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University of Tennessee Agricultural Experiment Station

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AGRICULTURAL EXPERIMENT STATION
Knoxville

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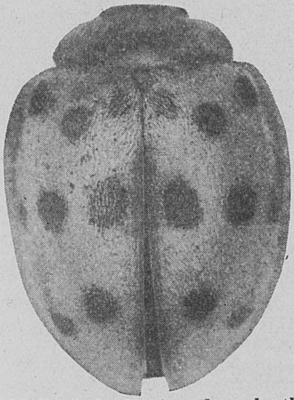

Adult of the Mexican bean beetle

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# UNIVERSITY OF TENNESSEE AGRICULTURAL EXPERIMENT STATION

## Knoxville

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# NEW INSECTICIDES FOR THE MEXICAN BEAN BEETLE AND OTHER INSECTS

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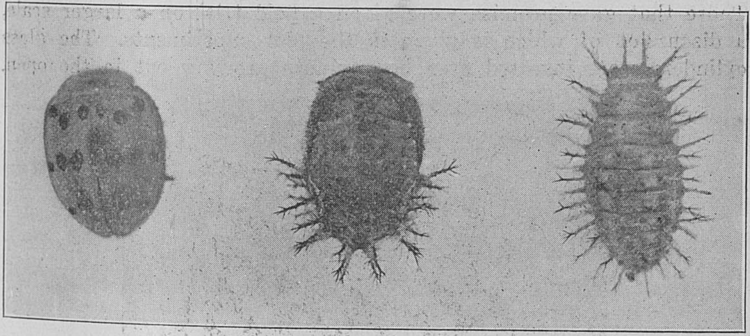
S. Marcovitch

## INTRODUCTION

When the Mexican bean beetle (*Epilachna corrupta* Muls.) first invaded Tennessee, in 1920 and 1921, it was at once recognized as a pest that would not readily yield to the insecticides then known. The arsenicals acted mainly as repellents, and were both deficient in killing power and injurious to the tender bean foliage. Control of the pest seemed so hopeless to farmers and truckers that large numbers of them have given up bean growing, except for the early crop. Others depend on hand-picking small patches for home use. Many growers and consumers also fear the possibility of poisoning from eating beans sprayed or dusted with arsenicals. Thus several factors have operated to reduce the growing of beans and to double or triple the price of green beans.



Stages of the Mexican bean beetle: Adult (left), Pupa (center), Larva (right)

During the early invasion of this State there was considerable fear that cowpeas and soybeans would be destroyed. Fortunately, the beetle has not shown any great liking for either of these forage crops and will not attack them severely if no garden beans are close by to serve as a breeding place.

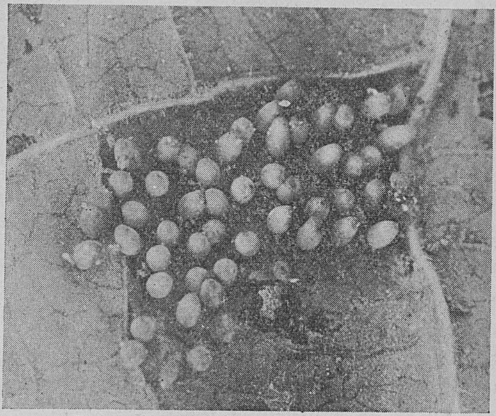
In order satisfactorily to solve the problem of bean beetle control in the home garden and for the trucker it was evident that new insecticides were necessary. Experiments were therefore conducted with numerous non-arsenical compounds that gave promise as cheap and efficient insecticides. A special study was made of the fluorine compounds, since the efficiency of sodium fluoride for roaches and chicken lice is well known. Due to its solubility, it is very injurious to plant life. Fortunately, the less soluble fluosilicates of sodium and calcium, as well as cryolite, were found to be highly effective. Mustard gas adsorbed on charcoal also gave good results against the adult beetles. With these materials it is not necessary for the beetles to eat bean foliage in order to be killed, as is the case with the arsenicals. It is necessary only that they walk over plants dusted with either sodium fluosilicate or charcoal impregnated with mustard gas, so that some of the dry powder clings to their legs and body. These materials induce an irritation which causes the beetles to lick their feet. Thus the poison enters the mouth and death results within a few hours. When properly used, these chemicals are not injurious to bean foliage.

Not all of the experimental work reported was carried out to a satisfactory conclusion, but publication is considered justifiable in view of the possibility that other investigators will find the suggestions useful.

