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FURTHER EXPERIMENTS ON
MEXICAN BEAN BEETLE CONTROL

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MEXICAN BEAN BEETLE CONTROL*

NEELY TURNER and R. B. FRIEND

The Mexican bean beetle (*Epilachna corrupta* Mulsant) entered the southwestern part of Connecticut in 1929. It was first reported from Stamford in July of that year, and later in the season spread as far east as Hartford and New Haven. In 1930, beetles were present in all parts of the State, and serious injury to bean plants occurred in Fairfield County. In 1931, damage was noticed in many locations throughout the State, and in 1932, unsprayed plants were generally defoliated. Since that year the infestation of bean beetles has varied locally, but in general the pest has been less abundant than in 1932. However, serious injury occurs in all sections of Connecticut.

Preliminary research on the biology and control of the Mexican bean beetle was started in 1930. In 1931, more extensive studies were made and the results published (1).† Further publications containing reports of progress were made in 1933 (4, 5). The present report summarizes the data obtained during 1932, 1933 and 1934. The experiments were planned to study (1) the effects of cultural practices on control of the bean beetle, (a) date of planting, (b) distance of spacing plants in the row; and (2) control by means of insecticidal treatments on string, lima and shell beans.

WEATHER RECORDS

The climate of Connecticut is generally favorable to bean beetles, according to Marcovitch and Stanley (2), and Sweetman and Fernald (3).

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* Experiment Station Bulletin 332.

† For number references, see bibliography on page 452.

The only climatic condition likely to affect bean beetle abundance seems to be hot, dry weather in summer. According to Sweetman and Fernald (3), a constant temperature of 89.6° F. is necessary to kill the different stages of the bean beetle. Such temperatures rarely occur in Connecticut for more than eight consecutive hours.

Hibernation mortality is affected by moisture conditions and by low temperatures. The winters of 1930–31 and 1931–32 were unusually warm and bean beetles survived in large numbers. Since 1932, the winters have been more severe, and apparently the adults have not survived in so large numbers.

Temperature and rainfall records for the three years during which experiments were carried out are given in Table 1. The records were taken from instruments located within a few feet of the bean plots, and the normal figures were taken from records of the New Haven office of the U. S. Weather Bureau.

TABLE 1. WEATHER RECORDS—MOUNT CARMEL FARM

Month	1932	1933	1934	Normal*
Monthly mean temperatures				
May	58.0	59.7	59.2	57.9
June	66.1	67.2	68.2	66.6
July	70.7	69.5	72.3	71.8
August	70.4	69.2	65.7	70.3
September	62.8	64.1	64.8	63.5
Rainfall				
May	2.0	2.6	6.7	3.7
June	2.1	2.7	4.6	3.1
July	1.8	3.2	2.3	4.3
August	4.4	6.7	2.2	4.3
September	3.7	5.7	11.1	3.5
Total for year	**44.0**	**46.6**	**57.3**	**45.5**

*New Haven Weather Bureau.

These records show that the average monthly temperatures in 1932 were practically normal, with the exception of those in July, which were slightly lower than normal. The rainfall during 1932 was much below normal during May, June and July, and about normal in August and September.

In 1933, the temperature averages for May, June and September were above normal, and for July and August were below normal. Rainfall was again deficient in May, June and July, and exceeded the average in August and September.

In 1934, May, June, July and September were above normal in temperature, and August was much below normal. Rainfall was much above normal in May, June and September, and below normal in July and August.

The dry weather in June and July, 1932, affected the bean crop considerably. Likewise, the lack of moisture in July and August, 1934, reduced yields, especially on lima beans. The deficiency in 1933 was too small to injure the crop. The variations in temperature and rainfall apparently had no important effect on the activity of Mexican bean beetles. In no case was the temperature high enough to interfere with bean beetle development. On one occasion in 1933, the maximum temperature exceeded 90° F. for four days in succession, but the daily average was lower than 80° F. Even in the absence of moisture, these temperatures were not sufficiently high to kill the larvae.

SOIL CONDITIONS

The experimental plots were located at the station farm at Mount Carmel on soil classified as Cheshire loam, an upland soil fairly well adapted to bean production. The plots received an annual application of 4–8–7 fertilizer, broadcast at the rate of 2,000 pounds to the acre. Each year a cover crop of rye or rye grass was grown after the beans were harvested, and was turned under the following spring. The acidity was neutralized when necessary by applications of hydrated lime. The analysis of the soil, made in 1932 by the Soils Department of the Connecticut Agricultural Experiment Station, was as follows:

MECHANICAL

	Per cent
Colloids	20.5
Fine sands	40.5
Coarse sands	39.0

CHEMICAL

	Total pounds per acre
Calcium	10,350
Magnesium	5,196
Potash	27,424
Phosphorus	1,500
Nitrogen	2,010
Available nitrogen	100
Available P_2O_5	200

LIFE HISTORY OF THE MEXICAN BEAN BEETLE

Detailed studies of the life history of the Mexican bean beetle were published in 1931 (1). These showed that the period of incubation of eggs is from 7 to 9 days, that the larval period lasts from 18 to 25 days, and that pupation requires from 6 to 10 days. The total period of development takes from 32 to 41 days. In general, higher temperatures cause first generation individuals to develop more rapidly than those of the second generation.

Over-wintering adults usually emerge from hibernation during the last week in May and the first week in June, but in 1932 emergence was not completed until June 17. Egg deposition starts about June 7 and continues until the last of June. First generation larvae are present during the period of June 15 to July 10. First generation adults appear about July

18 and continue to emerge until about August 10. In an insectary experiment some of these adults lived until time for hibernation in the fall, but it is not known whether or not they survived until the following spring.

Second generation eggs are deposited from about August 1 until September 10. The larvae are present from early in August until late in September, and pupation occurs during September. The majority of second generation adults emerge from pupation between September 6 and 30. On one occasion, newly emerged adults were found on October 25, eleven days after the first killing frost. Hibernation usually starts early in October, and by October 10 most of the beetles have left the bean plants.

ABUNDANCE OF BEAN BEETLES

In 1932, a large number of beetles came out of hibernation. The first generation caused serious injury, and the second generation caused very serious injury. In 1933, fewer over-wintering beetles emerged, and damage from both generations was much less than during the preceding year. A further reduction in emergence occurred in 1934, and the first generation caused only a moderate amount of injury. However, second generation larvae caused as much damage as in 1933.

Under the conditions of these tests, it was necessary to have many unsprayed plots. Consequently a very large number of adult beetles developed and migrated as soon as they emerged. They caused serious injury to sprayed plants, especially to the pods. The pod injury on crops maturing during beetle flight was, therefore, unusually severe. In experiments conducted under normal commercial growing conditions, the entire crops received insecticide treatment with better results.

DATE OF PLANTING EXPERIMENTS

In 1932 and 1933, plantings of the Bountiful variety of string beans were made at intervals of 10 days during the growing season. In 1932, the planting dates were from May 2 to July 21, and 18 rows, 10 feet long, were planted on each date. In 1933, the dates were from May 11 to July 21, and six rows, 15 feet long, were planted on each date.

Half of each planting was sprayed as necessary, using three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water. The pods were picked as they matured, and the yield of each row was recorded. From two to four pickings were necessary in harvesting the crop, the number depending on the yield and uniformity of pod maturity. A record of the amount of pod injury was kept in all cases. Records were made of the development of the Mexican bean beetle infestation on each planting.

The records showing the dates of planting, of appearance above ground, of attack by the bean beetle and of picking, are given in Table 2. The dates of the spray applications, yield per plant and reduction in yield of unsprayed as compared with sprayed plants, are given in Tables 3 and 4 (Page 428). The results are shown graphically in Figures 73 and 74.

