any one garden. All gardens had a heavy fall infestation.

Hibernating Quarters in Leaves Under Oak Tree. Note Bean Plantings Near.

During the winter, 1921-22, adults were discovered among pine needles at the edge of wood land across the road from a field where a truck grower had attempted to raise beans the previous fall. Again in late winter a colony of about 500 beetles was found in a hole filled with oak leaves under a lone oak tree at the edge of another field where beans had grown. In the hibernation cage the beetles did not remain dormant throughout the winter but became active and moved about on warm days, crawling upon the wire of the cage where they were seen each month during the winter.

N. F. Howard (31, p. 269) has reported as follows regarding hibernation:

> "The preferred winter quarters so far observed are wooded slopes, especially pine and oak growths. Well protected spaces where oak branches, tree trunks, or other obstructions have caused an accumulation of leaves or pine needles, are chosen. The beetles occur in this material at a depth of an inch or more, seldom

> resting on the ground. . . . The beetles ordinarily have been observed under good drainage conditions but usually considerable moisture is present. As hibernating material dries out, the beetles seek a moist location and go deeper under the leaves. On warm days they become active. A few beetles have been found hibernating one mile from the nearest bean field, 25 individuals three-fourths of a mile from the nearest field and large numbers one-fourth and three-eighths of a mile from the nearest fields. The majority of those observed, however, were within one-fourth of a mile of bean fields which had been destroyed."

In addition to pine needles and oak leaves a hollow log was found in one instance to be sheltering many of the adults. Apparently the beetles exhibit a tendency to be gregarious in hibernation, a characteristic habit that exists among related species of the family Coccinellidae.

In 1921, five generations went into hibernation in the insectary. The number of beetles in each generation was as follows:

1st Gen.	2nd Gen.	3rd Gen.	4th Gen.	5th Gen.	Total
6	35	84	69	1	195

Howard (31, p. 270) has found that 5.37 percent of the 2nd generation, 55.17 percent of the 3rd generation, and 90.88 percent of the 4th generation enter hibernation.

Emergence of Beetles

From Artificial Hibernation

In October, 1920, approximately 7700 beetles were collected and placed in five compartments of a hibernation cage built for the purpose of studying emergence of beetles from various types of hibernating material. The cage was 8' x 12' x 4½' and the top and four sides were covered with 16 mesh screen wire. The first beetle found in the field in 1921 was on March 22, and on the same date an egg mass was found.* Ten days later the removal from the cage of beetles found active on the wire began and the results are considered as an indication of the emergence. The materials placed in the several compartments, the number of beetles present, the date and number removed all appear in the following table.

*Records of N. F. Howard.

TABLE III

Relationship of Hibernating Material and Emergence of Beetles, 1921

Materials	Compartment 1 Boxes and loose wood	Compartment 2 Corn stalks	Compartment 3 Heavy grass	Compartment 4 Grass and weeds	Compartment 5 Bare ground	Total
No. beetles in cage on Oct. 23, 1920	1600	1600	1600	1600	950*	7350
			Emergence			
April 1	98	1	0	0	21	120
5	69	1	0	0	9	79
7	21	0	0	0	7	28
9	49	0	0	0	5	54
13	3	0	0	0	0	3
21	21	0	0	0	8	29
23	14	0	0	0	11	25
28	80	3	0	1	10	94
29	24	0	0	0	8	32
May 10	14	0	0	0	4	18
19	28	0	0	3	2	33
June 8	4	0	0	0	3	7
Totals	425	5	0	4	88	522
Percentage	26.5	.3	0	.25	9.3	7.1

* Remainder after 350 were removed from 1300.

On March 19, 161 active beetles were counted in the hibernation cage. They were not removed. The first collection on April 1st, netted the largest number because of the accumulated emergence up to that date. All collections were made at the same time of day, 7:30 A. M.

A source of error occurs in the number removed from compartment No. 5 where there was nothing but bare ground. Entrance into compartment No. 1 was through compartment No. 5. A wooden strip which had to be removed when entrance to No. 1 was made was not always fitted back as tightly as possible and on these occasions beetles were found in cracks which would permit passage from compartment No. 1 to compartment No. 5 or vice-versa. This did not occur until after removal of beetles began.

Of the 1600 beetles placed in compartment No. 1, in which there were old shingles, parts of crates, and loose wood, 26.5 percent were removed. Less than one-fourth of 1 percent of 4800 beetles came through the winter in three sections of the cage containing corn stalks, heavy grass, leaves, weeds, etc., while 9 percent of 950 were removed from compartment No. 5 where nothing in the form of shelter occurred. Allowing for the greatest possible margin of error the survival in compartment No. 1 was not more than 493 beetles or 30.8 percent. The reason for the low survival in the other compartments of the cage is not clear unless it be that the corn stalks, heavy grass, weeds, etc., which were cut and lying on the ground, became wet and heavy as a result of the numerous winter rains causing the beetles to succumb to the constant dampness.

The winter of 1920-21 was slightly more severe than that of 1921-22 but it is reasonable to suppose that the emergence was about the same. Only 3.5 percent of approximately 7000 beetles placed in a hibernation cage in the fall of 1921 survived, but in this case the sheltering material was undoubtedly insufficient. It consisted of grass, weeds, loose bark, rotten wood, and a few boards.

On November 3, 1921, at the close of the season's work on life history, 195 pedigreed beetles were carefully provided with hibernating material consisting of rotten wood, paper, and light trash and placed under shelter where they would not be disturbed during the winter. This location and condition proved too dry for the beetles, not one surviving. The hibernating insects were distantly removed from the Auburn headquarters, preventing observation until too late to correct the conditions.

Of the 522 beetles that passed the winter of 1920-21 in artificial hibernation 54 percent emerged by April 10 and 88 percent emerged by May 1.

The following year, 1921-22, 69 percent of 251 beetles emerged from artificial hibernation by April 13, and 100 percent by May 1. The cage experiments in artificial hibernation indicated that emergence was practically completed by the first to the middle of May, depending on the degree of shelter which the warm spring weather must penetrate. In 1921-22, with less protection in the cage, emergence was completed earlier.

From Natural Hibernation

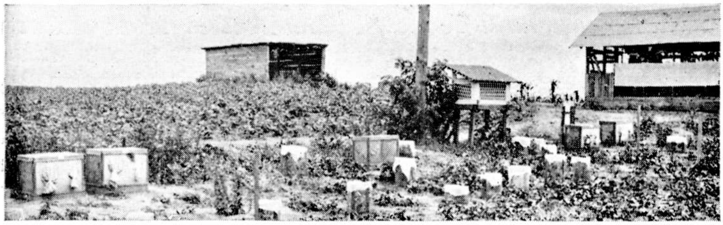
Data upon emergence of the beetles from natural hibernation were obtained by keeping a close watch and recording the increase in adult infestation on 2½ acres of beans which were located in an area one-half mile square with pine and oak woods adjacent on two sides and more distantly located on a third side. This area is used largely for growing of truck crops, and beans have been a main source of income. A heavy infestation of bean beetles was present in the fall of 1921.

In the spring of 1922 the first record of the occurrence of an adult on beans in the field was made on April 6 by N. F. Howard. On April 13 the maximum for any plat was 1 beetle to 100 hills of beans or a 1 percent infestation. This infestation increased very rapidly, as follows:

4/13	4/16	4/25	5/1	5/9	5/12 (4 plats.)	5/16
1%	4%	16%	20%	29%	(40% 44% 50% 56%)	68%

The first time that a 100 percent infestation was recorded was on May 11. These records were not carried beyond May 16 for as the infestation approximated a high percentage the beetles became restless and would occassionally fly away in search of fresh food. Although the duration of the emergence period was not obtained a heavy emergence about May 10 is indicated by the rapid increase in the adult infestation of bean plantings.

These results tend to show that emergence from natural hibernation is slower than emergence from artificial hibernation. This is readily understood when it is kown that the beetle prefers to hibernate in accumulations of leaves, usually in the edges of woodlands, in locations that are less accessible to the warmth of the sun's rays than the hibernation cages constructed in the open.



Insectary and Types of Breeding Cages Used in Life History Studies.

Development

Most of the life history studies set forth in this bulletin are results of work done in 1921 in an outdoor insectary where the beetles were confined by cylindrical wire cages to bean plants growing in 5 inch flower pots. The top end of the cage was covered with cheese cloth. When a group of eggs was found the beetles were transferred to another plant and the eggs were kept under observation for hatching. The larvae were then confined and transferred to fresh plants as food was needed. Breeding work was also conducted in cages placed in the field.

In pesenting the data on development all four generations which matured are used, although only two generations and a partial third are considered typical for Alabama.

Egg Laying by Hibernated Beetles

As the beetles were removed from the hibernation cage some were taken and used in breeding work. Thirteen females were thus taken and the results are summarized in Table IV.

TABLE IV

Egg Records of Hibernated Beetles, 1921

Beetle	Date of first eggs	Date of last eggs	No. of egg groups	Total eggs	Date when ½ eggs laid	No. days for laying ½ eggs	No. days for laying all eggs
1 ------	4/15	7/6	26	1344	6/2	48	82
5 ------	4/14	6/13	16	789	5/19	35	58
6 ------	4/19	6/18	16	883	5/22	33	60
7 ------	5/18	5/30	5	274	5/24	6	12
9 ------	4/26	5/19	4	81	5/9	13	23
11 ------	4/15	7/16	24	1332	6/1	46	92
12 ------	5/23	7/31	20	1152	8/19	27	69
21 ------	4/20	6/17	17	956	5/26	36	58
24 ------	4/19	5/19	8	466	5/1	12	30
25 ------	4/22	6/9	16	828	5/19	27	47
38 ------	5/13	6/9	11	657	5/26	13	27
42 ------	5/27	7/29	17	935	7/7	41	63
64 ------	6/15	6/22	3	125	6/18	3	7
Totals --			183	9822		340	628
Averages			14.0	755.5		26.1	48.3

Earliest date on which hibernated beetles laid eggs--March 23
Latest date on which hibernated beetles laid eggs ----July 31

Egg laying period for one female: Days
- Average ---------------------------------- 48.3
- Maximum ---------------------------------- 92
- Minimum ---------------------------------- 7

Number of egg groups laid by one female:
- Average ---------------------------------- 14.0
- Maximum ---------------------------------- 26
- Minimum ---------------------------------- 3

Number of eggs deposited by one female:
- Average ---------------------------------- 755.5
- Maximum ----------------------------------1344
- Minimum ---------------------------------- 81

Number of days required to lay ½ her eggs ------ 26.1 days

First Generation

The incubation period, time required for larval development and the pupal period are tabulated in the three parts of Table V. According to the weighted average time required in the egg, larval, and pupal stages the total period necessary for a first generation beetle to develop from deposition of egg to transformation of adult would average about 33 days.

TABLE V

Development of First Generation

Eggs		
Number of Records	Incubation Period	Egg Days
2	14	28
10	13	130
6	12	72
3	11	33
1	10	10
8	9	72
14	8	112
27	7	189
52	6	312
12	5*	60
135		1018

Larvae		
Number of Records	Larval Period	Larval Days
1	36	36
1	30	30
4	28	112
1	27	27
2	24	48
2	23	46
2	22	44
1	21	21
5	19	95
4	18	72
5	17	85
12	16	192
6	15	90
2	13	26
48		924

Pupae		
Number of Records	Pupal Period	Pupal Days
5	8	40
8	7	56
28	6	168
9	5	45
50		309

*Date of laying not observed.

	Days
Incubation period:	
Weighted average	7.54
Maximum	14
Minimum	5
Larval period:	
Weighted average	19.25
Maximum	36
Minimum	13
Pupal period:	
Weighted average	6.18
Maximum	8
Minimum	5

To check the results in Table V a similar average of 51 records of complete development of the first generation shows that 34 days are necessary from egg deposition to adult transformation. This is shown in Table VI.

TABLE VI

Complete Development of First Generation, Egg to Adult

Number of Groups	Total Development	Development Days
1	56	56
1	52	52
1	49	49
1	48	48
1	46	46
2	45	90
4	43	172
1	42	42
3	41	123
1	40	40
1	38	38
1	36	36
1	35	35
1	34	34
1	32	32
2	31	62
4	30	120
8	29	232
11	28	308
3	27	81
1	26	26
1	25	25
51		1747

Complete development:	Days
Weighted average	34.2
Maximum	56
Minimum	25

Because of the number of records involved 33 days is probably more nearly correct.

TABLE VII

Egg Record of First Generation, 1921

Beetle	Date of first eggs	Date of last eggs	No. of egg groups	Total eggs	Date when ½ eggs laid	No. days for laying ½ eggs	No. days for laying all eggs
126	8/12	9/14	13	617	8/24	12	33
24B	6/25	8/31	35	1603	7/26	31	67
46	6/10	7/22	12	665	6/29	19	42
6D	6/30	7/23	12	671	7/10	10	23
48	6/9	8/1	19	942	7/12	33	53
49	6/10	8/18	27	1507	7/24	44	69
59	6/15	6/24	5	307	6/20	5	9
60	6/10	6/18	5	238	6/14	4	8
66	6/22	7/8	7	263	6/27	5	16
1123*	9/18	10/26					
Totals			135	6813		163	320
Averages			15	757		18.1	35.5

Earliest date on which first generation laid eggs ---- **June 1
Latest date on which first generation laid eggs ---- October 26
Egg laying period for one female: Days
- Average ---------------------------------- 35.5
- Maximum ---------------------------------- 69
- Minimum ---------------------------------- 8

Number of egg groups laid by one female:
- Average ---------------------------------- 15
- Maximum ---------------------------------- 35
- Minimum ---------------------------------- 5

Number of eggs deposited by one female:
- Average ---------------------------------- 757.0
- Maximum ---------------------------------- 1603
- Minimum ---------------------------------- 238

Number of days required by female to lay ½ her eggs ---- 18.1

Second Generation

The incubation period, time required for larval development, and the pupal period are tabulated in the three parts of Table VIII. According to the weighted average time required in the egg, larval, and pupal stages the total period necessary for a second generation beetle to develop from deposition of egg to transformation of adult would average 28 or 29 days.

*This female No. 1123 matured August 9 but was not used in breeding work until September 18. No record was kept of the number of eggs previously laid and, therefore, the record was left incomplete.