# EXPERIMENTAL WORK WITH INSECTICIDES

## CAGE EXPERIMENTS

More than 40 different chemicals and combinations were tested in the course of the work against the Mexican bean beetle. They were first tried out in small wire cages or under glass cylinders. Those that gave promise were given a field trial on a larger scale, a discussion of which is given in the plot experiments. The glass cylinders were inverted over bean plants growing out in the open



Egg mass of the Mexican bean beetle

and for each material tried out 10 beetles were used. When lime was used as a carrier, the chemicals were measured out by volume because of their high density. Observations were made twice a day as to the rapidity with which the materials killed. Records were kept of the date the first beetles died, and the time required to kill all of the 10. Foliage injury was recorded as "severe" if all of the leaves were badly injured, "medium" if one or two leaves were injured, and "slight" if injury occurred only at the tips or edges of the leaves and could hardly be detected. Some of these chemicals that were injurious to bean foliage were not detrimental to cotton plants.

TABLE 1—*Test of insecticides used as dusts against the Mexican bean beetle under cages—ten beetles used under each cage*

| Material or compound | Date of application | Date first beetles died | Date last beetles died | Injury to bean plant | Notes |
|---|---|---|---|---|---|
| Sodium fluoride (NaF) | May 1 | May 2 | May 3 | Severe | |
| Calcium fluoride ($CaF_2$) | May 1 | May 24 | May 30 | None | |
| Sodium fluosilicate ($Na_2SiF_6$) | May 1 | May 2 | May 3 | Slight | |
| Sodium fluosilicate plus 9 parts lime | June 5 | June 6 | June 9 | None | |
| Natural cryolite ($Al_2F_6.6NaF$) | June 6 | June 7 | June 7 | None | |
| Natural cryolite plus 5 parts lime | June 7 | June 8 | June 8 | Severe | |
| Synthetic cryolite | June 26 | June 27 | June 28 | None | |
| Silica ($SiO_2$)—by-product Knoxville Fertilizer Company | June 7 | June 8 | June 9 | None | Contains a small amount of fluorine compounds |
| Calcium arsenate plus 9 parts lime | June 6 | June 8 | June 10 | None | |
| Crude anthracene | June 6 | June 7 | June 7 | Severe | |
| Calcium fluosilicate ($CaSiF_6$) | July 22 | July 22 | July 22 | Severe | All beetles dead in 6 hours |
| Calcium fluosilicate plus 9 parts lime | Aug. 12 | Aug. 13 | Aug. 14 | None | |
| Magnesium fluosilicate ($MgSiF_6$) | July 22 | July 22 | July 24 | Severe | |
| Charcoal plus 10% nitrobenzene | July 10 | July 11 | July 12 | None | |
| Charcoal plus 10% creosote | July 10 | July 11 | July 12 | Severe | |
| Charcoal plus 10% kerosene | July 21 | July 22 | July 22 | None | |
| Charcoal plus .6% mustard gas | July 22 | July 22 | July 23 | None | All but one dead in 4 hours |
| Charcoal plus .01% mustard gas | Aug. 20 | Aug. 20 | Aug. 21 | None | All but one dead in 6 hours |
| Charcoal plus 2% nitrobenzene and .5% mustard gas | Sept. 8 | Sept. 8 | Sept. 10 | None | All but one dead in 4 hours |

Table 1 gives the results of the more important chemicals tested as dusts against the adults of the Mexican bean beetle. The soluble fluorides, such as sodium fluoride, and the soluble magnesium fluo-

Bean leaf, showing work of the Mexican bean beetle

silicate, were effective in killing the beetles, but were injurious to the bean foliage. Fluorspar, an insoluble fluoride, did not kill rapidly enough to be of value. The insoluble cryolite, however, gave excellent results, as it is easily decomposed by the acids within the alimentary canal of the insect. This material is also easily decomposed by alkalies, such as hydrated lime, which when mixed with cryolite in certain proportions resulted in injury to the plant.

The slightly soluble fluosilicates of sodium and calcium were very efficient in destroying the beetles. Sodium fluosilicate even when used pure, showed very little injury to the foliage. When mixed with hydrated lime its killing efficiency was not greatly reduced. Calcium fluosilicate, although comparatively insoluble, showed severe injury to the foliage, due to the fact that it hydrolyzes. The injurious effect, however, disappeared when it was mixed with hydrated lime.

Certain very toxic organic compounds when adsorbed on charcoal were also effective in destroying the beetles, and did not injure the bean foliage. A discussion of these will be taken up more fully in another section.

## SODIUM FLUOSILICATE

**Control of other insects.**—Experiments were conducted with sodium fluosilicate against cockroaches and poultry lice, for which sodium fluoride is commonly recommended. It was found effective against roaches, and superior to sodium fluoride for poultry lice. Mr. Zuger, of the poultry department of the University, who conducted most of the tests, observed that after an application of sodium fluosilicate, chickens remained free of lice for a much longer period than when dusted with sodium fluoride. He also found that the wing louse (*Lipeurus variabilis*) was more effectively controlled by sodium fluosilicate.