Dates of Planting and Beetle Attack

In the 1932 series, the May 2 and 12 plantings had sprouted when the over-wintering adults appeared. The May 21 planting was attacked three

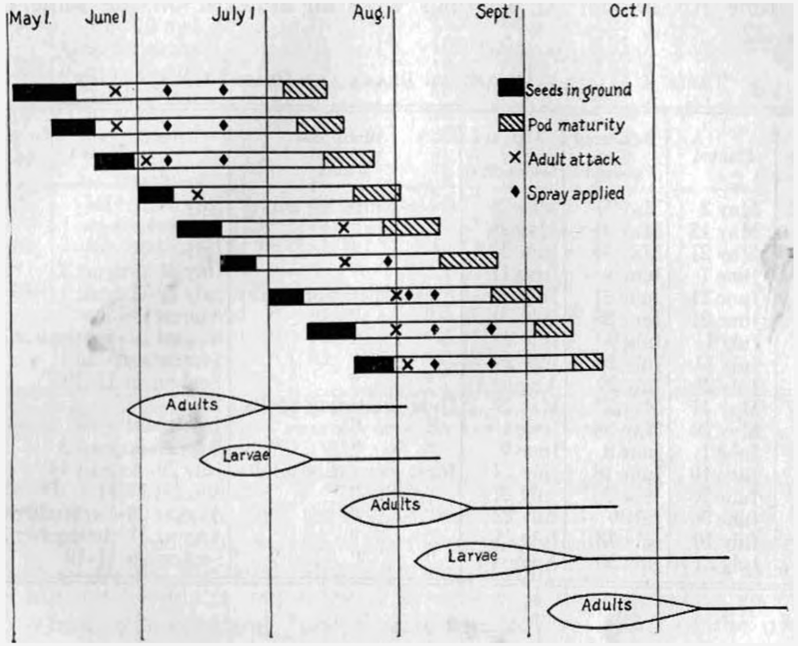

FIGURE 73. This diagram shows the relation between the date of planting, date of bean beetle attack and date of spraying.

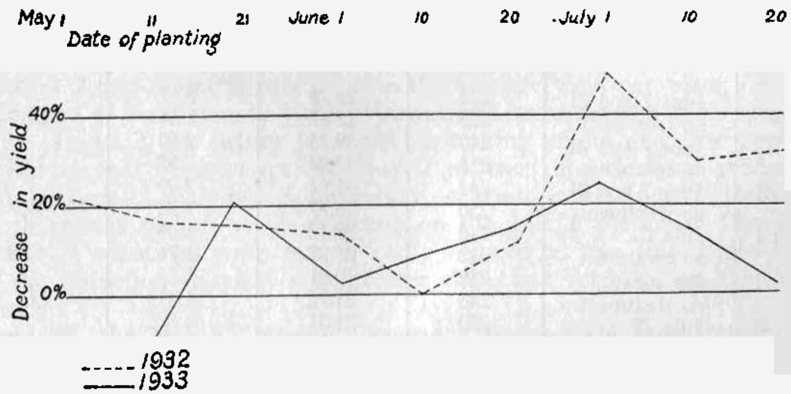

FIGURE 74. The relation between the date of planting and the percentage of crop reduction due to bean beetle attack is shown here.

days after the plants appeared above ground. The June 1 planting was attacked on June 15 by a very few over-wintering adults. The June 11 planting was attacked by first generation adults on July 20, nine days before the pods matured. The June 21 planting was attacked on the same date, and the July 1 planting, on July 29. The July 21 planting was attacked August 1, two days after the beans sprouted.

In 1933, the dates of attack were similar to those in 1932, except that the June 10, 20 and 30 plantings were all attacked on the same day, July 22.

TABLE 2. DATE OF PLANTING BEANS AND BEAN BEETLE ATTACK

Year	Planted	Appeared above ground	Attacked by bean beetles	Adults first attacking plants	Picked
1932	May 2	May 17	May 26	Over-wintering adults	July 5–15
	May 12	May 21	May 26	" " "	July 8–19
	May 21	May 31	June 3	" " "	July 14–26
	June 1	June 9	June 15	" " "	July 21–August 2
	June 11	June 21	July 20	First generation adults	July 29–August 9
	June 21	June 28	July 20	" " "	August 9–16
	July 1	July 9	July 29	" " "	August 22–September 1
	July 11	July 24	July 29	" " "	September 6–13
	July 21	July 29	August 1	" " "	September 13–19
1933	May 11	May 21	May 27	Over-wintering adults	July 3–13
	May 20	May 28	June 1	" " "	July 13–24
	June 1	June 8	June 9	" " "	July 21–August 3
	June 10	June 18	July 22	First generation adults	July 29–August 14
	June 20	June 26	July 22	" " "	August 14–31
	June 30	July 9	July 22	" " "	August 23–September 5
	July 10	July 18	July 25	" " "	August 31–September 11
	July 21	July 30	August 5	" " "	September 11–19

TABLE 3. SUMMARY OF RESULTS—DATE OF PLANTING EXPERIMENT—1932

Date of planting	Date of spraying	Number of plants	Total yield (pounds)	Average yield per plant	Per cent reduction in yield
May 2	June 7 and 21	222	28.78	2.07	
	no treatment	222	22.87	1.64	21.7
May 12	June 7 and 21	246	39.75	2.59	
	no treatment	250	33.94	2.17	16.2
May 21	June 7 and 21	245	31.94	2.09	
	no treatment	250	26.87	1.72	17.7
June 1	July 1	240	29.12	1.94	
	no treatment	242	25.87	1.71	11.8
June 11	not sprayed	250	20.81	1.33	
	no treatment	246	21.72	1.41	+6
June 21	July 29	250	25.31	1.62	
	no treatment	245	22.72	1.48	8.7
July 1	July 29, Aug. 9	224	24.69	1.76	
	no treatment	230	12.81	.89	49.4
July 11	Aug. 9 and 23	240	13.50	.90	
	no treatment	240	10.56	.70	22.2
July 21	Aug. 9 and 23	238	12.44	.83	
	no treatment	240	8.72	.58	30.1

TABLE 4. SUMMARY—DATE OF PLANTING EXPERIMENT—1933

Date of planting	Date of spraying	Number of plants	Total yield (pounds)	Average yield per plant (ounces)	Per cent reduction in yield
May 11	June 10 and 22	78	14.72	3.02	
	no treatment	81	16.97	3.35	+10.9*
May 20	June 10 and 22	70	19.97	4.56	
	no treatment	83	18.90	3.64	20.2
June 1	June 10†	79	25.90	5.24	
	no treatment	79	25.15	5.09	2.8
June 10	June 22	56	15.06	4.30	
	no treatment	56	14.03	4.01	6.9
June 20	July 19	94	17.37	2.95	
	no treatment	44	6.87	2.50	15.2
June 30	July 29, Aug. 7	83	10.62	2.05	
	no treatment	65	6.28	1.54	24.9
July 10	Aug. 7	66	7.03	1.70	
	no treatment	59	5.31	1.44	15.3
July 21	Aug. 7 and 30	78	5.94	1.22	
	no treatment	83	6.22	1.19	2.2

* Larger yield on untreated plot due to severe spray injury on sprayed plot.
† Special test of arsenical sprays; spray not necessary to control bean beetles.

The two general periods of infestation occurred between May 26 and June 15, during which time the over-wintering adults migrated, and between July 18 and August 15, when the first generation adults emerged from pupation and migrated. Beans growing during either of these periods were injured by adults and infested by larvae of the succeeding generation. Those planted about June 1 were attacked by adults of the over-wintering and first summer generation, but the over-wintering adults were usually few in number, and the first generation beetles emerged just as the crop was maturing.

Relation to Yield Reduction

Tables 2 and 3 and Figure 74 give the average yield per plant and the percentage of reduction in yield of unsprayed as compared with sprayed plants. In 1932, the injury from over-wintering adults and first generation larvae was greatest on the May 2 planting and declined gradually until the June 11 planting. Some injury occurred on the June 21 planting, and there was serious yield reduction on the July 1 planting. The July 11 and 21 plantings were not so badly injured as the July 1 planting, but the reduction in yield was greater than was recorded in the May plantings.

In 1933, the May 11 planting showed a larger yield from unsprayed than from sprayed plants. The latter were injured by the spray material (an unsatisfactory brand of magnesium arsenate) which accounted for the small crop. Bean beetles caused the least injury on the June 1 planting, decreasing the yield by 2.8 per cent, an insignificant amount. The yield was decreased from that time until the June 30 planting, which showed the greatest damage during the year. Injury on beans planted after July 1 steadily diminished until the July 21 planting which approached normal.