**The female laying these eggs escaped after 9 groups of eggs were laid and is not included in the above table.

TABLE VIII

Development of Second Generation

Eggs		
Number of Records	Incubation Period	Egg Days
1	14	14
1	13	13
1	9	9
4	8	32
9	7	63
50	6	300
25	5*	125
91		556

Larvae		
Number of Records	Larval Period	Larval Days
1	27	27
1	25	25
3	19	57
3	18	54
10	17	170
19	16	304
11	15	165
1	14	14
1	13	13
50		829

Pupae		
Number of Records	Pupal Period	Pupal Days
2	8	16
6	7	42
22	6	132
16	5	80
46		270

	Days
Incubation period:	
Weighted average	6.1
Maximum	14
Minimum	5
Larval period:	
Weighted average	16.58
Maximum	27
Minimum	13
Pupal period:	
Weighted average	5.87
Maximum	8
Minimum	5

A weighted average for complete development of the second generation, as shown in Table IX, is about 28 days or practically the same as the sum of the weighted averages for the stages in Table VIII.

*Date of laying not observed.

TABLE IX

Complete Development of Second Generation, Egg to Adult

Number of Records	Period for Total Development	Development Days
2	31	62
3	30	90
5	29	145
17	28	476
14	27	378
7	26	182
48		1333

Complete development: Days
- Weighted average ---------- 27.77
- Maximum ---------- 31
- Minimum ---------- 26

TABLE X

Egg Record of Second Generation, 1921

Beetle	Date of first eggs	Date of last eggs	No. of egg groups	Total eggs	Date when ½ eggs laid	No. days for laying ½ eggs	No. days for laying all eggs
3A1 ----	7/5	7/26	11	679	7/16	11	21
3A8 ----	7/28	9/12	23	1308	8/17	20	46
4A -----	7/23	9/3	21	1061	8/10	18	42
24B7* --	8/18	8/31					
24B1* --	7/26	8/3					
Totals --			55	3048		49	109
Averages			18.3	1016		16.33	36.3

*Escaped.

Earliest date on which 2nd generation laid eggs ------July 5
Latest date on which 2nd generation laid eggs---**October 26
Egg laying period for one female: Days
- Average ---------- 36.3
- Maximum ---------- 46
- Minimum ---------- 21

Number of egg groups laid by one female:
- Average ---------- 18.3
- Maximum ---------- 23
- Minimum ---------- 11

Number of eggs deposited by one female:
- Average ----------1016
- Maximum ----------1308
- Minimum ---------- 679

Number of days required by female to lay ½ her eggs---16.33

** Record taken from stock cage.

Third Generation

The incubation period, time required for larval development, and pupal period are shown in the three parts of Table XI. According to the weighted average time required in the egg, larval, and pupal stages the total period necessary for a third generation beetle to develop from deposition of egg to transformation of adult would average about 30 days.

TABLE XI

Development of Third Generation

Number of Records	Incubation Period	Egg Days
EGGS		
1	8	8
6	7	42
32	6	192
8	5*	40
47		282

Number of Records	Larval Period	Larval Days
LARVAE		
1	33	33
1	29	29
1	20	20
2	19	38
12	18	216
11	17	187
6	16	96
3	15	45
37		664

Number of Records	Pupal Period	Pupal Days
PUPAE		
1	16	16
2	11	22
5	7	35
16	6	96
10	5	50
34		219

	Days
Incubation period:	
Weighted average	6.0
Maximum	8
Minimum	5
Larval period:	
Weighted average	17.94
Maximum	33
Minimum	15
Pupal period:	
Weighted average	6.44
Maximum	16
Minimum	5

*Date of laying not observed.

A weighted average for complete development of the third generation, as shown in Table XII, is a little over 29 days or nearly the same as the total of the averages for the different stages inTable XI.

TABLE XII

Complete Development of Third Generation, Egg to Adult

Number of Records	Period for Total Development	Development Days
1	40	40
1	35	35
1	32	32
3	31	93
4	30	120
10	29	290
12	28	336
2	27	54
34		1000

Complete development:	Days
Weighted average	29.4
Maximum	40
Minimum	27

TABLE XIII

Egg Record of Third Generation Beetles

Beetle	Date of first eggs	Date of last eggs	No. of egg groups	Total eggs	Date when ½ eggs laid	No. days for laying ½ eggs	No. days for laying all eggs
3A11	8/11	9/10	14	645	8/25	14	30
3A12	8/13	9/8	15	827	8/25	12	26
3A14	8/15	9/9	7	378	8/20	5	25
3A15	8/12	9/19	16	884	8/31	9	38
3A16	8/13	9/1	7	397	8/21	8	19
4A04	10/5	10/30	2	125	10/17	12	25
4A14	9/30	10/20	4	267	10/4	4	20
24B71	9/29	10/27	5	268	10/9	10	28
Totals			70	3791		74	211
Average			8.7	473.8		9.25	26.3

Earliest date on which 3rd generation laid eggs ---- August 11
Latest date on which 3rd generation laid eggs ---- October 27

Egg laying period for one female:	Days
Average	26.3
Maximum	38
Minimum	19

Number of egg groups laid by one female:

Average	8.7
Maximum	16
Minimum	2

Number of eggs deposited by one female:

Average	473.8
Maximum	884
Minimum	125

Number of days required by female to lay ½ her eggs----9.25

Fourth Generation

The incubation period, time required for larval development, and pupal period are shown in the three parts of Table XIV. According to the weighted average time required in the egg, larval, and pupal stages, the total period necessary for a fourth generation beetle to develop from deposition of egg to transformation of adult would average nearly 34 days.

TABLE XIV

Development of Fourth Generation

Eggs		
Number of Records	Incubation Period	Egg Days
1	16	16
2	15	30
1	14	14
1	12	12
1	9	9
2	7	14
22	6	132
30		227

Larvae		
Number of Records	Larval Period	Larval Days
1	38	38
1	19	19
3	18	54
11	17	187
3	16	48
19		346

Pupae		
Number of Records	Pupal Period	Pupal Days
1	18	18
1	15	15
2	13	26
2	8	16
9	6	54
3	5	15
18		144

Incubation period	Days
Weighted average	7.56
Maximum	16
Minimum	6
Larval period:	
Weighted average	18.2
Maximum	38
Minimum	16
Pupal period:	
Weighted average	8.0
Maximum	18
Minimum	5

The longer time, 34 days for complete development, as shown in Table XIV is due to presence of late incubation and larval records of individuals that had no chance to mature.

The weighted average for complete development of the fourth generation, as shown by Table XV, is nearly correct for late maturing beetles.

TABLE XV

Complete Development of Fourth Generation, Egg to Adult

Number of Records	Period for Total Development	Development Days
1	44	44
2	36	72
1	32	32
1	31	31
2	30	60
8	29	232
3	28	84
18		555

Complete development:	Days
Weighted average	30.83
Maximum	44
Minimum	28

Most of the beetles of this generation entered hibernation without depositing eggs, but the few that did lay were quickly through, or were apparently very reluctant to oviposit so late in the season.

TABLE XVI

Egg Record of Fourth Generation Beetles

Beetle	Date of first eggs	Date of last eggs	No. of egg groups	Total eggs	Date when ½ eggs laid	No. days for laying ½ eggs	No. days for laying all eggs
3B	9/23	9/26	2	141	9/23	1	3
4C	9/26	9/27	2	130	9/26	1	2
4D	9/26	10/29	4	239	9/30	5	33
Totals			8	510		7	38
Average			2.6	170.0		2.3	12.66

Earliest date on which 4th generation laid eggs--September 23
Latest date on which 4th generation laid eggs ----October 29

Egg laying period for one female: Days
- Average ---------- 12.66
- Maximum ---------- 33
- Minimum ---------- 2

Number of egg groups laid by one female:
- Average ---------- 2.6
- Maximum ---------- 4
- Minimum ---------- 2

Number of eggs deposited by one female:
- Average ---------- 170
- Maximum ---------- 239
- Minimum ---------- 130

Number of days required by female to lay ½ her eggs ----2.3

Summary of Development

TABLE XVII

Maximum and Minimum Records of Complete Development by Stages and Generations

	1st Gen.		2nd Gen.		3rd Gen.		4th Gen.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Egg	12	6	7	6	7	6	6	6
First Instar	9	3	4	3	3	3	3	3
Second Instar	8	3	3	3	4	3	4	3
Third Instar	10	3	4	3	3	4	4	4
Fourth Instar	9	5	6	6	8	5	8	6
Pupa	8	5	7	5	15	6	18	6
Total larval period	36	14	17	15	18	15	19	16
No. days for complete development	56	25	31	26	40	27	44	28

FOOTNOTE:—The average incubation period of eggs of the 5th generation was 10.5 days with a maximum of 16 and a minimum of 8 days. With the exception of one record of 27 days for development of larvae there are no other records on this generation until the mid-winter observation when adults were found to have matured in the insectary after a killing frost occurred.

TABLE XVIII

Summary of Weighted Averages Showing Period for Development of Stages in Each Generation

	1st Gen.	2nd Gen.	3rd Gen.	4th Gen.	Av. Gen.
	Days	Days	Days	Days	Days
Egg	7.54	6.10	6.0	7.56	6.50
Larval	19.25	16.58	17.94	18.2	16.73
Pupal	6.18	5.87	6.44	8.0	6.36
Total days, egg to adult	32.97	28.55	30.38	33.76	29.59

The sum of the general averages or the period for total development is 29.59 days.

TABLE XIX

Summary of Weighted Averages Showing Period for Complete Development

First Gen.	Second Gen.	Third Gen.	Fourth Gen.
34.2 days	27.77 days	29.40 days	30.83 days
General average period for complete development--30.70 days			

The average period from deposition of the egg to transformation of the adult may be considered, therefore, as 30 days.

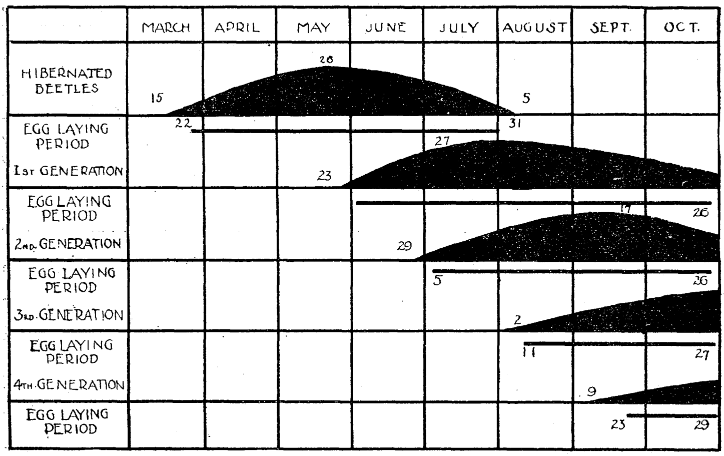
TABLE XX

Summary of Generations

Hibernated Beetles	
Hibernating adults began to appear	March 15
First eggs deposited	March 22
Half of beetles emerged by	April 15
Average feeding period before laying eggs	15 days
Half of oviposition period for hibernated beetles	26 days
Maximum infestation of hibernated beetles occurs	May 26
Last eggs deposited	July 31
Last adult died	August 5
First Generation	
Average development	34 days
Adults first appeared	May 23
First eggs deposited	June 1
Average feeding period before laying eggs	10 days
Half of oviposition period	18 days
Maximum infestation of first generation occurs	July 27
Last eggs deposited	October 26
Second Generation	
Average development	28 days
Adults first appeared	June 29
First eggs deposited	July 5
Average feeding period before laying eggs	8 days
Half of oviposition period	16 days
Maximum infestation of 2nd generation occurs	Sept. 17
Last eggs deposited	Oct. 26
Third Generation	
Average development	29 days
Adults first appeared	Aug. 2
First eggs deposited	Aug. 11
Average feeding period before laying eggs	13 days
Half of oviposition period	9 days
Maximum infestation of 3rd generation	Nov. 9
Last eggs deposited	Oct. 27
Fourth Generation	
Average development	31 days
Adults first appeared	Sept. 9
First eggs deposited	Sept 23
Very few beetles lay eggs in fall.	

Table XXI

Graphic Summary of the Occurrence of Generations



Oviposition

Records of Generations

An average of 52.9 eggs was found in a total of 602 egg groups containing 31,895 eggs. Usually they are laid on the lower surfaces of the leaves of beans, but are sometimes, though rarely, found on the upper surface. Two egg groups may occur on the lower surface of one leaf, although other uninjured leaves without eggs are present on the same plant. Eggs have also been found on non-food plants in close proximity to the normal host. Even glass, soil, wire, paper, cheese cloth, wood, and the stem of a bean plant have been used by females as places to deposit eggs. The eggs of a typical group are usually laid in irregular rows and close together. Scattered eggs in one group sometimes occur and may cover an area 1⅜ inches by ¾ of an inch.

A summary of the egg records of the different generations is found in Table XXII. Only those females with complete records are included, excepting six which entered hibernation after beginning to lay. Many adults entered hibernation without laying; none of these are included in the following summary.

TABLE XXII

Summary of Egg Records of all Generations, 1921

Beetle	No. females	Period covered	Av. No. egg groups per female	Av. No. eggs per female	No. days for one female to lay: * ½ eggs	No. days for one female to lay: All eggs
Hibernated	13	4/14- 7/31	14.0	755.5	26.1	48.3
1st Gen.	9	6/ 9- 9/14	15.0	757.0	18.1	35.5
2nd Gen.	3	7/ 5- 9/12	18.3	1016.0	16.33	36.3
3rd Gen.	8	8/11-10/27	8.7	473.8	9.25	26.3
4th Gen.	3	9/23-10/29	2.6	170.0	2.3	12.66
Totals	36	4/14-10/29				
Weighted average			12.5	666.0		36.24

*Data used in Table XX.

	Days
Number of eggs laid by one female:	
Weighted average	666
Maximum (Table VII)	1603
Minimum (Table XIII)	125
Number of egg groups laid by one female:	
Weighted average	12.5
Maximum (Table VII)	35
Minimum (Table XIII)	2
Period required by female to lay all her eggs:	
Weighted average	36.24
Maximum (Table IV)	92
Minimum (Table XVI)	2

Before depositing eggs it is necessary for females to take food, after which a short time elapses until eggs are laid. Young adults do not begin to feed until 1½ to 3 days after transforming. Among 17 beetles that passed the winter of 1920 the interval between taking of food and laying of eggs averaged 12.3 days. An exceptional interval of 43 days occurred in the case of one hibernated beetle, but because of the unusual length of time (21 days being the next longest interval) the record was not included in the above average.

TABLE XXIII

Interval Between Transformation to Adult and Deposition of Eggs

	No. females in record	Maximum Days	Minimum Days	Average Days
Hibernated	17	*21	*7	*12.3
1st Gen.	9	13	8	10.5
2nd Gen.	6	17	6	7.8
3rd Gen.	8	24	9	13.3
4th Gen.	4	17	14	15.5

*Intervals between taking of food and deposition of eggs in spring.

	Days
Average interval	11.7
Maximum	21
Minimum	6

It is possible for some of the beetles to live 29 days after emerging from hibernation without taking food and then revive, mate, and lay fertile eggs if brought into the presence of food. Later generations are not capable of such endurance.

Observations of two females showed that one was capable of laying 22 eggs in 19¾ minutes with a maximum interval of 2 minutes and a minimum of ½ a minute between eggs. The other female laid 25 eggs in 69 minutes with a maximum interval of 4¼ minutes and a minimum of ½ minute. These observations were taken on April 5 and 6 while the females were ovipositing upon wire of the cage. At the faster rate it would take a little over three-fourths of an hour for a beetle to lay an average group of 52 eggs.

TABLE XXIV

Average Number of Egg Groups per Beetle Each Month for Each Generation

Month	No. females in record	Egg laying beetle days	Egg groups	Egg groups per female
Hibernated Beetles				
April	14	221	29	3.93
May	23	584	117	6.21
June	13	250	71	8.56
July	4	92	27	9.09
August	2	7	0	0.00
		1154	244	6.34
First Generation				
June	12	172	48	8.37
July	9	214	84	11.70
August	5	82	37	13.98
September	4	21	8	7.74
October	1	31	4	4.00
		530	181	10.24
Second Generation				
July	6	72	29	12.48
August	5	110	44	12.40
September	2	35	5	4.28
		217	78	10.78
Third Generation				
August	5	105	39	11.41
September	7	104	22	6.34
October	3	93	9	3
		302	70	6.95
Fourth Generation				
September	4	51	7	4.11
October	3	94	2	.65
		145	9	1.86

NOTE.—Explanation of above Table: In April there were 14 beetles (Hibernated adults) having 221 "egg laying beetle days" during which 29 egg groups were laid. If 29 egg groups were laid within 221 days, 3.93 egg groups will be laid within 30 days.

Although the first egg group was found in the field March22 the breeding work did not begin early enough to obtain data regarding the number of egg groups per beetle for March. The principal egg laying period for hibernated beetles is May and June, the maximum record for a single beetle in one month being 12 and occurring in June. Although the highest individual average record was made in July, this is discounted by the fact that 75 percent of the hibernated females have died by the end of June. Among first generation beetles oviposition begins in June and is especially abundant in July and August; 16 egg groups laid in July being the maximum monthly record for a beetle of this generation. The main oviposition period of second generation beetles is reduced to two months, July and August. All the second generation adults used in the breeding work were among the first to transform and the records of these did not last until October. A female of this generation laid 17 egg groups during August, which is the maximum monthly record for any beetle in the work of 1921. The main oviposition period of the third generation is August, when this generation begins to lay. Ten egg groups laid in this month is the maximum for the third generation. In 1921 eggs were found in the field as late as October 28. The first and second generations each averaged 10 to 11 egg groups per female each month of their existence. The average for each of the hibernated and third generation females was 6 to 7 egg groups for each month of existence.

TABLE XXV

Maximum Number of Egg Groups for any Female in One Month

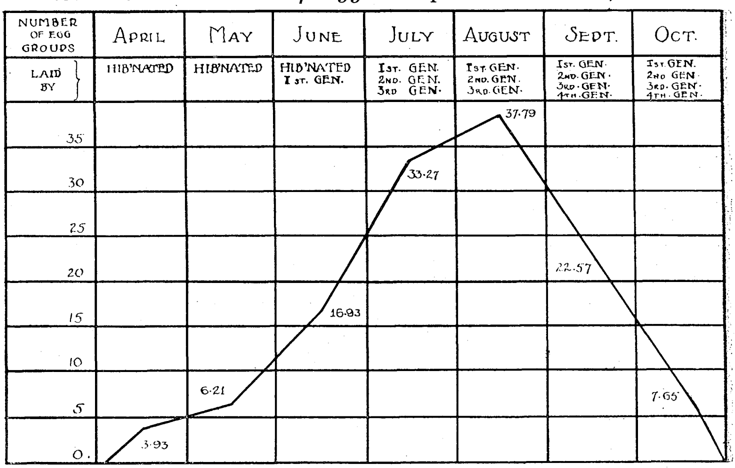
	April	May	June	July	Aug.	Sept.	Oct.
Hibernated	4	11	12	11	0	-	-
1st Gen.	-	--	9	16	15	4	4
2nd Gen.	-	--	--	11	17	4	0
3rd Gen.	-	--	--	--	10	8	4
4th Gen.	-	--	--	--	--	2	2

Although some of the hottest weather of the summer comes in September, beetles instinctively begin to refrain from egg laying even though food is plentiful. In Table XXIV it may be seen that the average number of egg groups for each female decreased in September by about 50 percent from the number laid in August.

Only hibernated beetles were active in April and May. Two generations of adults including hibernated beetles were active in June. Three generations laid eggs in July and August, and 4 in September and October. The peak of egg production occurred in the month of August, but both July and August were outstanding months in regard to deposition of eggs.

TABLE XXVI

Relative Abundance of Egg Groups in the Field, 1921



Relation to Meteorological Conditions

Practically all observations for recording oviposition by beetles were made at least once every 24 hours throughout the season. Five hundred and forty-one records of egg deposition were made in this manner. Of this number 73 percent were made in the morning and 27 percent in the afternoon. Female beetles were observed in the act of laying eggs 112 times out of the 541 instances when eggs were recorded.

TABLE XXVII

Egg Laying in Relation to Time of Day

	All observations made within 24 hours			Positive observations having definite time				
	A. M.	P. M.	Total	Before 9:30 A. M.	After 9:30 A. M.	12-1 Noon	P. M.	Total
Hibernated	140	82	222	20	6	2	8	36
First Gen.	143	33	176	26	4	4	5	39
Second Gen.	58	11	69	8	4	3	3	18
Third Gen.	46	18	64	13	1	1	3	18
Fourth Gen.	7	3	10	0	0	1	0	1
Totals	394	147	541	67	15	11	19	112
Percent	73	27	100	60	13	10	17	100

The 112 positive observations are tabulated in four groups according to the time of the record. Sixty percent of these positive observations occurred before 9:30 A. M. This is the only important conclusion that can be drawn from Table XXVII, for upon analysis it will be seen that the same relative proportion of 73 and 27 exists between the morning and afternoon total observations. Furthermore, 20.8 percent of morning observations were positive and 20.4 percent of the afternoon observations were positive.

Thermohygrograph records made in connection with the life history work and correlated with the positive observations of egg laying show that the maximum range in temperature when eggs were deposited was 26 degrees or between 65 and 91 degrees F.

TABLE XXVIII

Egg Laying in Relation to Temperature

	Temp. before 9:30 A. M.		Temp. after 9:30 A. M.		Temp. P. M.	
	Max.	Min.	Max.	Min.	Max.	Min.
Hibernated	79	76	79	65	85	77
First Gen.	82	72	91	75	90	74
Second Gen.	80	72	90	80	89	87
Third Gen.	77	70	88	83	89	83
Fourth Gen.	--	--	79	79	--	--

A correlation of the positive observations of egg laying and the records for humidity show that the maximum range was between 40 and 95 percent.

TABLE XXIX

*Egg Laying in Relation to Humidity**

	Humidity before 9:30 AM		Humidity after 9:30 AM		Humidity in PM	
	Max.	Min.	Max.	Min.	Max.	Min.
Hibernated	74	67	90	70	67	49
First Gen.	87	60	70	45	91	44
Second Gen.	88	71	75	43	53	45
Third Gen.	95	64	72	52	53	40
Fourth Gen.	--	--	61	61	--	--

*Based on 75 observations, or 67% of the positive observations.

Fertility

Only eggs laid by paired females were included in the records of fertility. Entirely infertile egg groups were found to occur in all generations and also groups of eggs that were 100 percent fertile. The fact that groups of infertile eggs were laid at all is remarkable because all of the beetles were paired. A summary of the percentage of infertile egg groups shows a general increase in number as the season developed. Before becoming infertile one hibernated female laid as many as 11 groups containing fertile eggs without mating in the spring. The fertility of the hibernated beetles and those of the first and second generation was about the same. Only about a third of the eggs of the third generation were fertile and the small number of eggs laid by the fourth generation was beyond consideration.

TABLE XXX

Summary of Average Fertility of Each Generation

	Egg Groups			Eggs		
	Total	Infertile	%Infertile	Total	Fertile	%Fertile
Hibernated	88	4	4.5	4904	3529	71.9
First Gen.	101	12	11.8	5330	3520	66.0
Second Gen.	48	1	2.0	2675	1981	74.0
Third Gen.	48	17	35.4	2550	929	36.4
Fourth Gen.	4	3	75.0	261	30	11.4
Totals	289	37	---	15720	9989	---
Average %			12.8			63.5

Infertile egg groups 12.8%
Fertile eggs 63.5%

Fertility of the eggs of the Mexican bean beetle is greatest in the months of June and July, the highest percentage occurring in July among eggs of the second generation.

TABLE XXXI

Average Percent Fertility of each Generation by Months

	April	May	June	July	Aug.	Sept.	Oct.
Hibernated	62.6	72.0	77.6	68.7	---	---	---
First Gen.	---	---	73.2	68.0	51.1	79.9	35.0
Second Gen.	---	---	---	83.4	71.2	60.1	---
Third Gen.	---	---	---	---	41.2	23.1	32.2
Fourth Gen.	---	---	---	---	---	11.4	---

The maximum and minimum records of fertility for all the eggs of a single individual in each generation are recorded in the following table:

TABLE XXXII

Maximum and Minimum Records of Fertility

	No. females in records	Percentage fertile	
		Maximum	Minimum
Hibernated	13	88.8	61.6
First Gen.	13	96.8	29.7
Second Gen.	7	89.5	31.6
Third Gen.	8	68.7	5.5

Proportion of Sexes

Sex of Over-wintered Beetles

The sex of beetles emerging from artificial hibernation was obtained only during the latter part of the emergence period. The proportion of sexes of those emerging from natural hibernation was obtained by noting in the field from time to time the sex of the beetles throughout the emergence period. The results appear in Table XXXIII.

TABLE XXXIII

Sex of Beetles Emerging from Artificial Hibernation

Year	Period	No. Beetles	Males	Females
1921	4/21-5/19	188	65%	35%
1922	4/20-5/ 1	251	56%	44%

Sex of Beetles Emerging from Natural Hibernation

Year	Period	No. Beetles	Males	Females
1922	4/14-5/11	160	30%	70%

The large proportion of males surviving artificial hibernation where conditions were probably not entirely satisfactory is an indication that the male has more power of endurance.

It is worthy of note in connection with the proportion of sexes among beetles emerging from natural hibernation that most of the beetles were collected before the 1st of May and that the proportion of sexes among beetles taken after that time was nearly equal. Possibly a majority of the males remain with the females in winter quarters until the heavy emergence takes place.

Sex of Later Maturing Beetles

The data regarding sex of beetles maturing in 1921 were obtained from adults that developed in the breeding cages. The sex of all beetles developing was not determined but the proportion of males and females among 1298 beetles in which the sex was determined was very nearly the same as shown in Table XXXIV.

TABLE XXXIV

Proportion of Sexes

	May		June		July		Aug.		Sept.		Total		Percent	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
First Gen.	10	10	103	138	34	48	38	40	---	---	185	236	44	56
Second Gen.	--	--	7	8	65	55	89	107	52	41	213	211	50	50
Third Gen.	--	--	---	---	--	---	59	75	102	98	161	173	48	52
Fourth Gen.	--	--	---	---	--	---	---	---	62	57	62	57	53	47
TOTALS	10	10	110	146	99	103	186	222	216	196	621	677	48	52

Total number of beetles 1298
Males 48%
Females 52%

Duration of Life

All the beetles that passed the winter of 1920-21 in the hibernation cage were collected in the field in October, 1920. The maximum period for a hibernated beetle to live after collection was 293 days, 121 of which were spent after emerging from hibernation in the spring. In the first generation, one male entering hibernation had already lived 100 days up to November 3. There was not much difference in the length of life of males and females; the greatest difference averaging 20 days longer life for males among over-wintered beetles. The data in Table XXXV is based upon the records of beetles that died naturally.

TABLE XXXV

Average Length of Life

Beetle	Males		Females	
	No. Beetles	No. Days	No. Beetles	No. Days
Hibernated	6	270.8	13	252.0
1st Gen.	3	63.3	9	56
2nd Gen.	2	55.5	3	54.
3rd Gen.	6	35.3	5	46.6
4th Gen.	1	23.	-	----
Total	18	447.9	30	407.0

	Days
Length of life of overwintered adults:	
Males	270.8
Females	252
Length of life of adults of other generations:	
Males	44.6
Females	52.8

Effect of Starvation

To determine the advisability of delaying the planting of beans with the object of starving the early emerging beetles, starvation tests were carried out with 57 beetles which were kept inside a glass jar covered with cheese cloth. Most of the time they rested. If the death rate of these is an indication of what would occur in nature, 85 or 90 percent of the beetles may be expected to die within two weeks after emerging if food is not found. Of 37 beetles on hand April 1, 67.5 percent died in 7 days.

TABLE XXXVI

Ability of Over-wintered Adults to Endure Starvation

Date 1921	Living	Dead	Date 1921	Living	Dead
April 1	37	0	April 28	20	0
7	14	23	May 17	3	17
8	12	2	21	1	2
9	9	3	25	1*	0
12	5	4	28	1	0
13	4	1	30	0	1
15	4	0			
18	4	0			
to					
29	4	0			
30**	2**	2			

*Able to fly.

**Food provided and beetles laid eggs May 13.

In another experiment 31 beetles were confined with grass and white clover. The soil in which these plants were growing received excess moisture twice a day. The white clover was considerably eaten and the grass was also eaten in several places; but evidently the food did not contribute much to a longer life for 28 percent of the beetles died in 6 days, 53 percent in 13 days, and 89 percent died in 22 days.

An environment possessing greater humidity than that to which an insect is normally accustomed may tend to cause the insect to change its habits and increase the variety of its food plants.

One fresh molted fourth instar larva was confined without food May 25 and was alive after 6 days but died on the 7th day.

Mortality

When eggs collapsed and did not hatch it was assumed that they were infertile. The developing embryo in some of the fertile eggs failed to break the shell and when it succeeded in doing so the young sometimes failed to get out.

The percentage of mortality among developing larvae was highest between the time of hatching and the second molt. Of 107 newly hatched larvae that were carefully cared for 41 percent died or were lost before the second instar. An additional 18 percent were lost before they transformed to adults. Some of the first instar larvae were occasionally found dead on leaves without apparent cause. In the fields rain beat some of the young larvae off the plants. Even live adults were occasionally found stuck in the soil, as it hardened after a severe rain.