The figures show that the least injury in 1932 occurred on the June 1 planting, and in 1933 on the June 1 planting. The season of 1932 was abnormal in that the first 13 days of June were hot and dry, stopping emergence from hibernation. On June 13 and 14, a rainfall of .7 inch caused migration to start again, and the June 1 planting was moderately infested. In 1933, weather conditions were more nearly normal than in 1932 and migration proceeded normally. There were few beetles on the June 1, 1933, planting.

Plantings infested by the largest numbers of bean beetles showed the largest reduction in yield. Plants attacked relatively early in their period of growth were more seriously injured than those attacked a few days before pod maturity.

Relation to Pod Injury

Both larvae and adults of the Mexican bean beetle seriously damaged pods by feeding on them. In cases of severe infestation by bean beetles, the pod injury was at least as serious as the reduction in yield. Feeding injury by adult beetles was more common than that by larvae. The larvae usually confined their feeding to foliage, and migrated to pods only when the leaves were totally consumed. The adults were apt to feed on pods, especially if the foliage had been sprayed. Furthermore, they lived over a long period of time and migrated freely.

Adult feeding injured pods during the periods of July 18 to August 15, and September 10 to September 30. Beans planted June 10 produced a satisfactory yield but the pods were of poor quality because of feeding scars. Pods from July 11 and 21 plantings were also badly scarred.

Although less injurious to pods, larval feeding occurred over a longer period of time. Pods maturing when the larvae were in the fourth and fifth instars were most seriously affected. Pods maturing during the first half of July and the last half of August were most subject to larval injury. Spraying the vines was found to be the best preventive for this trouble as the larvae were thus killed before the pods matured.

Reference to Figure 73 shows that all pods from all plantings matured during the time that larvae or adults were present. Therefore, all pods were subjected to damage from feeding scars. The larval injury was easily prevented by spraying, but adults were not killed by magnesium arsenate sprays. The amount of adult feeding could be reduced by spraying all plants in the field and thus allowing very few beetles to mature.

Relation Between Dates of Planting and Spraying

It has been found that adult Mexican bean beetles are very difficult to kill with magnesium arsenate diluted at the rate of three pounds in 100 gallons of water. However, when such applications were made before egg-laying, fewer eggs were deposited and feeding injury to the foliage was reduced.

Therefore, the first spray was applied as a preventive measure. The second application was made at the time half of the egg-masses present had hatched to kill the young larvae. This spray schedule was developed for use on plantings of beans that were infested by a complete generation of bean beetles. The dates of application were changed to meet the needs of plants that grew during the period between the two generations of beetles. The schedule of insecticide treatments is given in Tables 3 and 4, and is indicated in Figure 73.

In 1932, all the May plantings were sprayed on June 7 and June 21. The first spray was applied before many eggs were deposited, and the second when the larvae were feeding. These two applications reduced injury. By July 1, the June 1 planting required a spray to kill larvae. This planting was moderately infested, but the single treatment was very effective. The June 11 planting received no treatment, as the first beetles appeared on the plants only nine days before the first pods were picked. The June 21 plots required one spray on July 29. The July 1 planting was sprayed July 29 and August 9, and later plantings made in July were treated on August 9 and 23.

In 1933, the two May plantings were sprayed on June 10 and June 22. The June 1 planting was not seriously infested and required no spray. The June 10 planting received a special test spray on June 22 and a small increase in yield resulted. This spray was not considered necessary for bean beetle control. Later plantings were treated much as in 1932, except that the second spray was omitted on the July 10 planting.

It is evident that beans planted during May and after July 1 required two sprays because they were all subject to infestation by a complete generation of bean beetles. June plantings required special treatment. It is probable that in normal years beans planted June 1 and June 11 will not produce a profitable increase in yield due to spraying because of the light infestation on these plantings. The June 21 planting required one spray about July 25.

Relation Between Spray Dates and Maturity

In tests described later, it was found that sprays could not be applied after the pods formed without leaving an arsenical residue at harvest. Therefore, it was necessary to discontinue use of magnesium arsenate as soon as the blossoms dropped. Crops planted during May and July were not affected because the spray dates were well in advance of the dates of maturity. Beans planted June 11 and 21 required treatment at about the time of pod formation. A substitute treatment was applied when the beans blossomed, although few beetles were present then.

SPACING OF PLANTS AND BEAN BEETLE INJURY

The effect of the spacing between string bean plants in relation to control of the Mexican bean beetle has been studied on four crops of beans grown in 1932, 1933 and 1934. In 1932 and 1933, the plantings were infested by the first generation of the bean beetle, and a second planting in 1933 and one in 1934 were infested by second generation beetles.

The Bountiful variety of green string beans was used in all experiments. The plots were of six rows, each 10 feet long and 30 inches apart. The seeds were spaced 2, 4, 6 and 8 inches apart in the rows, one series of plots being used for each spacing. The seeds were planted by hand, and a yardstick was used to insure accurate spacing. The plots were arranged in Latin squares with each spacing occurring in four plots in each square. Three rows in each plot were sprayed with three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water. All spraying was done by hand, using a barrel pump and a rod with an angle nozzle. Only the under surfaces of the leaves were sprayed. Each planting was made at the time when it would receive the maximum infestation of bean beetles. The date of planting, dates of appearance above ground, date of attack by bean beetles, date of spraying and dates of picking each crop are given in Table 5.

TABLE 5. SPACING EXPERIMENTS

Year	Planted	Appeared above ground	Attacked by bean beetles	Sprayed	Picked
1932	May 23	June 2	June 6	June 25 and July 11	July 18–28
1933	May 15	May 26	May 28	June 10 and 29	July 11–17
1933	July 3	July 10	July 20	July 29 and Aug. 9	Aug. 28–Sept. 5
1934	July 5	July 13	July 20	Aug. 1 and 14	Aug. 29–Sept. 6

TABLE 6. NUMBER OF EGG-MASSES ON TWO ROWS OF BEANS (NOT SPRAYED)

Spacing	Year	Total number egg-masses	Number egg-masses on 100 plants
2"	1932	32	
	1933	48	
	1934	27	
		107	25.2
4"	1932	8	
	1933	11	
	1934	25	
		44	20.3
6"	1932	7	
	1933	10	
	1934	9	
		26	18.0
8"	1932	4	
	1933	4	
	1934	7	
		15	13.4

Spacing and Larval Injury

Counts of the number of egg-masses present were made on three of the four crops of beans about June 19 for the first generation, and August 1 for the second generation. The results are given in Table 6. These records show that the Mexican bean beetles deposited more eggs per plant on the closely spaced plants. There were almost twice as many eggs on 100 plants of beans spaced two inches apart as on beans spaced eight inches apart. This same ratio worked out on plantings made in

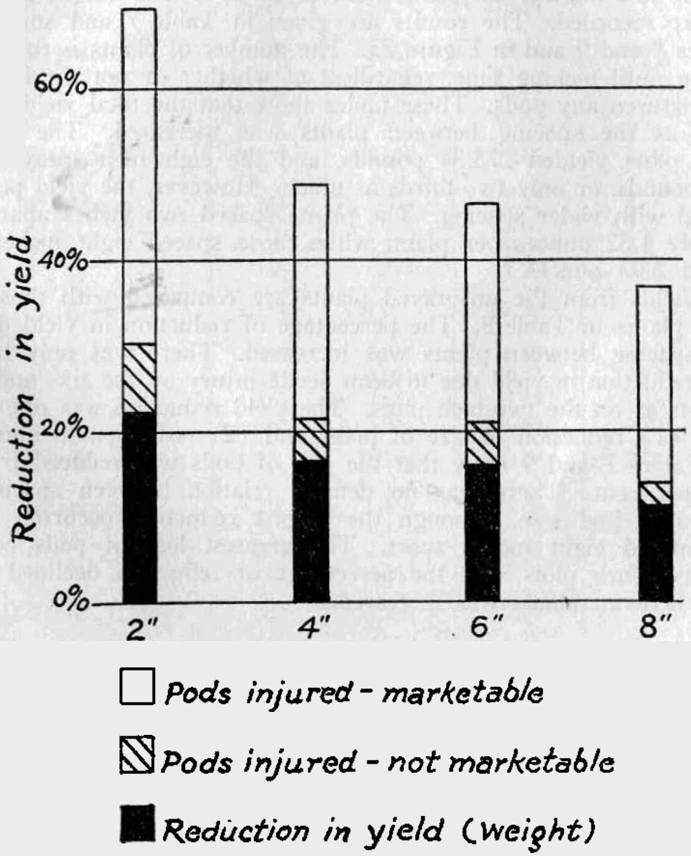

FIGURE 75. The chart shows the relation between spacing of plants and pod injury.

three different years, and indicated that the beetles preferred closely spaced plants for oviposition.