In general the length of life of beetles was shortened in proportion to the increase of activity among them.

TABLE XXXVII

Mortality of Females

Beetle	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
Hibernated	0	3	10	2	2	-	-	17
1st Gen.	-	-	1	4	2	2	-	9
2nd Gen.	-	-	-	2	0	2	-	4
3rd Gen.	-	-	-	-	0	5	0	5
4th Gen.	-	-	-	-	-	0	1	1

HABITS

Flight

Upon emergence from hibernation beetles soon take flight. Although having been without food while in winter quarters, they are strong flyers and may cover considerable distance if food is not found nearby.

Upon liberating 50 beetles April 1, just after they had emerged from hibernation, more than one-fourth took flight within ten minutes without crawling more than a few inches from the point of liberation. Most of them flew at an altitude of 12 to 15 feet.

After laying a group of eggs a female will usually leave the spot by a short flight to another plant or leaf. As the generations develop the newly transformed adults seek fresh plants on which to feed and lay eggs and if the beans are badly injured, the beetles may extend their search.

Near the end of September a beetle escaped from a stock cage in which the beans were destroyed, was seen to fly sharply upwards, and pass over the peak of a shed at least 25 feet above ground. Although half an acre of beans was close by the beetle demonstrated its instinct to leave that vicinity because of the food shortage it had experienced.

Flight in the field was common on October 22, 1921. As late as October 29, beetles were seen flying when the temperature was 73 degrees F.

Observations during the winter were limited on account of location. However, on January 16, 1922, an instance of flight was observed within the hibernation cage when the temperature was 50 degrees F.

Feeding

The adults feed usually on the lower surface, leaving portions of the upper epidermis, the larger veins, and a net work of tissue resembling veins of the leaf.

During the process of feeding there is a perceptible lateral movement of the whole body and as the leaf tissue is consumed the beetle exhibits a tendency to

---

Footnote: Howard, (31, P. 268) after liberating 5000 marked beetles made recoveries up to a distance of 5 miles from point of liberation and J. E. Graf has reported finding beetles in hibernation in New Mexico 7 1/2 miles from the nearest bean field.

turn gradually in its tracks and may eat entirely around itself if not interrupted or its appetite satisfied.

When feeding injury is fresh it is possible to tell where the beetle stood when performing that function. After being subjected to the elements the vein-like tissue and upper epidermis left by the beetles become broken and are beaten out, leaving an irregular ragged hole, characteristic of *Epilachna corrupta.*

The larvae when feeding sway their bodies like the adults with a slight lateral motion. A single feeding of larvae continues for a much longer period, one instance being observed which lasted 75 minutes.

The Mexican bean beetle is still somewhat unsettled in its habits of feeding. In 1921, for example, hibernated beetles would not feed even in confinement upon cowpeas and the first record of voluntary feeding in the field was July 21. But in 1922 voluntary feeding of over-wintered beetles was first observed on cowpeas as early as May 13, about one month after the peas came up.

Hatching

Following is a copy of the record made at the time of observation:

May 7, 12:00, noon.
Larva has just broken egg shell, gradually pushing out. Rested for several minutes before getting legs out.

May 7, 1:30 P. M.
Legs in view but close to the body. Operation of getting out is aided by using sucker-like apparatus which the larva attaches to inside of egg and by movements of abdominal segments. The spines are closely appressed.

May 7, 1:45 P. M.
Legs are free. Temperature 76 degrees F. As the legs become free the body is bent forward slightly; the spines stand out individually, pale and transparent. After all legs are free and 'tail' is attached to inside margin of egg shell, larva rests.

May 7, 2:45 P. M.
'Tail' released and larva stood on its legs on top of egg and rested. The only dark spots about the yellow larva are its mandibles which look like eyes. The process of hatching required nearly three hours. During this period, and until after the second molt, the young larva is rather delicate and very susceptible to the elements.

The length of time required for an egg to hatch varies considerably. One group of 72 eggs which began hatching on April 28 contained one egg from which the larva was trying to extricate itself as late as May 7. This period of 9 days is the maximum record in the work of 1921 for an egg group to complete hatching.

Molting and Pupation

The different stages or instars in the development of the larva are separated from each other by a molting or shedding of the larval skin, the larva first becoming inactive and partaking of no food for one to three days previous to this process. Upon attaining its growth the large yellow larva fastens itself by its anal segment to the surface on which it rests. After two or three days the larval skin splits about half way along the dorsal surface beginning at the anterior end and the bright yellow naked pupa appears, remaining half covered by the molted skin in which it is attached. The full grown larva has an instinct to rest in a place protected from the sun and weather and just before ready to transform it will migrate from a plant that is practically destroyed, or on which other larvae are feeding, and locate on the lower surface of a green leaf of some non-food plant or on the sides and roof of the cage in which it developed. As many as 32 pupae have been found on the base of a corn stalk which grew beside a row of beans. When ready to transform the larvae exhibit a distinct tendency to congregate and often a dozen or more pupae are found on the lower surface of the same leaf.

The molting process requires about an hour before the larva is free from the shed skin. At first the color is lemon yellow but in about 45 minutes the spot around the eyes, small spines, joints of the legs, and plates at base of spines begin to turn brown.

As the larvae develop the rate of growth varies, depending on the food consumed. In the same group some of the larvae get through molting before others begin. The period for a group of larvae to complete molting may be four days, and to complete pupation the period may be five to six days in cool weather.

The pupa usually hangs head downward when on a vertical surface and has the power of moving in a dorso-ventral manner. In summer the pupa is lemon yellow in color; the brown markings that sometimes appear thereon and the black spines on the larvae being due to cool weather.

Adult

When the newly transformed adult crawls out of the pupal skin it is entirely lemon yellow in color, no sign of black spots appearing. Within half an hour the membranous wings gradually become extended and the black spots begin to appear. In another 20 or 30 minutes the wings are folded beneath the elytra. At first the young adult clings to the lower surface of the leaf with legs fully extended. If placed on the upper surface of a leaf at this time, the beetle will crawl to the underside. In a few hours after the beetle gains strength, the body assumes a position parallel to the leaf surface, changing from its first position in which it appeared to be suspended by the legs.

The first excrement seen to be voided by the young beetles was a small clear watery looking drop. Yellowish drops of excrement then pass until after the beetles begin to feed when it becomes whiteish in color. The circular whiteish and yellow excrement spots on the foliage are very characteristic where the infestation is severe.

The only characteristic distinguishing the sexes, aside from the distended abdomen of the female when ready to lay, is a small notch in the posterior margin of the last ventral abdominal segment of the male. The same segment in the female is without a notch and has less pubescence. The young adults may begin to feed in 26 to 32 hours after transformation.

Reproduction

In the field there is a noticeable attraction between the sexes, especially when the infestation is new and on fresh bean plants. During the frequent inspection of young plantings in the early part of the season the location of a lone female was marked, and almost invariably other beetles were found with her upon examination the next day. On snap beans having an average infestation of 3 beetles to 100 hills on April 25, 3 adults were found on one plant and two days later 5 beetles were found on one plant, although the average infestation had not increased. In September it was not at all uncommon to see two males clinging to one female and on July 9, 1921, 5 beetles were observed clinging together and hanging from one female which was holding to a leaf. A female may lay as many as 11 groups of fertile eggs after emerging from hibernation in the spring with no opportunity to mate after beginning to feed. Although this number is unusual, such an occurrence is not at all uncommon. A freshly transformed adult may mate within six days. Only the youngest females enter hibernation in the fall without being fertilized. While confined in the hibernation cages several pairs of bean beetles were observed, April 12, 1922, in actual copulation before any opportunity to take food had been presented.

Fertilization of females is not necessary between the laying of egg groups, yet this is the general habit and occasionally pairs were observed in copula twice between the laying of two consecutive egg groups. Pairs were observed in connection from one hour to one hour and fifty minutes, and also when the temperature was as low as 43 degrees F.

Changes in Habits

From an insect having two broods in Colorado, the Mexican bean beetle immediately becomes a pest having two generations and a partial third. Including the hibernated beetles, the equivalent of three broods attack beans in Alabama.

Originally the beetle came from Mexico but extended its distribution northward, inhabiting both the upper and lower Sonoran Life Zones. Now it is in an entirely new region, the Austro-riparian Region of the lower Austral Life Zone, and with this transplantation a change in habits may be expected.

Chittenden and Marsh (24, p. 7) state: "In Colorado the beetles go into hibernation and remain dormant until about the middle of June. . . .It is somewhat remarkable that the beetles remain in hibernation during the last days of May and the first half of June when high temperatures of 90 to 95 degrees prevail." These habits of late emergence in spring after being dormant in winter change in Alabama. The beetle is not completely dormant here as it is in Colorado. In Alabama beetles are somewhat active throughout the winter and emerge earlier in spring.

In Colorado feeding is confined very largely to beans, but in Alabama cowpeas and beggarweed may be destroyed and accidental feeding may occur on velvet beans, Jack beans, corn, and crab grass.

NATURAL CONTROL

ENEMIES

Only one instance of parasitism was observed. In this case the remains of a fourth instar larva was covered with "cocoons of some braconid, probably of subfamily Euphorinae, cocoons were empty" (Rohwer).

Occasionally eggs were found that had been partially eaten but it was seldom that an entire egg group was destroyed in this manner. While keeping close watch of the infestation on 5½ acres of beans from April 15 to June 30, 1922, only two predators, *Stiretrus anchorago* Fab. and *Megilla maculata* D. G. were seen to attack the Mexican bean beetle or any of its stages. *Hippodamia convergens* Guer. is a very common predacious insect which fed upon eggs of the bean beetle in confinement but was not observed attacking eggs in the field. When food is scarce both adult and larval stages of *Epilachna corrupta* will eat its own eggs.

Probably the most important of the native enemies of the Mexican bean beetle is *Stiretrus anchorago* Fab. a species of the Pentatomidae. This bug when attacking its prey pushes its long beak into an egg or any of the larval stages. It has been observed attacking freshly transformed adults. Activity by this species in 1922 was first noticed May 23 when attack was made upon a fourth instar larva. After such an attack nothing but the skin of the larva was left. Nymphs and adults of *Stiretrus anchorago* will feed on eggs, larvae, and pupae of the bean beetle. They increase and in the fall of the year they are common.

The first attack of *Megilla maculata* observed in 1922 was on June 10 when an adult was seen eating a first instar larva of the bean beetle. This species of ladybird becomes very common in the fall.

Tiger beetles and ground beetles have not been observed attacking any stage of the bean beetle.

The common garden toad entirely ignored the presence of the adult beetles.

Hens and chickens will reject both adults and larvae. Guinea hens, when passing through bean plantings, paid no attention to the beetles or larvae.

The long spines of the larvae and the drops of yellow liquid exuded from the knee joints of the adults are apparently efficient in protecting the Mexican bean beetle from birds.

An interesting account of the importance of predaceous enemies was published by N. F. Howard in 1921 (28, p. 19).

Climatic Conditions

A remarkable instance of natural control by heat was observed on rows of white tepary beans during one of the hot spells when the temperature was 100 to 101 degrees F. in the shade. The foliage was already partly destroyed and the remainder was turned so that only the margin was presented to the sun's rays. Great numbers of all stages of larvae were found dead on the ground. Nothing of this kind was observed in connection with the commonly grown beans.

Following hard rain storms, especially when they were accompanied by rather strong winds, many larvae of all stages were beaten off the bean vines and found dead between the rows. Such storms have considerable influence in reducing temporarily the severity of an infestation.

INSECTS MISTAKEN FOR THE MEXICAN BEAN BEETLE

The other lady beetle which feeds upon foliage is the squash lady beetle, *Epilachna borealis,* Guer. a larger beetle with seven spots on each wing cover.

Diabrotica 12 *punctata* has been confused with *Epilachna corrupta* but the twelve spots and elongated appearance easily serve to distinguish it.

The work of *Ceratoma trifurcata* is often abundant and causes alarm but the adult responsible is not at all like the Mexican bean beetle. Only young bean plants are injured by feeding of this pest.

The Mexican bean beetle is frequently mistaken for the Colorado potato beetle, *Leptinotarsa decemlineata.*

PREVENTIVE AND CONTROL MEASURES

Experiments in 1921

Spraying and Dusting

The work of finding control measures began in July, 1921, and ended June 30, 1922. The 1921 experiments were preliminary, the object being to find something that could be used with safety to bean foliage and at the same time something that would control the pest. In these experiments 22 insecticides, including the various dilutions and combinations, were used. Eighty-four applications were made to both snap beans and butterbeans. These applications were made during July, August, and September, the hottest months of the summer.

The main insecticides used with the number of treatments in which each insecticide occurred are given in Table XXXVIII.

TABLE XXXVIII

Insecticides used in 1921

Insecticide	How Used*	Applications
Dusts:		
Pyrethrum	100% to 20%	22
Arsenate of Lead	20% to 10%	8
Powdered Bordeaux	100% to 33.3%	2
Calcium arsenate	25% to 11.1%	5
Calcium arsenate, sulphur and Lime	1-1-2	3
	1-1-4	19
Calcium Arsenate and Sulphur	1-1	2
Sulphur	25%	1
Pyrethrum, Calcium Arsenate, Sulphur, and Lime	2-1-1-4	2
Nicotine Lime	2% Nicotine sulphate	2
Sprays:		
Kilspray	1-500	2
	1-1000	5
	1-2000	9
Black-leaf 40	1-1500	1
	1-2000	1

*Where percentages indicate dilution, hydrated lime was used. In the sprays water was the diluent.

After three months of experimenting with these insecticides several promising dusts were found which seemed to control the insect but not all appeared equally safe for the plants. However, one of the mixtures clearly demonstrated its ability to check destruction by the bean beetle. Not the slightest trace of injury to the foliage occurred after 19 treatments. This mixture contained calcium arsenate, fine dusting sulfur, and hydrated lime in the proportions of 1-1-4 by weight.

An interesting fact in connection with the mixture is that the calcium arsenate and sulphur were bought ready mixed and had been on hand for two years. It was obtained under the trade name "Niagara Mixture A," and was said to contain 50 percent calcium arsenate and 50 percent sulphur. The mixture used for controlling the bean beetle was made by taking 1 part of this "Niagara Mixture A" and thoroughly mixing with 2 parts by weight of hydrated lime, thereby making the proportions 1 part calcium arsenate, 1 part sulphur, and 4 parts hydrated lime.

Other important results obtained from the control work in 1921 may be briefly summarized as follows:

1. None of the dusts or sprays used prevented hatching of the eggs, although egg laying was greatly retarded by several of the treatments.

2. Spraying by means of a hand compressed air pump did not prove practical. The pressure could not be kept up sufficiently to completely cover the foliage of mature plants. Also, when spraying, the extra time and labor involved was a big factor and one which prevented spraying experiments in 1922.