Notes on larval injury, taken at the time of the last picking of pods, show that the visible larval injury decreased as the spacing between plants increased. On three of the four crops there was distinctly less injury on the wider spacings. The two- and four-inch untreated plots were defoliated, while the six- and eight-inch plots were much less seriously injured. In 1933, the second planting showed less difference in amount of injury. The unsprayed rows were all defoliated at the time the last picking of pods was made. The second generation of bean beetles in 1933 was very destructive, and the untreated plots failed to show any effect of spacing. However, the sprayed plots showed a distinct decrease in amount of injury as the spacing between plants was increased.

Yield and Spacing on Treated and Untreated Plots

The pods from these plots were picked two or three times as they matured. The number of plants, number of pods and weight from each row were recorded. The results are given in Table 7 and summarized in Tables 8 and 9 and in Figure 75. The number of plants is the number surviving until picking time, regardless of whether or not the individual plants matured any pods. These tables show that the total yield declined steadily as the spacing between plants was increased. The two-inch sprayed plots yielded 275.34 pounds, and the eight-inch sprayed plots, 184.14 pounds, or only two-thirds as much. However, the yield per plant increased with wider spacing. The plants spaced two inches apart averaged only 1.32 ounces per plant, while those spaced eight inches apart averaged 3.93 ounces.

The yields from the unsprayed plants are compared with those from sprayed plants in Table 8. The percentage of reduction in yield declined as the spacing between plants was increased. There was only half the rate of reduction in yield due to bean beetle injury on the six- and eight-inch plots as on the two-inch plots. The yield reduction was due to two factors: (1) reduction in size of pods, and (2) reduction in number of pods. Tables 7 and 9 show that the size of pods was reduced from 1.9 to 6.8 per cent. There was no definite relation between spacing and reduction in pod size, although the largest reduction occurred on the plants spaced eight inches apart. The greatest loss of pods occurred on the two-inch plots, and the percentage of reduction declined as the spacing between plants was increased.

TABLE 7. DISTANCE OF SPACING AND YIELD

Year	Spacing and treatment	Number of plants	Number of pods	Total yield pounds	Yield per plant ounces	Number of pods per pound
1932	2" sprayed	628	7,548	54.56	1.51	126.7
1933	2" "	626	6,936	79.81	2.03	86.9
1933	2" "	646	3,788	47.69	1.18	79.4
1934	2" "	636	6,953	88.28	2.22	78.7
	Totals	2,536	25,225	275.34	1.73	
1932	2" check	644	5,451	40.44	1.00	134.7
1933	2" "	656	6,054	63.87	1.55	94.9
1933	2" "	640	3,197	39.72	.99	80.5
1934	2" "	636	5,603	66.62	1.67	84.1
	Totals	2,576	20,305	210.65	1.31	96.3
1932	4" sprayed	322	6,635	56.12	2.78	118.2
1933	4" "	337	5,415	68.62	3.25	78.9
1933	4" "	321	3,254	40.65	2.02	80.0
1934	4" "	336	5,714	76.90	3.66	74.3
	Totals	1,316	21,018	242.29	2.94	87.1
1932	4" check	323	5,653	46.97	2.32	120.3
1933	4" "	330	5,036	59.94	2.90	84.0
1933	4" "	325	2,652	31.19	1.53	85.0
1934	4" "	343	5,058	66.44	3.09	75.9
	Totals	1,321	18,399	204.54	2.47	89.9
1932	6" sprayed	217	5,886	54.06	3.99	108.8
1933	6" "	219	4,271	53.72	3.92	79.5
1933	6" "	224	2,378	28.72	2.05	82.8
1934	6" "	222	4,753	65.59	4.73	72.4
	Totals	882	17,288	202.09	3.66	85.5
1932	6" check	219	5,569	51.44	3.75	108.2
1933	6" "	221	4,146	52.69	3.81	78.6
1933	6" "	214	2,056	24.03	1.79	85.5
1934	6" "	223	3,934	51.90	3.72	75.8
	Totals	877	15,705	180.06	3.28	87.2
1932	8" sprayed		4,948	52.40	5.48	94.4
1933	8" "		3,743	50.65	4.74	73.9
1933	8" "		1,949	24.31	2.34	80.1
1934	8" "	172	4,064	56.78	5.28	71.5
	Totals	662	14,704	184.14	4.45	79.8
1932	8" check	169	5,299	52.84	5.00	100.2
1933	8" "	158	3,394	42.90	4.40	79.1
1933	8" "	173	1,880	22.31	2.06	84.2
1934	8" "	161	3,392	44.81	4.45	75.7
	Totals	661	13,965	162.86	3.94	85.7

TABLE 8. SUMMARY—REDUCTION IN YIELD

Spacing	Average yield per plant (ounces)		Reduction in yield	
	Sprayed	Check	Ounces	Per cent
2 inches	1.73	1.31	.42	24.2
4 inches	2.94	2.47	.47	15.9
6 inches	3.66	3.28	.38	10.4
8 inches	4.45	3.94	.51	11.2

TABLE 9. SUMMARY—REDUCTION IN NUMBER AND SIZE OF PODS

Spacing	Average number pods per plant		Reduction in number of pods		Number of pods per pound		Per cent reduction in size
	Sprayed	Check	Number	Per cent	Sprayed	Check	
2 inches	9.94	7.88	2.06	21.0	91.6	96.3	4.6
4 inches	15.97	13.93	2.04	12.8	87.1	89.9	3.2
6 inches	19.60	17.91	1.69	8.6	85.5	87.2	1.9
8 inches	22.21	21.11	1.10	4.9	79.8	85.7	6.8

Spacing and Quality of Pods

Each time the pods were picked (with the exception of the 1932 crop) a sample of beans was examined for bean beetle injury. This sample consisted of the entire crop from one sprayed and from one unsprayed row for each spacing. The pods were examined carefully and classified as "injured" or "not injured" by bean beetle feeding. The injured pods were further classified as "marketable" or "not marketable". This last division was arbitrary and was done on the basis of the amount of feeding injury. A summary of the results is given in Tables 10, 11 and 12.

These results show that the percentage of uninjured pods and the percentage of marketable pods increased as the spacing between plants increased. This was true on both sprayed and unsprayed plants. It is also evident that the difference between the amount of injury to pods from unsprayed and sprayed plants decreased as the spacing between plants was increased. Thus the pods from unsprayed plants two inches apart showed 21 per cent more injury than those from sprayed plants, and the pods from unsprayed plants eight inches apart showed only 4 per cent more injury than those from the corresponding sprayed plants.

There was wide variation in the percentage of injured pods from year to year. The second generation of bean beetles caused more injury than the first generation. The injury in 1934 was not so severe as for the corresponding generation in 1933. The second picking of each crop showed much more injury than the first picking. The percentage of marketable pods was high in both the sprayed and unsprayed series. However, the number and percentage of pods classified as "injured but marketable" was very large in some cases. In the two- and four-inch sprayed plots, about one-third of the marketable pods were injured. Less than one-fourth were injured on the six- and eight-inch plots. Half of the marketable pods on unsprayed plants two inches apart were injured, while only one-fourth of those on plants set at six and eight inches were injured. Observations have shown that if more than one-third of the beans were injured, the crop could not be sold to advantage unless many of the injured pods were removed. The pods from the two-, four- and six-inch unsprayed plots were frequently too badly damaged to be sold without sorting. The two- and four-inch sprayed plots also produced some pickings that were not salable until sorted. The second picking from the six-and eight-inch

TABLE 10. BEAN BEETLE INJURY TO BEAN PODS—TWO- AND FOUR-INCH SPACINGS

Year	Spacing	Treatment	Pods uninjured		Pods injured		Pods injured but marketable		Total marketable	
			Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
1933	2"	Sprayed	253	90	28	10	28	10	281	100
			212	69	96	31	70	22	282	91
1933	2"	"	169	72	66	28	54	23	223	95
			20	18	92	84	60	53	80	71
1934	2"	"	193	54	166	46	160	44	353	98
			108	47	118	53	118	53	226	100
			955	63	566	37	490	32	1,445	95
1933	2"	Check	161	65	87	35	87	35	248	100
			139	54	116	46	74	29	213	83
1933	2"	"	100	53	86	47	69	37	169	90
			12	14	72	86	48	57	60	71
1934	2"	"	101	31	217	69	202	63	303	94
			29	13	182	87	151	71	180	84
			542	42	760	58	631	48	1,173	90
1933	4"	Sprayed	170	93	12	7	12	7	182	100
			223	92	18	8	15	6	238	98
1933	4"	"	138	64	77	36	69	32	207	96
			19	18	87	82	62	58	81	76
1934	4"	"	168	71	68	29	67	28	235	99
			87	38	141	62	141	62	228	100
			805	66	403	34	366	30	1,171	96
1933	4"	Check	198	87	29	13	29	13	227	100
			165	85	28	15	25	13	190	98
1933	4"	"	106	64	59	36	47	28	153	92
			10	11	77	89	52	59	62	70
1934	4"	"	169	61	108	39	107	38	276	99
			39	21	141	79	109	60	148	81
			687	61	442	39	369	32	1,056	93

late crops in 1933 and 1934 were not marketable as picked. Otherwise, these two spacings produced pods of excellent quality.

Attention is called to the fact that half of these plantings were not sprayed, and therefore a large number of larvae fed and matured. The emerging beetles migrated to pods on sprayed vines and caused much damage. Under field conditions pod injury on well-sprayed plants of any spacing was usually of little practical importance. However, field observations on commercial plantings substantiated the fact that the bean beetle was much more easily controlled when the plants were spaced four or more inches apart.

Table 11. Bean Beetle Injury to Bean Pods—Six- and Eight-Inch Spacings

Year	Spacing	Treatment	Pods uninjured		Pods injured		Pods injured but marketable		Total marketable	
			Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
1933	6″	Sprayed	226	94	13	6	13	6	239	100
			152	88	19	12	12	7	164	95
1933	6″	"	114	76	37	24	36	23	150	99
			23	22	79	78	61	59	84	81
1934	6″	"	144	84	26	13	26	13	170	100
			113	80	28	20	28	20	141	100
			772	79	202	21	176	18	948	97
1933	6″	Check	190	86	31	14	31	14	221	100
			89	71	36	39	25	20	114	81
1933	6″		70	67	34	33	30	29	100	96
			13	15	69	85	39	47	52	62
1934	6″		63	77	19	23	17	20	80	97
			86	45	102	55	93	49	179	94
			511	64	291	36	235			
1933	8″	Sprayed	262	97	6	3	6			
			163	89	23	11	15			
1933	8″	"	68	75	22	25	21			
			12	16	62	84	55		67	90
1934	8″	"	176	84	34	16	31	14	207	98
			75	40	110	60	110	60	185	100
			756	75	257	25	238	23	994	98
1933	8″	Check	130	98	3	2	3	2	133	100
			178	90	19	10	17	9	195	99
1933	8″	"	84	75	28	25	24	21	108	96
			10	20	39	80	30	61	40	81
1934	8″	"	80	51	78	49	73	46	153	97
			54	53	48	47	45	44	99	97
			536	71	215	29	192	26	728	97

Table 12. Summary—Bean Beetle Injury to Pods

Spacing	Treatment	Per cent uninjured	Per cent injured	Per cent injured but marketable	Total per cent marketable
2″	Sprayed	63	37	32	95
4″	"	66	34	30	96
6″		79	21	18	97
8″	"	75	25	23	98
2″	Check	42	58	48	90
4″		61	39	32	93
6″		64	36	29	93
8″		71	29	26	97

Spacing and Amount of Insecticide Used

All plots were sprayed by hand, using a barrel pump and a four-foot rod with an angle nozzle. An effort was made to cover the under surface of the foliage very thoroughly. The amount of spray necessary was measured for the second spray application in 1932. Results were as follows: Two-inch plots required 10.5 gallons; four-inch plots, 6 gallons; six-inch plots, 5.5 gallons, and eight-inch plots, 6 gallons. Almost twice as much spray material was required to cover thoroughly plants two inches apart, in comparison with the other spacings.

Spacing and Effectiveness of Spraying

Magnesium arsenate at the rate of three pounds in 100 gallons of water is an effective insecticide and has sufficient toxicity to kill all of the larvae present on the foliage. In spite of the fact that unusual care was taken to cover the under sides of the leaves of all plants in spraying, there was a variation in control of the bean beetle. Apparently it was impossible to cover the foliage completely when the beans were planted two inches apart. The degree of control was about equal on the six- and eight-inch spacings, was less on the four-inch and still less on the two-inch spacing. The results indicated that more efficient control was possible when the plants were at least six inches apart in the row.

INSECTICIDES FOR BEAN BEETLE CONTROL

In 1932, sprays containing two pounds of magnesium arsenate and three pounds of casein-lime were used to control the Mexican bean beetle. Dusts were tested, using one pound of magnesium arsenate with six pounds of hydrated lime, and one pound of barium fluosilicate with six pounds of hydrated lime. These materials were applied four times to string and lima beans and controlled the bean beetle adequately.

In the published report (1) of this work, it was suggested that growers use three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water, and one pound of magnesium arsenate or barium fluosilicate with five pounds of hydrated lime as a dust. This change was made because many growers failed to apply enough material on the plants to give adequate control.

In 1932, 1933 and 1934, tests of insecticides were made on string, lima and horticultural beans. The Bountiful variety of string beans, Fordhook bush lima beans and French Horticultural beans were used in the tests.

Insecticide Tests on String Beans

Six series of tests on string beans were made during three years, half on plots arranged in Latin squares and half on replicated plots. All dusts were applied with a knapsack duster, which distributed the material uniformly. The sprays were applied as described above and all insecticides were applied to the under surface of the foliage. The records of the plantings are given in Table 13.

TABLE 13. RECORDS OF BEANS PLANTED FOR INSECTICIDE TESTS

Plot arrangement	Planted	Appeared above ground	Attacked by beetles	Treated	Picked
Latin square	May 2, 1932	May 17	May 26	June 7–21	July 5–15
Latin square	May 24, 1932	June 2	June 6	July 28–Aug. 11	July 19–25
Replicated	July 1, 1932	July 9	July 29	Aug. 1–23	Aug. 22–Sept. 1
Latin square	May 15, 1932	May 26	June 2	June 10–23	July 12–18
Latin square	July 3, 1933	July 10	July 22	July 29–Aug. 26	Aug. 29–Sept. 6
Replicated	May 23, 1934	June 1	June 5	June 26	July 13–19
Replicated	July 5, 1934	July 12	July 19	Aug. 1–20	Aug. 28–Sept. 5

Insecticides and Egg Deposition

In June, 1932, over-wintering adults caused serious injury by feeding on young bean plants. These plants were sprayed on June 7, using three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water, in an effort to prevent further injury. The spray application did not kill the adult beetles and did not entirely prevent feeding on the foliage. On June 21, the number of egg-masses present on the plants was recorded. The counts showed that there were 93 egg-masses on nine rows of sprayed plants, and 190 on nine unsprayed rows.

In 1933, plants were sprayed on June 10 and egg-mass counts were made on June 19. These counts showed that 63 egg-masses were present on 16 rows of sprayed plants and 146 on the same number of unsprayed rows.

A second test made in 1933 included magnesium arsenate spray and dust, barium fluosilicate spray and dust, and copper-lime-calcium arsenate dust. The materials were applied June 10 and the counts made June 20. The results are given in Table 14. In general, the arsenical treatments prevented oviposition to a greater extent than the fluosilicate treatments. Magnesium arsenate spray was most effective in reducing egg deposition. However, the results were quite variable, possibly due to lack of uniformity of infestation. In spite of the variations, it was evident that magnesium arsenate applied to bean vines prevented deposition of eggs by over-wintering beetles. This seemed to be due to a repellent effect rather than to toxicity of the materials to adult bean beetles.