3. Pyrethrum produced the most immediate results, but was not effective for any length of time. Best results were obtained when used in the proportion of 1 part pyrethrum and 2 parts hydrated lime.

4. Arsenate of lead was much slower than pyrethrum in its action but far more effective in length of efficiency. When used with hydrated lime in the proportion of 1 to 8 good control was obtained, but this did not prove safe for the beans because late injury or burn resulted. When used 1 to 9 it was less effective.

5. Powdered Bordeaux had a slight repellant action to adults.

6. Calcium arsenate, sulphur, and hydrated lime was also used in the proportion of 1-1-2, containing 25 percent calcium arsenate. Three applications were made without causing injury to bean foliage. "Niagara Mixture A" was used in making this combination. Pure "Niagara Mixture A" severely burned the foliage.

7. A mixture of calcium arsenate and hydrated lime containing 20 percent calcium arsenate burned the leaves. Injury also resulted when used in the proportion of 14 $^{2}/_{7}$ percent. Apparently sulphur prevented injury by calcium arsenate when mixed with it as recorded in paragraph 6.

8. Sulphur had a slight repellant effect on adults when used at a strength of 25 percent in the only application made.

9. A nicotine-lime mixture containing 2 percent nicotine sulphate was not effective.

10. Black Leaf 40 as used in the spray applications was too weak. No injury resulted.

11. Kilspray is an alcoholic extract of pyrethrum prepared in the form of a heavy liquid soap, which mixes readily with water. It was found to be repellant to adults and effective against larvae in dilutions as high as 1 part Kilspray to 2000 parts of water.

Fumigation Experiments

The possibility and danger of bean beetles being transported in shipments of hay was demonstrated in November, 1921, by finding 6 beetles and 3 pupae in a barn containing cowpea hay. Evidently the insects had been brought in with the hay.

It had frequently been noticed that the adult bean beetles were more resistant than other insects to the effects of the poison bottle. Having an opportunity to use a small room in which nursery stock was fumigated nine experiments with hydrocyanic acid gas were conducted to test the resistance of beetles, and to determine the dosage necessary to kill. The results of these experiments which were performed during the middle of December, 1920, appear in Table XXXIX. In each experiment sodium cyanide, sulphuric acid, and water were used in the proportions 1-1½-2. The room contained 685 cubic feet.

TABLE XXXIX

Resistance of Beetles to Fumigation

				Epilachna corrupta	
Amount NaCN used, Oz.	Dosage per 100 cu.ft. Ounces	Exposure Minutes	Temp. Degrees F.	No. to begin	No. alive at end
6.9 -----	1.0	40	70	12	3
9.0 -----	1.3	45	50	6	6
10.5 -----	1.5	45	50	4	0
8.0 -----	1.16	75	45	6	3
9.0 -----	1.3	75	50	6	1
10.5 -----	1.5	75	55	6	0
7.0 -----	1.02	60	60	19	0
7.0 -----	1.02	90	65	6	0
8.0 -----	1.16	45	60	6	0

With the temperature 60 degrees F. about 1 ounce to 100 cu.ft. for an hour will probably be sufficient to kill beetles. At 50 degrees F. 1½ ounces to 100 cu.ft. for 45 minutes may be required.

Other Experiments

In conducting burial tests, beetles were covered with good friable clay loam soil to a depth of 1, 2, 3, 4, and 5 inches. The soil was not packed. All the beetles emerged from a depth of one inch, but failed to appear when covered two inches or more.

In November, 1920, other beetles were submerged in water for varying lengths of time, namely, 22, 46, 52, and 70 hours. Those submerged for 22 hours recovered upon removal but none were alive after undergoing the longer tests. In December additional submergence tests were made with partly dormant beetles. The periods of submergence were 12, 24, 36, 43, 52 and 64 hours. Six beetles were used in each test and all of the 36 beetles recovered.

Experiments in 1922

Plan and Method of Work

In order to more thoroughly test the most promising insecticides, the control investigations in 1922 were conducted on a much broader scale and applied to varieties of beans commonly grown in the South. These included both bush and pole varieties of *Phaseolus vulgaris* and *Phaseolus lunatus.*

Infestations were taken to provide not only a means for comparing the susceptibility of different types of beans to attack by the bean beetle, but more especially to compare the results of poison applications.

When taking the infestation no effort was made to count the individual larvae but the different stages of larvae observed were recorded; also the presence of pupae, the number of egg groups, and in most cases the number of adults.

Except three plats of bush snap beans which were planted in the drill all beans were planted in hills which is the unit used when mentioning the percentage of infestation. It was never difficult to distinguish separate hills of bush beans although consecutive hills frequently overlapped at maturity. In the case of the three plats planted in the drill, one foot of row is the unit.

The percentages of infestations and relation to treatments were tabulated in connection with each experiment, but, except to illustrate the method, the tabulations are not recorded in the following pages. The graphic summaries, pages 81 and 89, tell the story in part.

Results of experiments are briefly summarized and arranged in groups according to the type of beans, as follows:

Experiments with bush, snap or string beans on 17 plats, comprising 2.53 acres.

Experiments with pole snap beans or string beans on 9 plats, comprising 1.48 acres.

Experiments with butterbeans or lima beans on 2 plats, comprising .86 acre.

Experiments with cowpeas on 2 plats, comprising .32 acres.

The control work was brought to a close June 30, 1922.

Definitions

A "hill," "pole," or "foot of row," was declared to be infested if examination revealed eggs or larva of *Epilachna corrupta.*

Pupae and adults while recorded are not considered when giving the percentage of infestation as such. Pupae will not injure the plant, and, unlike the egg group, their latent power for producing injury is not necessarily confined to the plant where found. The presence of adults is not an indication of the true value of an insecticide because of their ability to fly. Where the occurrence of adults is mentioned the reference is always specific, e. g., "percentage of adult infestation" or just "adult infestation."

The number of infested hills in one hundred is the percentage of infestation. Since eradication is not claimed it is possible to have a high percentage of infestation with relatively little injury, but, in general, a high infestation is accompanied by injury. The presence of destroyed hills indicates loss of control.

Insecticides Used

Dust applications were made with powdered insecticides in all experiments of 1922. Whenever mixtures were prepared a mixing machine having a capacity of 15 pounds was utilized.

Following is a list of insecticides used:

TABLE XL

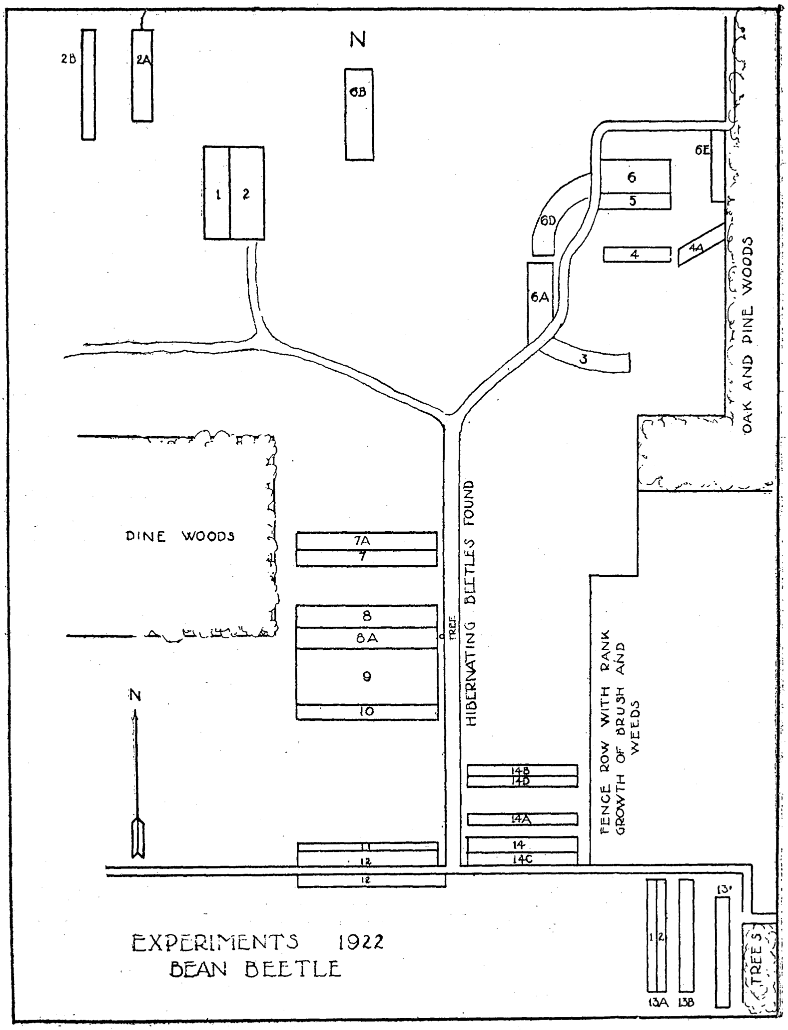
Insecticides used in Control and Proportion of Materials in Mixtures

Insecticide	Percentage of Material in Mixture
1 Bol-wee Compound, 1 part Hydrated lime, 2 parts	*Calcium arsenate 26.66 Magnesium Compound 6.66 Hydrated lime 66.66 As_2O_5 10.66
2 Cal-Sulphur	*Calcium arsenate 16.66 Sulphur 16.66 Hydrated lime 66.66 As_2O_5 6.66
3 Dosch Mixture, B-14, 20-10-70	*Calcium arsenate 9.5 Copper Sulphate (Monohydrated) 19.5 Hydrated lime 71.0 As_2O_5 3.8
3 Dosch Mixture, B-15, 20-20-60	*Calcium arsenate 19.5 Copper Sulphate (Monohydrated) 19.5 Hydrated lime 61.0 As_2O_5 7.8
4 Niagara Mixture A, 1 part Hydrated Lime, 2 parts	*Calcium arsenate 16.66 Sulphur 16.66 Hydrated lime 66.66 As_2O_5 6.66
4 Niagara Mixture A, 2 parts Hydrated Lime, 5 parts	*Calcium arsenate 14.28 Sulphur 14.28 Hydrated lime 71.42 As_2O_5 5.71
5 Pyrethrum, 1 part Hydrated Lime, 2 parts	Pyrethrum 33.33 Hydrated lime 66.66
5 Pyrethrum, 2 parts Hydrated Lime, 5 parts	Pyrethrum 28.56 Hydrated lime 71.42

*With same specifications as calcium arsenate recommended by U. S. Department of Agriculture for boll weevil control.

1, Bobwhite Chemical Co. 2, Vaycide Chemical Cor. 3, Dosch Chemical Co. 4, Niagara Sprayer Co. 5, Imported.

The experiments in the different groups are listed numerically by plats; the graphic summaries, pages 81 and 89, are drawn according to date that beans came up.



Sketch showing Location of Bean Plats.
Scale: ¼ inch = 120 feet.

Experiments with Bush Varieties of Snap or String Beans (Phaseolus vulgaris)

Plat 1, Early Valentine, .19 Acres

Beans came up April 17. Treated twice: 28 percent pyrethrum on May 14 and Cal-sulphur on May 25. Control not obtained. The beans of this plat were undersized, lack of fertilizer being the main reason. The injury caused by the beetles and larvae to these small plants increased rapidly and soon became relatively severe. The weak pyrethrum treatment was applied when the foliage was wet with dew and apparently had little effect. The arsenical application was not made until 30 days after beetles were first seen on the plat and the infestation by that time had become so heavy in proportion to the size of the plants that only slight benefit resulted.

The futility of attempting to grow small undernourished beans in territory infested by the Mexican bean beetle is demonstrated by this experiment. Such beans become infested as early as any and the percentage of injury resulting to them is far greater because of the small amount of foliage they possess. In less than two months from the date of coming up the beans of this plat were destroyed in spite of the treatments, and were ploughed up by the grower. Attention is called to a comparison of yield of this plat (75 baskets per acre) with that of Plat 11 (40 baskets per acre) where undersized beans were not treated.

Plat 2A, Early Valentine, .19 Acres

Late planted; coming up May 20. These beans escaped an early infestation and were not in need of treatment until about a month after coming up. After emerging from hibernation beetles appearing in this vicinity had been attracted to Plat 1 and as long as that source of food supply held out there was practically no migration to Plat 2A, 175 feet distant. With the destruction of beans on Plat 1, and also with the maturing of the first generation beetles, there was a decided increase in the adult infestation on Plat 2A the second week in June. Very few beetles had been found on this Plat up to that time. No treatment was given.

PLAT 3, EARLY VALENTINE, .22 ACRES

Beans came up April 15, the stand was poor and the plants suffered from lack of cultivation. One application of Cal-sulphur was made and the destruction temporarily checked, but the plants were unable to recover.

This plat furnished another example similar to Plat 1. It is a question whether the returns from such beans would net a profit if the bean beetle were not present, but under beetle conditions it is poor economy to grow beans that are not properly cared for or that are undernourished.

PLAT 4A, EARLY VALENTINE, .16 ACRES

Plat 4A Three Weeks Old, after Two Applications. These rows treated with Dosch Mixture. Original.

Of the snap beans experimented with those growing on this plat were the latest, coming up June 3. The plat was divided into three parts and three different insecticides tested. Two applications, June 17 and 23, were made to each part and the insecticide used on each was the same for both applications except in the case of the Dosch mixture which was stronger the second time. Good control was obtained with each insecticide.

There was no lack of nourishment or care given to the beans of this Plat. They grew well and soon became heavily infested. The insecticides used were:

Rows	4- 7	Niagara Mixture A and Lime, 1 to 2
	8-13	Dosch Mixture, B-14, and B-15
	14-16	Bol-Wee Compound and Lime, 1 to 2

The results from using the Niagara Mixture and Bol-Wee compound were so nearly the same that the graphic summary of Plat 4A, Table XLII, page 81, applies to both these insecticides. The infestation had rapidly increased to 60 or 70 percent. After the second treatment the infestation dropped to between 20 and 30 percent.

The final infestation of plants dusted with the Dosch mixtures was about 45 percent, due largely to the weaker mixture B-14 used in the first application.

No injury resulted from any of the applications which were all made when dew was on the foliage.

Plat 6, Early Valentine, .24 Acres

Beans came up April 14, grew rapidly, and soon became infested. First adults were found April 17, and eggs April 25. The infestation showed little increase until about the middle of May and then in spite of two pyrethrum treatments of 28 and 33 percent strength applied 5 days apart, the infestation rose rapidly and control was lost. Two other insecticides were then tested. Dosch B-14 applied to one-half the plat, and to the other half a mixture containing 14 percent calcium arsenate and 14 percent sulphur. Both applications failed to regain control, but the latter mixture proved superior to Dosch B-14 containing about 10 percent calcium arsenate.