TABLE 14. EGG-MASSES ON PLANTS TREATED JUNE 10, 1933

Treatment	Row	Egg-masses June 20
Magnesium arsenate dust	1	4
	2	8
	3	3
	4	9
	Total	24
Magnesium arsenate spray	1	2
	2	7
	3	2
	4	7
	Total	18
Barium fluosilicate spray	1	9
	2	9
	3	16
	4	9
	Total	43
Barium fluosilicate dust	1	5
	2	9
	3	6
	4	9
	Total	29
Copper-lime-calcium arsenate dust	1	4
	2	3
	3	12
	4	3
	Total	22
No treatment	1	15
	2	7
	3	16
	4	2
	Total	40

Insecticides and Yield

The pods were picked two or three times from each planting as they matured. The total weight of pods from each row and the number of plants in the row were recorded. The results are given in Tables 15 and 16. These tables show the average yield per plant and the percentage increase in yield of treated plants compared with untreated plants. Table 16 gives the comparative average yield in relation to the insecticide used.

Poisonous Sprays and Dusts

The averages given in the vertical columns in Table 16 show that no consistent significant differences resulted, whether magnesium arsenate or barium fluosilicate sprays or dusts, or copper-lime-calcium arsenate dust was applied. On the basis of three crops, magnesium arsenate spray produced a slightly higher yield than barium fluosilicate spray; but on the basis of two crops, the barium fluosilicate spray produced the higher yield. The widest variation in yield in any vertical column is about 5 per cent, and this difference is not significant.

Calcium arsenate dust, made by diluting one pound of calcium arsenate with nine pounds of hydrated lime, was used in one test in 1932. No arsenical injury developed and the dust controlled bean beetles satisfactorily. However, commercial brands of calcium arsenate vary considerably in their effects, and this compound is not generally safe on bean foliage.

Non-poisonous Sprays and Dusts

Pyrethrum and derris dusts and sprays were used following poisonous applications in 1933. Pyrethrum dusts were used throughout the season in tests in 1932 and pyrethrum and derris dusts were so tested in 1934. Table 15 gives the results of these tests. The variation in yields prevents any valid conclusions, except that the use of these materials produced at least as high a yield as the use of poisonous dusts and sprays.

TABLE 15. YIELD OF BEANS—INSECTICIDE TESTS

Year	Material	Dilution	Number of applications	Number of plants	Yield (pounds)	Average yield per plant (ounces)	Per cent increase over check
1932	Magnes im arsenate spray	2–100	2	829	77.84	1.50	76.4
	Barium luosilicate spray	2–100	2	831	68.97	1.33	56.4
	Magnes im arsenate dust	1–5	2	838	73.69	1.40	64.7
	Barium luosilicate dust	1–5	2	846	79.44	1.50	76.4
	No trea nent	....	...	824	43.94	.85	
1932	Copper-li ie dust	none	4	254	44.12	2.78	
	Calcium 'senate dust	1–9	4	260	40.75	2.51	
	Magnesi ı arsenate dust	1–5	4	256	39.47	2.47	
	Pyrethrur dust	1–9	5	247	43.22	2.76	
1933	Copper-lime dust	no	3	422	97.81	3.71	18.1
	Magnesium arsenate dust	1–	3	438	110.44	4.03	28.3
	Barium fluosilicate dust	1–	3	430	98.59	3.65	16.2
	Magnesium arsenate spray	3–100	2	458	104.31	3.68	17.2
	Barium fluosilicate spray	3–100	2	438	109.75	4.01	27.7
	No treatment	....	...	436	85.56	3.14	
1933	Copper-lime dust	none	3	354	47.87	2.16	30.1
	Barium fluosilicate spray	3–100	2	358	34.56	1.54	—7.2
	Magnesium arsenate spray	3–100	2	359	41.15	1.83	10.2
	Magnesium arsenate spray	3–100	2	351	38.78	1.76	6.0
	Magnesium arsenate spray	3–100	2	338	40.81	1.93	16.4
	No treatment	....	...	350	36.34	1.66	
1934	Pyrethrum dust	1–1	1		52.44		10.9
	Derris dust (.6% rotenone)	15–85	1		49.87		5.5
	No treatment	....	...		47.25		
1934	Pyrethrum dust	1–3	3	340	90.65	4.26	17.0
	Pyrethrum dust	1–1	3	332	95.25	4.59	26.1
	Derris dust (.6% rotenone)	1–9	3	335	95.15	4.57	25.5
	Derris dust (.4% rotenone)	15–85	3	328	85.25	4.14	13.7
	No treatment	....	...	324	73.87	3.64	
1934	Magne ium arsenat spray	3–100	2	336	76.90	3.	17.3
	No tre tment	....	...	343	66.87	3.	

TABLE 16. SUMMARY—COMPARATIVE YIELDS IN INSECTICIDE TESTS

Treatment	Year	Yield per plant (ounces)	Average yield per plant		
			3 crops 1932–33	2 crops 1932–33	2 crops 1932–33
Magnesium arsenate spray	1932 I	1.50			
	1933 I	3.68	2.34	2.59	
	1933 II	1.83			
Barium fluosilicate spray	1932 I	1.33			
	1933 I	4.01	2.29	2.67	
	1933 II	1.54			
Magnesium arsenate dust	1932 I	1.40			
	1932 II	2.47		2.71	3.25
	1933 I	4.03			
Barium fluosilicate dust	1932 I	1.50			
	1933 I	3.65		2.57	
Copper-lime dust	1932 II	2.78			3.25
	1933 I	3.71			

Insecticides and Quality of Pods

In 1933 and 1934, samples of each picking of pods were examined for pod injury and classified as described above. The "injured but marketable" classification included pods with a small amount of feeding injury. The results are given in Tables 17 and 18.

Poisonous Treatments

Table 17 includes results from three dust and two spray materials. Barium fluosilicate dust (one pound with five pounds of hydrated lime) produced a smaller percentage of both uninjured and marketable pods than magnesium arsenate dust used in the same proportions. Magnesium arsenate spray and dust, barium fluosilicate spray and copper-lime-calcium arsenate dust produced almost equal percentages of uninjured pods, due to a comparatively light infestation of bean beetles.

Non-poisonous Dusts

Derris dusts containing .4 and .6 per cent rotenone, and pyrethrum dusts containing 25 per cent and 50 per cent pyrethrum flowers, were used in

TABLE 17. BEAN BEETLE INJURY TO PODS—INSECTICIDE TESTS

Treatment	Pods uninjured		Pods injured		Pods injured but marketable		Per cent Marketable
	Number	Per cent	Number	Per cent	Number	Per cent	
1933							
Magnesium arsenate spray	326	95	17	5	11	3	98
Magnesium arsenate dust	358	96	19	4	11	3	99
Barium fluosilicate spray	331	94	18	6	17	5	99
Barium fluosilicate dust	179	88	24	12	16	8	96
Copper-calcium arsenate dust	366	94	22	6	16	4	98
No treatment	245	72	94	28	53	15	87
1934							
.4% rotenone dust	422	88	56	12	55	11	99
.6% rotenone dust	350	91	34	9	32	8	99
25% pyrethrum dust	354	82	78	18	70	16	98
50% pyrethrum dust	474	89	59	11	59	11	100
No treatment	228	52	207	48	200	46	98
1934							
Magnesium arsenate spray	285	55	209	45	208	44	99
No treatment	208	45	249	55	216	47	92

1934 (see Table 17). The 25 per cent pyrethrum dust was less effective than the derris dust containing .4 per cent rotenone. All of these dust applications were very effective in producing a high percentage of uninjured pods. Two applications of magnesium arsenate spray (three pounds in 100 gallons of water) were not as effective as three applications of the non-poisonous dusts.

Non-poisonous Following Poisonous Applications

Non-poisonous sprays and dusts were used on plants that had been treated previously with poisonous materials. The schedule of treatments was as follows:

Poisonous Treatments		Non-Poisonous Treatments	
Materials used	Dates of application	Materials used	Dates of application
Magnesium arsenate spray	July 29, Aug. 7	None	......
Magnesium arsenate spray	July 29, Aug. 7	Derris dust[1]	August 26
Magnesium arsenate spray	July 29, Aug. 7	Pyrethrum dust (50%)[2]	August 26
Magnesium arsenate spray	July 29, Aug. 7	Pyrethrum dust (10%)[2]	August 26
Magnesium arsenate spray	July 29, Aug. 7	Derris spray[3]	August 26
Magnesium arsenate spray	July 29, Aug. 7	Pyrethrum spray[3]	August 26
Barium fluosilicate spray	July 29, Aug. 7	None	......
Barium fluosilicate spray	July 29, Aug. 7	Derris spray[3]	August 26
Barium fluosilicate spray	July 29, Aug. 7	Pyrethrum dust[2]	August 26
Copper-lime-calcium arsenate dust	July 29, Aug. 7 and 15	None	......
Copper-lime-calcium arsenate dust	July 29, Aug. 7 and 15	Derris dust[1]	August 26
None	....	None	......
None	....	Pyrethrum dust (50%)[2]	August 26
None	....	Derris dust[1]	August 26

[1] Proprietary product containing .59 per cent rotenone.
[2] Proprietary "activated" product.
[3] Proprietary products, used according to manufacturer's directions.