Plat 6A, Giant Stringless Greenpod, .16 Acres

The beans in this plat were dusted four times with Cal-sulphur, the first three applications were made when the plants were wet with dew and the fourth when the foliage was dry. An American Beauty Duster was used and an Italian put on the second and third applications. (The 14th row was treated by the writer when showing the Italian how to use the machine). In this experiment a very striking illustration developed in the infestations which showed the results of the right and wrong way of using an American Beauty Duster when applying poison to bush beans.

TABLE XLI

Infestations Showing Results of Right and Wrong Way of Applying Dust with Bellows Type of Machine

1922	Egg groups	Instars and No. groups found					Hills			
		1st	2nd	3rd	4th	Pupae	Destroyed	Infested	Examined	Percent infested
April 27	Beans came up.									
May 1	0	0	0	0	0	0	0	0	150	**0**
9	0	0	0	0	0	0	0	0	75	**0**
20	Beans blossoming. Treated with Cal-Sulphur. Dew.									
June 1	Best preserved Plot.									
3	Treated with Cal-Sulphur. Dew.									
5	Began to pick.									
	2	2	12	30	6	0	0	19	50	**38**
7	Treated with Cal-Sulphur. Dew.									
9	2	4	12	26	38	0	0	37	50	**74**
	Row 2									
13	4	4	4	8	64	16	24	20	25	**80**
	Row 14									
16	4	0	8	0	8	0	0	4	25	**16**
	Row 2									
16	0	4	8	4	52	16	0	19	25	**76**
	Treated with Cal-Sulphur. Dry.									
	Row 14									
22	4	0	0	8	36	0	8	11	25	44
26	16	0	4	16	12	0	0	10	25	40
July 6	Beans ploughed up.									

Attention is called especially to the infestations recorded on the 9th, 13th, and 16th of June following the treatment of June 7. The high percentage of infestation found on the 9th and 13th of June was unexpected in view of the results accomplished on other plats. By the 16th of the month the reason became obvious. The Italian, while making the second and third applications, made the mistake of holding the delivery pipe of the dusting machine too low and too close to the plant so that the poison passed through the lower part of the plant without touching the upper leaves. As the attack and injury on the unprotected portions of the plants developed this fact became apparent and is further corroborated by a comparison of the two infestations taken on June 16. The 14th row was the one treated when showing the Italian how the job should be done.

Plat 6E, 5 Weeks Old, not Treated and not Infested. Original.

Plat 6E, Giant Stringless Greenpod, .07 Acres

Beans came up April 27, two weeks later than those of the nearest plat (No. 6) about 100 feet distant. The difference in dates of planting and the distance from other beans saved these from an early infestation. Forty days after coming up when picking began "no bugs" were seen, and as late as June 9 not a single larva could be found. The beans were practically through bearing by June 26, at which time there was a 60 percent infestation. The beans were not treated and the grower estimated that there was no loss in yield on this plat which produced 400 baskets per acre. Compare Plats 6E and 6A. The same interval occurred in time of planting between 6A and 3, (the nearest plat) as occurred between 6E and 6 (nearest plat). But 6A was infested one month before 6E. The distance separating 6A from the nearest plat was 20 feet while the distance separating 6E from its nearest plat was 100 feet.

Plat 7A, Early Valentine, .28 Acres

Late planted beans came up May 30. Three insecticides were tested on three divisions of this plat.

Rows	1- 3	Dosch Mixture B-14, and B-15
	4- 6	Cal-sulphur
	7-11	Niagara Mixture A and Lime, 1 to 2

Good control was maintained by all and the beans were in excellent condition the last of June when the work closed. After two applications of each had been made the infestations on rows 4-6 and 7-11 were the same, (Plat 7A, Table XLII, page 81). The last infestation on rows 1-3 was 40 percent. This undoubtedly would have been lower if the stronger Dosch Mixture B-15 had been applied both times instead of using B-14 for the first application. No injury resulted, all rows growing equally well.

PLAT 8, EARLY VALENTINE, .14 ACRES

Plat 8 and 8A, left. Both 11 Weeks Old and Well Protected from the Bean Beetle.

Beans came up April 10. This was an outstanding plat in the degree of control obtained. As a result of four treatments these beans reached an age of 87 days after coming up and were still being maintained 43 days after picking began.

The control obtained on this plat is seen to be more remarkable when the infestation records are compared with Plat 6. The beans on both plats came up about the same time and adults emerging from hibernation found both within a few days. By the first of May the number of adults on Plat 8 had increased tenfold while on Plat 6 the increase for the same period was two and one-half fold. The per centage of infestation on both plats was about the same, but increased more rapidly in Plat 8. The difference in control was clearly demonstrated (Table XLII). Every hill on Plat 6 was infested by June 5 while the maximum for Plat 8 was only 40 percent occurring on June 7.

Plants from Typical Hill of Plat 8, Showing Beans Developing 43 Days after Picking Began.

The plants were blooming and beans forming as late as July 6.

Bean Foliage, Plat 8, after Receiving Two Applications of Cal-sulphur.

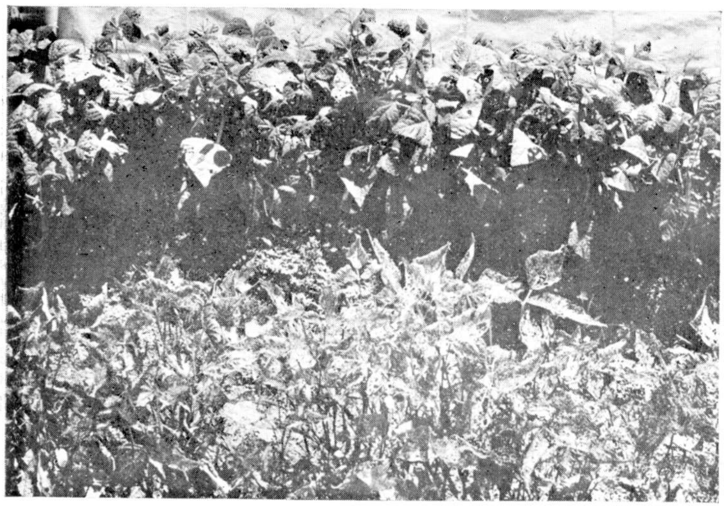
PLAT 11, EARLY VALENTINE, .05 ACRE

Beans came up April 6 but were of small size and were not treated. This plat may be compared with Plat 1 having similar undernourished beans. The difference in yield of 35 baskets in favor of Plat 1 is largely the result of the application of 70 cents worth of insecticide.

PLAT 13, GIANT STRINGLESS GREENPOD, .18 ACRES

Beans came up April 13, growing in land richly fertilized. The effectiveness of pyrethrum applied to dry foliage in the heat of the day was compared with its effectiveness applied when the dew was on the plants. A 28 percent pyrethrum mixture was used and two applications were made May 11 and 19 under each condition. The only difference which occurred as a result of the dew and dry applications was in the adult infestation which was constantly lower on the area receiving the "dry" treatment. Larvae and eggs were not abundant enough at this time for conclusions to be drawn. The pyrethrum applications were supplemented by a third treatment on May 27 with a mixture containing 14 percent calcium arsenate, 14 percent sulphur, and hydrated lime. Good control was affected and the grower estimated no loss in yield on the treated area.

This variety is naturally a larger plant which produces more foliage than the Early Valentine. Consequently, an equal infestation would produce less injury on the Giant Stringless Greenpod.



Condition June 7, Showing Untreated Row Plat 13. Row in Background Received One Application of Cal-Sulphur May 19.

PLAT 13A2, HOBSON'S IMPROVED VALENTINE, .08 ACRES.

Late planted, came up May 22. Received three treatments of Niagara Mixture A and Lime. The first treatment was given May 27 in the proportion of 2 to 5, the last two in the proportion of 1 to 2. Although the first application was weaker, the value of an early treatment is shown by comparing the infestation with that of Plat 13B, Table XLII, page 81. Good control resulted.

PLAT 13B, LONGFELLOW, .08 ACRES

Late planted, came up May 25. On May 30, 53 percent of the hills showed feeding injury, and on the check 44 percent. Two applications of Cal-Sulphur were made, the first on June 9 and the second on June 21. The percent of infestation ran high as a result of delaying the first application. Compare with infestations on Plat 13A2 and Plat 7A, Table XLII, page 81. However, control was gained as seen by the reduced infestation. The increase of infestation on the check is shown in Table XLII, page 81.

PLAT 14A, EARLY VALENTINE, .10 ACRES

Early planted beans came up April 10 anl grew well. On May 11 an application of Cal-sulphur was given to the west half of the plat when the foliage was dry and on the following morning the same insecticide was dusted on the east half of the plat when the foliage was wet with dew. The person applying the dust, and the hand gun used, were the same in both cases. At the request of the grower no further treatment was given. On May 13 there was an adult infestation of 112 percent on beans treated when dew was present compared with 53 percent on beans treated dry. But the most impressive result of this experiment is the final observation taken by one who did not know the plan of treatment or the insecticide used. The observation as recorded by Mr. Whitlock follows: "6/10/22. Heavy infestation, all plants destroyed except about 40 hills in each row on the west half of the plat." This half was dusted when the foliage was dry. When dew is present, especially a heavy dew, the leaves droop and hang closer to the ground. Not only is it difficult to force a cloud of dust through to the underside of the leaves but wet leaves nearest the nozzle catch and hold too much of the insecticide, thus preventing an even distribution of poison.

PLAT 14B, EARLY VALENTINE, .13 ACRES

Beans were planted between rows of cabbages and came up April 12. They did not receive proper cultivation. No treatment was given and no infestation taken until May 26 when they were found to be heavily infested and nearly destroyed.

PLAT 14D, EARLY VALENTINE, .08 ACRES

Late planted. Came up May 16. These beans were adjacent to Plat 14B which was rapidly becoming infested. At first the beans of Plat 14D were protected because of the later time of planting; and also partly because of an early treatment with Niagara Mixture A and Lime, 1 to 2. On May 27 there was only a 4 percent infestation, but with the destruction of Plat 14B the infestation on 14D jumped to 64 percent on June 9.

The results of 3 applications within the following 2 weeks using the same insecticide as in the early treatment may be seen in the reduced infestation of Plat 14D, Table XLII, page 81. On June 24 only 8 percent of the plants were infested while the check showed 100 percent.

PLAT 15, EARLY VALENTINE, AVERAGE GARDEN

In this garden a second planting of snap beans and a fall crop of butterbeans were destroyed by bean beetles in 1921. The first planting matured without loss in yield and the following year, 1922, early beans were again planted. They came up April 12. As late as May 23 not a beetle or larva had been found on them. On May 31 an infestation of 29 percent was found.

Evidently not a beetle passed the winter of 1921-22 in this garden which also escaped discovery by those emerging from hibernation. Another garden 100 yards away became infested May 10 and was completely destroyed by June 5.

This varying condition in time of infestation in different gardens may be more or less regular from year to year or may vary in the same garden, depending on the proximity of winter quarters chosen by beetles.

GRAPHIC SUMMARY OF EXPERIMENTS ON SNAP BEANS

Explanation of Table XLII, page 81.

Progress of infestation by *E. corrupta* in snap beans indicated by black area.

Vertical lines represent dates; total time included is from April 10 to June 29; date when beans were planted indicated by left margin of stipuled area.

Arrows show dates when infestations were taken.

Figures on right are the number of baskets of beans gathered per acre.

Lined area Plat 6A represents all rows of Plat except row 14 which is represented by black area.

Treatments given have been indicated as follows:

c. s.: Calcium arsenate, sulphur, and hydrated lime, 1-1-4; commercial.

P.: Pyrethrum diluted with hydrated lime.

1: Calcium arsenate, sulphur, and hydrated lime, 1-1-4; home mixed.

2: Calcium arsenate-magnesium compound and lime, 1-2.

3: Calcium arsenate, sulphur and hydrated lime, 1-1-5.

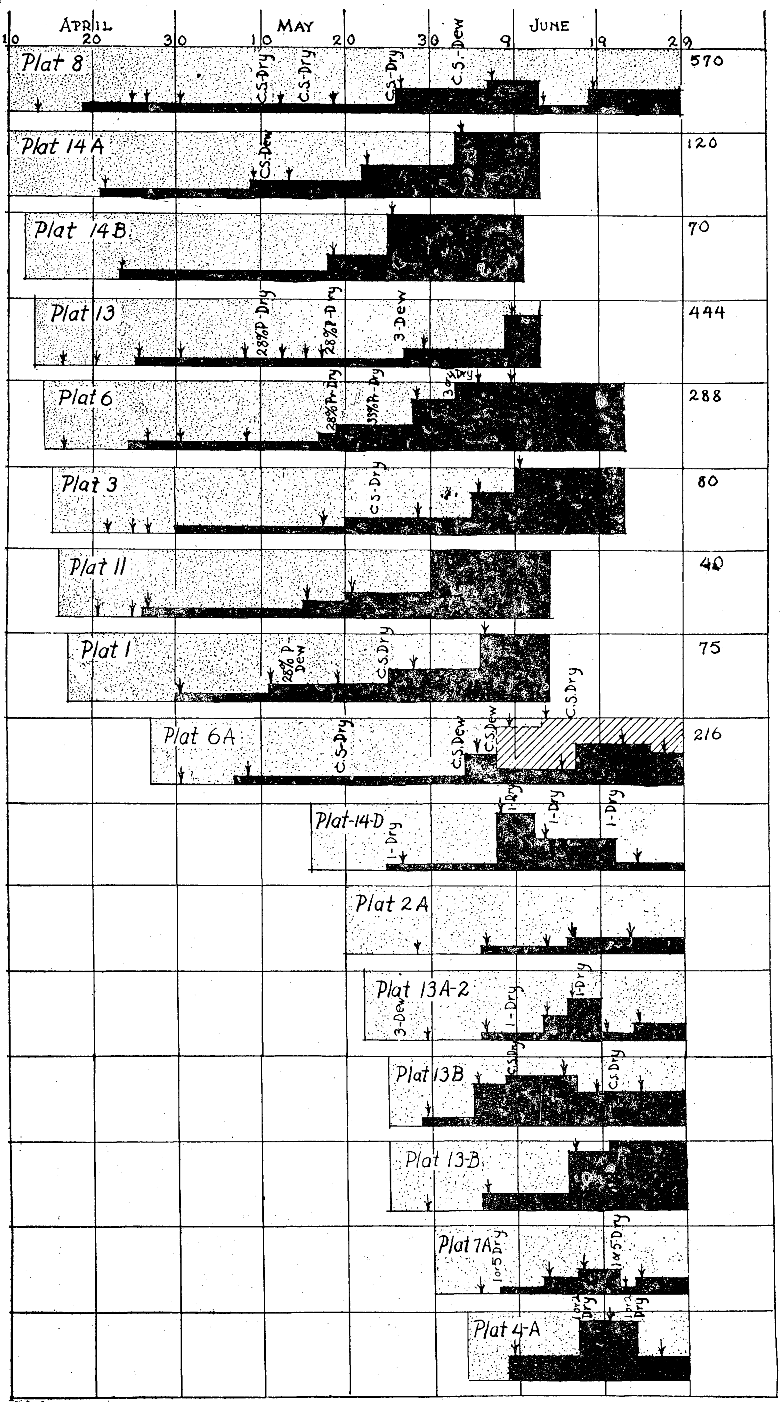
4: Copper, calcium arsenate, and hydrated lime, 20-10-70.

5: Same as c. s.

Dry, dew: refer to condition of foliage at time of treatment.

TABLE XLII

Graphic Summary of Experiments on Snap Beans



Experiments with Pole Snap Beans (Phaseolus vulgaris)

Plat 2, Texas Pole Beans, .17 Acres

Came up May 11. This plat was adjacent to the bush beans of Plat 1. The high percentage of infestation in June, in spite of the treatments, are direct results of the destruction of beans on Plat 1 and consequent migration of adults and larvae from that Plat to Plat 2.

Plat 2B, Texas Pole Beans, .22 Acres

These beans were about 200 feet away from Plat 1, the nearest early planting. They came up May 30 but very few first generation beetles found them until late in June when the larvae which migrated from Plat 1 to Plat 2 had transformed and become adults. On June 16 the adult infestation was 4 percent and one week later it had increased to 80 percent.

Plat 4, Pole Beans, .17 Acres

Pole Beans, Plat 4, 13 Weeks Old, after 5 Applications

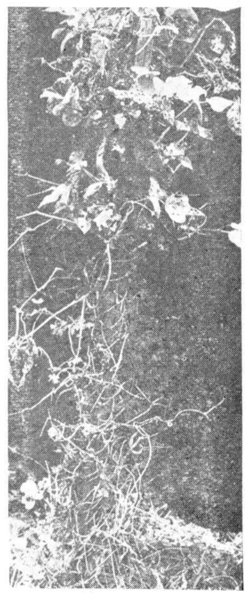
These were the earliest of all the beans, coming up April 3. Not until May was the infestation more than 1 percent. For the first two treatments pyrethrum mixtures were used, but little benefit was derived and on June 3 arsenicals were substituted. The insecticides used were the following:

Niagara Mixture A and Lime, 1 to 2
Cal-sulphur
Dosch Mixture B-14, and B-15

One dew treatment and two dry treatments were made with each on separate divisions of the plat. The infestation on each division was lowered and control obtained. This protection was shown by the absence of destroyed hills on the treated areas as compared with the number destroyed in the untreated section. On June 16, 16 percent of the check was destroyed and on June 24, 76 percent.

Because of the larger leaf area of pole beans the percentage of infestation may run higher than on bush beans with less injury resulting.

The width of rows on this plat was barely three feet, the poles were 18 inches to 2 feet apart in the rows. The beans grew to a height of more than 6 feet. Thoroughly covering all the foliage of the plants by dusting one side of the row was a tedious proposition when thus narrowly confined even when the foliage was dry. But when dew was present the operator usually got wet from the waist down and there was less inclination to do the job properly.



Destroyed Hill, Plat 4, after 11 weeks. Untreated.

PLAT 6D, TEXAS POLE BEANS, .20 ACRES

Typical Foliage on Plat 6D on July 6, after 2 Treatments.

Beans came up May 22. They were late planted and located only 25 feet distant from early snap beans on Plat 6. Most of the infestation on Plat 6D was a result of adult migration from Plat 6 which was rapidly being destroyed at this time. Three insecticides were used on separate divisions of the plat, two applications were made with each insecticide and at the end of June when the work was closed there was no noticeable injury to the foliage of any of these divisions. All applications were made when dew was on the foliage. The three insecticides used were:

Niagara Mixture A and Lime, 1 to 2
Cal-sulphur
Dosch Mixture B-14, and B-15

PLAT 7, POLE BEANS, .11 ACRES

This was one of the earliest plats of beans, coming up April 3. The grower did his best to hand-pick the beetles and egg groups. The last of April, when placing poles for the beans, special care was taken and practically every hill examined. All stages of the insect found were killed. His efforts were undoubtedly influential in holding the infestation temporarily in check. Nevertheless, there was a general increase in the percentage of infestation and on May 11 the first of three pyrethrum treatments was applied. Except for a slight benefit at first these applications produced little relief and on June 6, when the infestation was 88 percent an arsenical, Niagara Mixture A and Lime, 1 to 2, was substituted and two applications made. The beans of this plat were slightly injured as a result of the high infestation for two weeks but they recovered and were not destroyed until the middle of July. No other treatment was applied.

PLAT 8A, POLE BEANS, .16 ACRES

Beans came up April 10. Five applications of Cal-sulphur were made to one-third of this plat; the whole plat received the first three applications. On another third Cal-sulphur was followed by two applications of Bol-Wee and lime, 1 to 2. On the last third Niagara Mixture A and lime, 1 to 2, was used following the three applications of Cal-sulphur. All applications were made when the foliage was dry. Although the percentage of infestation had run up high it was not heavy and no injury developed. The graphic reproduction of Plat 8A, Table XLIII, page 89, is representative of all three insecticides. The check area, on June 22, had an infestation of 70 percent.

PLAT 13A1, POLE BEANS, .16 ACRES

Beans and corn came up May 22. Two applications were made. The first was Niagara Mixture A and lime, 2 to 5. Niagara Mixture A and lime, 1 to 2, and Bol-Wee and lime, 1 to 2, were used on separate areas for the second application. Later infestations showed an advantage of a little less than 20 percent in favor of the Bol-Wee and lime, 1 to 2. Good control was produced by both. The check had an infestation of 88 percent.

PLAT 14, POLE BEANS, .15 ACRES

Beans came up April 15. This plat furnished a good demonstration of the destruction that may be caused by the Mexican bean beetle when allowed to go unchecked or when improperly treated.

Although reliable insecticides were used, the first application was not given soon enough and the interval between applications was too great.

The two treatments that were made saved the beans for two weeks after the destruction of those on the untreated portion but the infestation had become so heavy that it could not be reduced in time to save the beans and the ground was cleared for ploughing June 26.

PLAT 14C, POLE BEANS, .10 ACRES

These beans came up late, May 20, and were adjacent to Plat 14. The increasing infestation on Plat 14 gradually spread to Plat 14C. Four applications of

Cal-sulphur proved sufficient to protect this planting until the menacing migration from Plat 14 was over. The first application was made 5 days after the beans came up. On July 6, larvae were scarce and the foliage was in fair condition.

Experiments with Pole Butter Beans (Phaseolus lunatus)

PLAT 6B, POLE LIMA OR BUTTERBEANS, .43 ACRES

Came up late, May 15, and had a 3 percent infestation 10 days later. Several different treatments were made to these beans, the first application being made on dry foliage June 2. At this time Niagara Mixture A and lime, 1 to 2, Cal-sulphur, and Dosch Mixture B-14, were used on separate divisions of the plat. Except for a slight increase in infestation where Dosch Mixture B-14 was used the percentage of infestation was lowered on all sections of the plat. For the two remaining applications dew was on the foliage. Bol-Wee and lime, 1 to 2, was substituted for Dosch mixture B-14. Otherwise the same insecticides were used.

Only a light infestation was present at any time on this plat, good control being maintained. The percentage of infestation when last taken on June 26 was a little lower where the Bol-Wee and lime had been applied. No injury resulted from this insecticide although it contained 26 percent calcium arsenate.

A low percentage of infestation was found June 22 on all the areas of this plat. This was due to two severe rain and wind storms which whipped many larvae off the vines. The leaves of butterbeans are small and their surfaces smooth, thereby subjecting larvae and eggs more to the violence of winds and rains. Most of them crawled back to the vines because the next infestation showed a very large increase on all divisions.

On July 6 the foliage was in very good condition. Very few larvae were on the leaves but adults and eggs were numerous. On July 30 injury was apparent but none of the beans on this plat were destroyed, even after going without protection for over a month.

PLAT 9, POLE LIMA OR BUTTERBEANS, .43 ACRES

Butterbeans, Plat 9, left, in Good Condition, July 29, one Month Without Treatment. Plat 8A, Right, Destroyed.

In contrast with those of the preceding plat, these beans came up early, April 15. The first treatment was applied May 24, Cal-sulphur being used on the entire area. On June 3, a different insecticide was used on each of four divisions of the plat and repeated in the two remaining applications, made June 14 and 21, to three of the divisions. The fourth division was dusted a total of three times only, and received the weakest arsenical used in the experiments, for the second and third applications. By the end of June the insect was well under control on all divisions of the plat. The check area was badly injured, some hills being nearly destroyed.

The insecticides used were as follows:

Niagara Mixture A and lime, 1 to 2
Cal-sulphur
Bol-Wee and lime, 1 to 2
Dosch Mixture B-14

The graph of Plat 9, Table XLIII, page 89, shows the treatments and infestation on that division receiving the poorest protection. The remainder of the plat received four applications.

Except the second, all applications were made when the foliage was dry. No injury resulted from any of the treatments.

GRAPHIC SUMMARY OF EXPERIMENTS ON POLE BEANS

Explanation of Table XLIII, page 89.

Progress of infestation by *E. corrupta* in pole beans indicated by black area.

Vertical lines represent dates; total time included is from April 3 to June 29; date when beans were planted indicated by left margin of stipuled area.

Arrows show dates when infestations were taken.

Daily rainfall shown at the bottom of plate.

Treatments given have been indicated as follows:

c. s.: Calcium arsenate, sulphur, and hydrated lime, 1-1-4; commercial.

P.: Pyrethrum diluted with hydrated lime.

1: Calcium arsenate, sulphur, and hydrated lime, 1-1-4; home mixed.

2: Calcium arsenate-magnesium compound and lime, 1-2.

3: Calcium arsenate, sulphur and hydrated lime, 1-1-5.

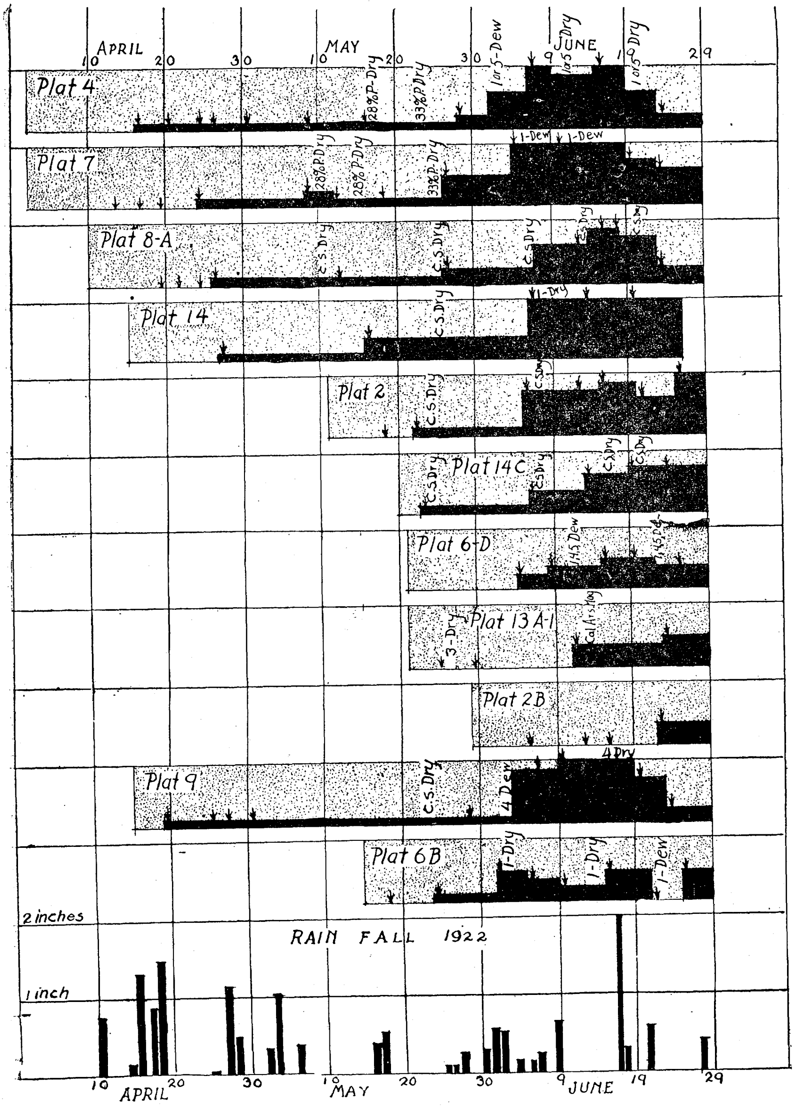
4: Copper, calcium arsenate, and hydrated lime, 20-10-70.

5: Same as c. s.

Dry, dew: refer to condition of foliage at time of treatment.

TABLE XLIII

Graphic Summary of Experiments on Pole Beans



Experiments on Cowpeas (*Vigna sinensis*)

Plat 12, California Black-eyed Peas, .17 Acres

Planted early. They came up April 15, adjacent to Plat 11. On May 16 four plants showed signs of feeding injury and an adult bean beetle was found. One application of Dosch Mixture B-15 was sufficient to protect the peas up to the first of July.

Plat 14, California Black-eyed Peas, .15 Acres

Planted late and near beans that were finally destroyed. The last of July the peas were heavily infested and suffering considerable injury. No treatment was applied.

A plat coming up July 15, 1921, was located adjacent to beans that were later destroyed. Less than a 1 percent infestation was found two weeks after coming up, but in August the beans were destroyed and the cowpeas were heavily attacked. The ground was entirely covered by the rank growth and it would have been necessary to tramp upon and injure the vines considerably if an application were made. The peas were not treated and 7 weeks after coming up they were practically destroyed.

Use of Dusted Beans as Food

Chemical analyses of several samples of dusted beans were carefully made. The insecticide used, contained 6.66 percent As_2O_5. The beans in one sample had been dusted when the foliage was dry and in another sample when the foliage was damp with dew. In each case a heavy application of dust had purposely been given. The beans from which the samples were taken were picked 1 hour and 3 hours respectively after dusting. Two other samples were picked from the same rows 9 days after dusting. In the meantime it had rained 1.26 inches in 24 hours.