The non-poisonous materials were applied August 26, and the pods were picked August 29 and September 6. These late applications were made to prevent serious pod injury and yet avoid poisonous residues. The results in Table 18 show that none of the non-poisonous materials increased the percentage of uninjured pods consistently when applied after poisonous applications. One application of 50 per cent pyrethrum dust, or derris dust containing .59 per cent rotenone, applied on plots receiving no previous treatment, produced a large increase in the percentage of uninjured pods. The untreated plants yielded 16.34 pounds and those receiving one application of dust yielded 20 pounds of pods. It is readily seen that this single dust application was very effective in increasing yield and reducing pod injury. Apparently the additional protection given by these same dusts applied following poisonous applications was very small.

TABLE 18. BEAN BEETLE INJURY TO PODS—INSECTICIDE TESTS

Treatment	Pods uninjured		Pods injured		Pods injured but marketable		Per cent Marketable
	Number	Per cent	Number	Per cent	Number	Per cent	
Magnesium arsenate spray	62	34	121	66	102	56	90
+derris dust	106	40	157	60	133	20	85
+50% pyrethrum dust	42	31	93	69	76	56	87
+10% pyrethrum dust	49	39	80	61	69	53	92
+derris spray	50	36	88	64	65	47	83
+pyrethrum spray	106	41	152	59	133	51	92
Barium fluosilicate spray	61	28	157	72	132	57.	85
+derris spray	18	29	43	71	36	59	88
+10% pyrethrum dust	46	40	69	60	62	54	94
Copper-calcium arsenate dust	99	47	111	53	97	46	93
+derris dust	72	37	122	63	111	57	94
No treatment	24	18	103	82	75	59	77
No poison							
+50% pyrethrum dust	51	42	71	58	59	48	90
+derris dust	22	47	25	53	21	44	91

Insecticide Tests on Lima Beans

Fordhook bush lima beans were grown in 1933 and 1934. In 1933, one plot of six, 15-foot rows was planted on June 3, sprouted June 10, and pods were picked August 28 and 31. Very few first generation larvae attacked this planting and no treatment was necessary until the first generation adults appeared. On July 29 and August 7, half of the plants were sprayed, using three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water. There was little visible difference in the amount of bean beetle feeding injury on sprayed and unsprayed plants. The yields, given in Table 19, show that the spray treatment more than doubled the crop.

TABLE 19. YIELD OF DWARF LIMA BEANS—1933

Treatment	Number of plants	Total yield (pounds)	Average yield per plant (ounces)	Increase in yield (per cent)
Sprayed	32	10.8	5.09	107
Unsprayed	34	5.75	2.41	

In 1934, 12 plots, each of five, 10-foot rows, were planted May 22 and pods were picked August 13 and September 10. A few first generation larvae attacked these plants and a treatment was necessary on June 28. Second generation larvae were moderately abundant and further treatment was necessary. The schedule of treatments was as follows:

	Materials	Dates of application
1.	4-4-50 Bordeaux mixture	June 28, Aug. 1 and 9
2.	Copper-lime-calcium arsenate dust	June 26
	followed by derris dust (.6% rotenone)	August 1 and 20
3.	No treatment	......

Bordeaux mixture was used without addition of poison because previous experience showed that this material repelled beetles and prevented serious injury. Derris dust was used following copper-lime-calcium arsenate dust after the pods had formed. The dust applications reduced bean beetle injury more than the Bordeaux mixture spray, and the untreated plants were moderately injured. The yields given in Table 20 show that the two treatments increased the yield substantially and about equally.

TABLE 20. YIELD OF DWARF LIMA BEANS—1934

Treatment	Number plants	Total yield (pounds)	Average yield per plant (ounces)	Increase in yield (per cent)
Bordeaux mixture	148	138.75	15.00	24.2
Copper-lime-calcium arsenate dust and derris dust	151	142.25	15.07	24.7
No treatment	56	42.28	12.08	...

In 1933, a demonstration spray schedule was applied to dwarf lima beans grown on the farm of J. B. Lewis in Southington. These beans were lightly infested by first generation larvae and moderately infested by second generation larvae. Applications of three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water on June 22 and July 27 were sufficient to control the bean beetle.

Insecticide Tests on Horticultural Beans

French Horticultural beans were grown in 1933 in one plot of six, 15-foot rows. The seed was planted June 3, sprouted June 10 and pods were picked August 23 and 31. The infestation by first generation larvae was very light and no sprays were necessary. Sprays to control second generation larvae were applied July 29 and August 7, using three pounds of magnesium arsenate and two pounds of casein-lime in 100 gallons of water. The sprays reduced bean beetle injury very much, but did not prevent defoliation by mosaic and leaf diseases. On account of this defoliation, there was not much difference in the appearance of sprayed and unsprayed vines late in the season. The yield is given in Table 21, and shows an increase of about 50 per cent due to insecticidal treatment.

TABLE 21. YIELD OF DWARF HORTICULTURAL BEANS—1933

Treatment	Number of plants	Total yield (pounds)	Average yield per plant (ounces)	Increase in (per cent)
Sprayed	42	6.25	2.38	49.6
Unsprayed	39	3.87	1.59	..

In 1934, six plots, each of five, 10-foot rows, were planted May 22 and pods were picked August 8. First generation larvae caused some injury and the second generation were moderately abundant. The schedule of treatments was as follows:

Material	Date of application
1. Magnesium arsenate (1 lb., lime 5 lbs.) dust	June 26
followed by derris dust (.6% rotenone)	August 1
2. Copper-lime-calcium arsenate dust	June 26
followed by pyrethrum dust (50%)	August 1
3. No treatment	......

Non-poisonous applications were made after the pods had formed. The copper-lime-calcium arsenate dust was slightly more effective than magnesium arsenate dust in preventing bean beetle injury. The non-poisonous dusts were applied at a time when they did not affect the yield. The results are given in Table 22. Both of the dusts produced a satisfactory increase in yield.

TABLE 22. YIELD OF HORTICULTURAL BEANS—1934

Treatment	Number of plants	Total yield (pounds)	Average yield per plant (ounces)	Increase in yield (per cent)
Magnesium arsenate dust	112	10.87	1.55	33.6
Copper-calcium arsenate dust	116	10.69	1.47	26.7
No treatment	122	8.87	1.16	...

In this test Horticultural beans were not seriously injured by either generation of bean beetles. The beans were planted late enough to avoid serious injury by first generation larvae and matured before the second generation was feeding. Treatments were required late in June and July.

Treatments Injurious to Foliage

Bean plants are very susceptible to injury by arsenical materials. Lead arsenate almost invariably causes serious injury to bean foliage. Calcium arsenate is usually safe if it is applied with large amounts of hydrated lime, but commercial brands vary so widely that they are generally not safe to use on beans. Calcium arsenate mixed with monohydrated copper sulfate and hydrated lime to form a dust is usually safe on bean foliage. In 1933, several reported cases of arsenical injury following application of this dust were investigated, and no serious injury was found. The standard brand of magnesium arsenate has caused no visible injury in any of the tests conducted. In some cases beans sprayed with magnesium arsenate and casein-lime have appeared slightly chlorotic, but this condition was never serious. In 1933, a new brand of magnesium arsenate was used in some tests and almost invariably caused serious foliage injury. This brand of magnesium arsenate is no longer on the market.

Barium fluosilicate sprays and dusts have not been observed to cause foliage injury in any tests. Some commercial growers have reported foliage injury following use of this compound, but in no case was the injury found to be directly attributable to barium fluosilicate.