The arsenic determination was made by Mr. S. J. Marion*, using the Modified Gutzeit Method. The results he obtained are shown in Table XLIV.

---

*Associate Research Chemist, Alabama Experiment Station.

TABLE XLIV

Arsenic Determinations on Beans

How Treated	Interval Before Picking	Wt. Sample Analyzed	Total As_2O_3
9-29-22 Dew	3 hours	200 grams	1.37 mg.
	9 days	400 grams	1.2 mg.
Dry 9-28-22	1 hour	200 grams	0.46 mg.
	9 days	400 grams	0.3 mg.

In order to get a fatal dose of arsenic a person would have to eat 40 pounds of green beans which had received a heavy application of dust.

However, visible traces of insecticides should be washed from beans before cooking. Ordinarily beans are always washed by truck growers before being placed on the market.

SUMMARY AND RECOMMENDATIONS

General Summary of Experimental Plats

The earliest destruction of a bush bean planting was observed June 1, 50 days after coming up; it was not treated. The plat of snap beans receiving the best protection lived about 100 days; it received four treatments.

The date when the first pole beans were destroyed was June 12, 58 days after coming up. Because of possessing more foliage, pole beans are capable of withstanding a heavier attack than bush beans.

Adult beetles show no preference between bush and pole beans when both are *Phaseolus vulgaris*. Butterbeans (*Phaseolus lunatus*) possess nearly the same attraction for the beetles, but the infestation of eggs and larvae develops slower.

Cowpeas may be attacked and completely destroyed but in most cases where this occurred, destroyed bean plantings were very near.

Summary of Insecticides

Applications of the insecticides listed in Table XL, page 69, were made to areas averaging one-tenth of an acre each, as follows:

63 to bush varieties of snap beans.
46 to pole varieties of snap beans.
22 to pole varieties of lima beans.
1 to cowpeas.

Six of the insecticides contained arsenic and the control resulting from their use was in proportion to the amount of arsenic they contained.

A brief summary of the results obtained with each arsenical follows:

Calcium Arsenate Magnesium Compound
(Bol-Wee) .... *1 part*
Hydrated Lime .... *2 parts*

This mixture contains 10.66 percent As_2O_5. The magnesium compound was added by the manufacturer to increase adherence of the calcium arsenate. Comparatively few applications of this insecticide mixture were made because of the high arsenic content. Eight treatments were made—5 to bush and pole snap beans and 3 to butterbeans—when the foliage was dry and when it was wet with dew. No injury or burning of any kind resulted. A safer and much lower arsenic content would be present if 1 part of the calcium arsenate magnesium compound were mixed with 4 parts of hydrated lime. Such a mixture would probably be easier to apply and would contain only 6.4 percent As_2O_5.

Copper Calcium Arsenate (*Dosch Mixture* B-15)
20-20-60

A stock mixture containing 7.8 percent As_2O_5. This insecticide showed more tendency to burn than any of the mixtures or other insecticides used. Six applications were made, but no noticeable injury resulted. The only trace of burning was indicated by a brown coloration which developed around the margins of injured spots or areas, especially on butterbeans. The Italian growers were inclined to favor this insecticide because of the bluish color; other insecticides appearing too much like lime.

Niagara Mixture A ------------- *1 part*
Hydrated lime ----------------- *2 parts*

This combination contains 6.66 percent As_2O_5. Forty-nine applications of this insecticide were made under all conditions. The periods during which these applications were made were as follows: July 15 to September 30, 1921, and May 10 to June 21, 1922, or the equivalent of one growing season. Not the slightest trace of burning resulted from any of the applications and if there was any stunting of the plants it was so little in evidence that the professional grower would not admit it. The formula recommended for controlling the Mexican bean beetle is based on the proportion of materials in this mixture. This proportion is given in Table XL, page 69.

Cal-Sulphur

Cal-sulphur contains 6.66 percent As_2O_5 and is a stock mixture commercially made according to the formula recommended by this Station. It was tested in 38 applications made during the period of May 10 to June 25 and compared with the preceding mixture on which the formula is based. Control was equally as good and no traces of burning or other injury developed as a result of any of the applications. In addition to these tests this insecticide was very widely used in the infested area during 1922.

Niagara Mixture A ------------- *2 parts*
Hydrated lime ----------------- *5 parts*

This combination contains 5.71 percent As_2O_5. Only 5 applications were made. A little benefit resulted from these applications but the infestation increased more rapidly than where stronger mixtures were used and the latter were substituted for this insecticide in order to hold the pest in check. Apparently this combination was too weak.

Copper Calcium Arsenate (*Dosch Mixture* B-14)
20-10-70

This is another stock mixture. It contains 3.8 percent As_2O_5. Fourteen applications of this insecticide were made to different species and varieties of beans. They failed to control the insect except in one instance on butterbeans. Even this strength caused a brown color to develop around the margins of injured spots on leaves of butterbeans but no noticeable injury resulted.

Pyrethrum mixtures are not to be depended upon for controlling the Mexican bean beetle.

Bean foliage is very susceptible to injury from the use of insecticides and, therefore, care should be taken before applying remedies that have not been recommended by the State Experiment Station or Government Entomologists.

Dusting Apparatus

Three types of hand dusting machines were used in applying the insecticides to beans and each proved to be good. These types were:

1. A small bellows attached to a 4 or 6 inch can.
2. A hand gun commonly used for dusting cotton.
3. A bellows type of machine carried on the back.

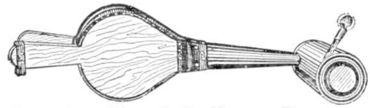


Fig. 1.—Hand Bellows Duster.

The first type, Figure 1, is a very good one for protecting the average garden or small areas. Two ounces of dust per application for 100 feet of row is enough for either bush or pole beans when using the small hand bellows. With this type the dust can be directly applied to the under sides of the leaves.

Fig. 2.—Hand Gun in Operation.

The second type, Figure 2, may be used with or without the fan shaped nozzle when dusting pole beans. When using the nozzle slightly better results are obtained if the dust is directed toward the side of the row. From 20 to 30 pounds per acre per application, or 3 ounces to 100 feet of row, are needed for bush and pole beans when using this gun.

Fig. 3.—Bellows Type of Duster.

The third type, Figure 3, is the most efficient when properly used. By fitting a wider spoon or disk on the end of the spout to deflect and spread the dust an application can be made directly to the under sides of the leaves. The nozzle should not be held near the base of the stems but moved in such a way as to uniformly dust all the leaves of a hill. The amount of insecticide used is more easily regulated with this machine. Ten to 40 pounds, depending on the size, per acre per application are needed to dust bush and pole beans.

Preventive and Cultural Measures

Beans should be stimulated by fertilization and cultivation to put on all the foliage they will carry.

Beans that are nearly destroyed and heavily infested should be ploughed under to a depth of 2 inches in order to kill the insects.

Hand-picking is not economical except perhaps in small gardens.

Frequently small patches of early beans may mature a crop without loss, especially in gardens.

Pole beans should not be planted adjacent to bush beans unless it is planned to protect the latter until ploughed up. This is because of the danger of a spreading infestation from bush to pole beans which have a longer life.

Pole beans should be planted in rows at least 4 feet wide to permit dusting without interference when the beans are grown. Planting in corn is not recommended because of the difficulty in making a thorough application.

With the knowledge of the gregarious habit of hibernating adults and the type of material in which they prefer to pass the winter, occasional search should be made during the winter and early spring among accumulations of leaves on the margins of wooded areas and under single trees near locations where bean plantings suffered from attack of the insect. Colonies of beetles containing several hundred may be found. Fence rows and ditch banks should be cleaned up and the rubbish burned. Not only will these measures help in destroying the winter quarters, which is very important, but the numbers of beetles may be materially reduced.

Early planting is advised, although no strong recommendations are given regarding the time of planting. It begins to appear as though late beans may suffer but little injury, when planted as late as a crop can be assured.

Plant cowpeas and soy beans as in the past. Until more investigation sheds new light, no change in crops is advised. The greater the distance between beans and cowpeas, the safer it is for the peas.

Control Methods

The Mexican bean beetle can be controlled economically by dusting the foliage of beans.

Several insecticides were used successfully. The one which is recommended has the following formula and contains 6.66 percent As_2O_5:

	Percent
Calcium arsenate (High grade)	16.66
Fine dusting sulphur	16.66
Hydrated lime	66.66

Green beans dusted with this insecticide are perfectly safe to be used as food, but washing is advised.

It is recommended that applications of insecticides be made when the foliage is dry and when little wind is blowing.

Four or five applications will usually be sufficient for protecting early planted bush varieties of snap or string beans. Those coming up about the middle of April should receive their first application in two or three weeks. The time of the first treatment for later plantings varies according to the infestation. Ordinarily it should begin soon after beetles are found, especially on beans planted after May.

Applications to bush varieties should be made once each week, for if the infestation is once allowed to become abundant, a certain amount of injury will result.

Five applications beginning the first week in May provided good protection for early planted pole beans until the last of June.

Control is more easily obtained on butterbeans than on snap beans. Treatment every ten days beginning the middle or last of May will be found amply sufficient to protect early planted butterbeans.

The foliage of butterbeans, *Phaseolus lunatus,* is more susceptible than that of snap beans, *P. vulgaris,* to injury from the use of insecticides.

Mature beans which have been well protected appear to be less attractive to the Mexican bean beetle and require very little in the way of treatment.

When dusting pole beans, the dust cloud may become thick around the operator. Sometimes it is necessary to wear a handkerchief over the lower part of the face and tied behind the head.

If cowpeas are being grown for seed and the vines become infested any of the insecticides recommended for use on beans will reduce the infestation and save the vines if applied in time. To facilitate the application of such treatments the cowpeas should be planted so that a skip occurs every fifth row, or if sown broadcast so that a space wide enough to walk is left between "beds" not over 12 feet in width.

If cowpeas, to be fed as hay to livestock, are in danger from the beetle as a result of destroyed bean plantings, immediate cutting is advised.

BIBLIOGRAPHY

(1) Mulsant, M. E.
1850. Species des Coleopteres Trimeres Securipalpes. Paris.

(2) Bland, H. J.
1864. Descriptions of New North American Coleoptera. In Proc. Ent. Soc. Phila., v. 3, p. 253-256.

(3) Crotch, G. R.
1874. A revision of the Coleopterous Family Coccinellidae. London.

(4) Riley, C. V.
1883. Epilachna Corrupta as an Injurious Insect. In General Notes, Amer. Nat., v. 17, p. 198-199. February.

(5) Wielandy, J. F.
1889-90. Injurious Insects in New Mexico. In U. S. Dept. Agr., Insect Life, v. 2, p. 113-115.

(6) ——————
1891. The New Mexican Epilachna. In U. S. Dept. Agr., Insect Life, v. 3, p. 121-122.

(7) Gillette, C. P.
1892. Observations upon Injurious Insects. Colo. Agr. Exp. Sta. Bul. 19.

(8) Gorham, H. S.
1897. Biologia Centrali-Americana, Coleoptera, v. 7.

(9) Griffin, H. H.
1897. Results of Experiments at the San Juan Substation. N. Mex. Agric. Exp. Sta. Bul. 21.

(10) Gillette, C. P.
1899. Colorado's Worst Insect Pests and Their Remedies. Colo. Agr. Exp. Sta. Bul. 47.

(11) Casey, T. L.
1899. A Revision of the American Coccinellidae. In Jour. N. Y. Ent. Soc., v. 7, p. 71-169.

(12) Chittenden, F. H.
1899. Insects Injurious to Beans and Peas. In Yearbook U. S. Dept. Agr., 1898, p. 233-260.

(13) Cockerell, T. D. A.
1900. Observations on Insects. N. Mex. Agr. Exp. Sta. Bul. 35.

(14) Caudell, A. N.
1902. Notes on Colorado Insects. In Some Miscellaneous Results of the Work of the Division of Entomology. VI. U. S. Dept. Agr. Bur. Ent. Bul. 38.

(15) Knaus, W.
1906. Coleoptera of the Sacramento Mountains of New Mexico. III. In Ent. News, v. 17, p. 329-333.

(16) Fall, H. C., and Cockerell, T. D. A.
1907. The Coleoptera of New Mexico. In Trans. Amer. Ent. Soc., v. 33, p. 145-272.

(17) Chittenden, F. H.
1907. Insects Injurious to Vegetables. New York.

(18) Sanderson, E. D.
1912. Insect Pests of Farm, Garden, and Orchard. New York.

(19) Morrill, A. W.
1913. Entomological Pioneering in Arizona. In Jour. Econ. Ent., v. 6, p. 185-195.

(20) Essig, E. O.
1915. Injurious and Beneficial Insects of California.

(21) Merrill, D. E.
1917. The Bean Beetle. N. Mex. Agr. Exp. Sta. Bul. 106.

(22) Orton, W. A., and Chittenden, F. H.
1917. Control of Diseases and Insect Enemies of the Home Vegetable Garden. U. S. D. A. Farmers Bul. 856.

(23) Chittenden, F. H.
1919. The Bean Ladybird and Its Control. U. S. D. A. Farmers Bulletin 1074.

(24) Chittenden, F. H., and Marsh, H. O.
1920. The Bean Ladybird. U. S. D. A. Bul. 843.

(25) Montgomery, J. H.
1920. Notes from the Quarantine Department. Quar. Bul. State Plant Board of Fla. Vol. V., No. 1. p. 2.

(26) Hinds, W. E.
1920. Mexican bean Beetle Situation, Jour. Eco. Ent. Vol. 13, No. 6, pp. 486-488.

(27) ————————
1921. The Mexican Bean Beetle, a New Pest in Alabama. Ala. Exp. Sta. Bul. 216.

(28) Howard, Neale F.
1921. The Mexican Bean Beetle and Its Bearing on Florida Citrus Growing. Quart. Bul. State Plant Board of Fla. Vol. VI, No. 1, pp. 15-24.

(29) Newell, Wilmon.
1921. The Mexican Bean Beetle. Quart. Bul. State Plant Board of Fla. Vol. V, No. 2, pp. 119-121.

(30) List, Geo. M.
1921. The Mexican Bean Beetle. Col. Agr. Exp. Sta. Bul. 271.

(31) Howard, Neale F.
1922. The Mexican Bean Beetle in the Southeastern United States. Jour. Eco. Ent. Vol. 15, No. 4, pp. 265-275.

(32) Bentley, G. M.
1922. The Mexican Bean Beetle, a New and Serious Pest in Tennessee. Tenn. St. Bd. of Ent. Vol. XI, No. 2 Bul. 41.

(33) Hinds, W. E.
1923. Mexican Bean Beetle Control. Ala. Poly. Inst. Ext. Service, Cir. 61.