Use of derris and pyrethrum sprays following magnesium arsenate applications invariably caused foliage injury, probably due to the soap spreaders acting on the arsenical residue. Such sprays cannot be used with safety on vines previously sprayed with arsenical compounds. Derris and pyrethrum dusts caused no foliage injury in any test.

Lima beans were slightly injured by 4-4-50 Bordeaux mixture in 1934. The injury appeared as a leaf scorch and was not serious. Lima bean leaves commonly had purplish spots very much like spots caused by arsenical applications. These spots were almost always present whether the vines had been treated or not. In some cases sprayed vines had more spots than unsprayed vines, but the injury was not important.

Poisonous Residues on Bean Pods

In 1932, considerable attention was given to the problem of arsenical and fluorine residues. Samples of pods from several treated plots were submitted to the Analytical Chemistry Department of this Station for residue analysis. The results are given in Table 23, and show that sprays applied eight days, and dusts applied five days, before picking, left excessive arsenical residues. In the case of the dusts, a rainfall of 1.3 inches occurred between the date of dusting and the date of picking. Even this large amount of rain failed to remove the spray residue. In all these tests the last application of insecticide was made while the pods were small. Apparently the size of the pods at the time of insecticidal appli-

TABLE 23. RESULTS OF ANALYSES OF BEAN PODS FOR POISONOUS RESIDUES

Material	Dilution	Date of last application	Date of picking	Residue As_2O_3 in parts per million*	Rainfall between treatment and picking
Magnesium arsenate spray	2 lbs.–100 gals.	July 11	July 19	2.2	.2 inch
Magnesium arsenate spray	2 lbs.–100 gals.	July 11	July 25	.6	.8 "
Magnesium arsenate spray	3 lbs.–100 gals.	July 11	July 22	1.4	.2 "
Magnesium arsenate spray	3 lbs.–100 gals.	July 29	Aug. 9	Trace	.9 "
Magnesium arsenate dust	1 lb.–5 lbs. lime	July 7	July 19	1.0	.2 "
Calcium arsenate dust	1 lb.–3 lbs. lime	Aug. 17	Aug. 22	1.2	1.3 "
Calcium arsenate dust	1 lb.–3 lbs. lime	Aug. 17	Aug. 26	Trace	1.3 "
Magnesium arsenate dust	1 lb.–5 lbs. lime	Aug. 17	Aug. 22	3.6	1.3 "
Magnesium arsenate dust	1 lb.–5 lbs. lime	Aug. 17	Aug. 26	Trace	1.3 "
Copper-lime-calcium arsenate dust	17 per cent calcium arsenate	Aug. 17	Aug. 22	1.4	1.3 "
Copper-lime-calcium arsenate dust	17 per cent calcium arsenate	Aug. 17	Aug. 26	.5	1.3 "
Arsenical dusts (last 3 above)		Aug. 17	Aug. 22	2.1	1.3 "
Arsenical dusts washed twice in clear water		Aug. 17	Aug. 22	Trace	1.3 "

* Arsenical tolerance 1.4 parts per million.

cation was more important than the amount of rainfall between the date of application and the date of picking. For instance, plants sprayed July 11, using two pounds of magnesium arsenate in 100 gallons of water, showed an excessive residue of 2.2 parts per million on pods picked July 19. A spray of three pounds of magnesium arsenate in 100 gallons of water, applied to other plants on July 11, produced residue of 1.4 parts per million on pods picked July 22. The same amount of rain fell in both cases, but in the second instance the pods were slightly smaller when the spray was applied.

Dusts containing calcium and magnesium arsenate were easily removed from pods by two changes of clear water. No washing experiments were tried on sprayed pods. However, washing bean pods is difficult and should be avoided if possible. It is preferable to forgo the use of poisonous materials after blossoms appear or to substitute non-poisonous materials if late applications prove necessary.

Actual observations of commercial practices revealed that some growers applied poisonous materials to plants bearing large pods. The pods from these plants undoubtedly bore more than the legal tolerance for arsenic. Since non-poisonous dusts can be used with success throughout the growing season, it is preferable to use them in order to avoid any chance of excessive residues.

Although the pods of lima and shell beans are not likely to be used for food, the Food and Drug Administration of the United States Department of Agriculture has ruled that the arsenical and fluorine tolerances apply. Therefore non-poisonous materials must be used after the pods have formed.

Fluorine Residues

One sample of pods picked July 19 from vines sprayed on July 11 with barium fluosilicate (two pounds in 100 gallons of water) failed to show any residue. However, use of cryolite or barium fluosilicate after the pods form would be likely to result in excessive residues. Therefore these compounds cannot be used on beans after the blossoms fall.

SUMMARY

The Mexican bean beetle entered Connecticut in 1929, and by 1932 caused very serious damage to garden beans throughout the State. Since 1932, the infestation has been lighter, but serious injury is common in all sections of the State.

This report presents a summary of research on the relation of cultural practices to bean beetle control, and the use of insecticides on string, lima and horticultural beans.

Weather records show that the summer temperatures here are not sufficiently high to cause the death of young larvae.

Experiments conducted at the Station farm at Mount Carmel, to learn the relation between the date of planting string beans and bean beetle injury, showed that beans growing between May 26 and June 15 were attacked by over-wintering adults and first generation larvae. Plants growing between July 18 and August 15 were attacked by first generation adults and second generation larvae. Maximum bean beetle injury occurred when a large number of adults attacked the plants early in the period of plant growth. Yield reduction was largest on beans planted July 1 and 10, and least on beans planted June 1 and 10.

Injury to pods due to bean beetle feeding was most serious between July 18 and August 15, and between September 10 and 30, because during these periods migrating adults commonly fed on bean pods.

Beans planted during May required two spray applications, about June 7 and June 21. Those planted June 1 and 11 failed to produce profitable increases in yield as a result of spray applications. Plantings made June 21 required one spray treatment about July 29. July 1 plantings required two sprays, about July 29 and August 9. Later July plantings required two sprays, about August 9 and 23.

Experiments in which string beans were planted two, four, six and eight inches apart in the row showed that the total yield was largest when the plants were two inches apart and decreased as the spacing between plants was increased. The rate of bean beetle infestation was largest on the plants spaced two inches apart. The percentage of yield reduction and the percentage of injured pods decreased as spacing between plants was increased. The yield per plant increased greatly as the spacing was increased. Sprays were much more effective and less spray material was required when the plants were spaced four or more inches apart. In general, beans planted at least four inches apart in the row produced the most satisfactory crop and decreased the difficulty of bean beetle control.

Magnesium arsenate applied to bean vines before the adult beetles had deposited their eggs reduced egg deposition considerably. Barium fluosilicate was less effective in reducing egg deposition.

Magnesium arsenate sprays and dusts, barium fluosilicate sprays and dusts, copper-lime-calcium arsenate dusts, and derris and pyrethrum dusts controlled bean beetles satisfactorily and produced substantial increases in yield. Derris and pyrethrum dusts were as effective in controlling bean beetles as the other materials and left no undesirable residues on the pods.

Bordeaux mixture without the addition of any poisonous material was moderately effective in preventing bean beetle injury to lima beans. Copper-lime-calcium arsenate dust followed by derris dust was slightly more effective. Three applications of spray or dust produced a satisfactory increase in yield of lima beans. One application was made about June 28, and the other two about August 1 and 9.

Dwarf horticultural beans were badly affected by mosaic and bacterial blight. Use of poisonous dusts about June 26, followed by derris and pyrethrum dusts about August 1, produced a satisfactory increase in yield.

All arsenical materials used in these experiments occasionally caused foliage injury to bean plants, but this injury was usually not serious. Barium fluosilicate caused no foliage injury in any test application. Derris and pyrethrum dusts caused no foliage injury.

The accumulation of poisonous residues on bean pods depended on the size of pods at the time of the insecticidal treatment rather than on the amount of rainfall between treatment and harvest. Any poisonous material applied after the pods formed left an undesirable residue. All poisonous applications should cease when the blossoms drop from the vines. Derris dust containing at least .4 per cent rotenone, or pyrethrum dust containing at least 25 per cent pyrethrum flowers, should be used after the blossoms fall. These materials leave no residue poisonous to man under normal conditions. They are very satisfactory for earlier applications and may be used throughout the season.

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