Tests conducted against the potato beetle (*Leptinotarsa decemlineata*), the potato flea-beetle (*Epitrix cucumeris*), the bean leaf-beetle (*Ceratoma trifurcata*), the cucumber beetle (*Diabrotica vittata*), and the tobacco hornworm (*Protoparce quinquemaculata*) showed that they could be readily killed with sodium fluosilicate when 1 part was mixed with 9 volumes of lime. When undiluted with lime it caused some injury to the plants, particularly in the case of tobacco.

Since sodium fluosilicate is both a contact and a stomach poison, it should, theoretically, be effective against the boll weevil (*Anthonomus grandis*), and such was found to be the case. Cotton is a comparatively resistant plant, and is not injured when sodium fluosilicate is used undiluted. In all the tests conducted, the weevils were killed in from 5 to 24 hours. Calcium arsenate under similar conditions required from 1 to 5 days to kill the weevils. It was also observed that they could be killed in the same length of time by contact alone. To make sure that they were killed by contact, some weevils were placed on a bean plant, which they do not eat. After the weevils had crawled over the bean plant, which had been dusted with sodium fluosilicate, 50 per cent were dead in 6 hours, and the rest were found dead the next morning.

**Advantages over the arsenicals.**—Sodium fluosilicate is superior to the arsenicals in several different ways. In the first place, it is cheaper; the wholesale price being 4 cents per pound at the present time, while calcium arsenate is quoted at 9 cents per pound, and magnesium arsenate at 25 cents per pound.

Secondly, it is both a contact and a stomach poison, and acts more rapidly than the arsenicals.

Shafer, in his classical work "How Contact Insecticides Kill,"* has shown how sodium fluoride is effective against roaches. In much the same way sodium fluosilicate is effective against the bean beetles. When a roach runs through powdered sodium fluoride, a little of the powder adheres to the lower part of the body, antennae, and feet. In attempting to clean itself the insect draws its feet and antennae across its mouth. Some of the material thus enters the mouth, and causes death in from 4 to 12 hours. Shafer observed

*Mich. Agr. Exp. Station Tech Bull. No. 21.

that sodium fluoride may kill roaches by contact in from 5 to 2 hours, even when none of the material is swallowed. "Some of the powder is moistened or dissolved in the exudation about the bases of the legs and on the thinner portions of the outer integument. This seems to cause some irritation and uneasiness; the insect soon begins to clean the moistened powder from the body by licking it. In doing this, enough of the poison may be brought into the mouth, and swallowed, to kill after a period varying from five hours to ten days." Sodium fluoride is more rapid as a stomach poison than as a contact insecticide, and appears to be detrimental to certain enzymes, particularly the catalases. Fortunately, bean beetles, in common with roaches and certain other insects, have the habit of cleaning themselves by putting their feet into their mouths, and hence are easily killed.

Thirdly, sodium fluosilicate is considered less dangerous to man. This is a distinct advantage, for in spite of the improbability of human poisoning from beans which have been dusted with calcium arsenate, the prejudice is so great that many farmers refrain from applying arsenicals to beans. On the other hand, sodium fluosilicate in small quantities is non-poisonous to man, and for that reason should be more popular than the arsenates for dusting beans. It should not be assumed, however, that there is no danger whatever and the material used carelessly. Recently a case was reported of fatal poisoning* from the eating of bread the flour of which had been accidentally mixed with sodium fluosilicate.

Another advantage of sodium fluosilicate is its efficiency against widely separated insects, such as chicken lice, cockroaches and potato beetles.

**Disadvantages.**—As obtained on the market today, sodium fluosilicate is two or three times as "heavy" as calcium arsenate. A pound of the latter will occupy 80 cubic inches, and will cover a larger surface than sodium fluosilicate. In the manufacture of calcium arsenate, however, considerable experimental work was necessary in order to obtain a light, fluffy material. A few preliminary experiments showed that sodium carbonate when added to hydrofluosilicic acid gives a precipitate the density of which is less than when sodium chloride is used. Sodium silicate added to hydrofluoric acid also gave a "light" precipitate, which showed properties analogous to those of sodium fluosilicate. It is probable that further research will solve this factor of density, and that a lighter sodium fluosilicate can be obtained.

Sodium fluosilicate can not be used as a liquid spray on beans because in this form it is more or less injurious to the tender bean

*Bull. Sci. Pharmacol. Vol. 30: 211. 1923.

foliage. Used as dust and mixed with hydrated lime it appears to cause no injury.

**Source and uses.**—Sodium fluosilicate occurs as a by-product in the manufacture of acid phosphate. When phosphate rock and sulphuric acid are mixed, hydrofluosilicic acid is produced. Upon the addition of common salt, sodium fluosilicate is precipitated. This is used in the ceramic industries and in enamel factories for the manufacture of glass and tile. It is also used as an antiseptic and germicide, and is considered superior to either the fluorides or corrosive sublimate in certain medical practices. It is soluble to the extent of 1 part to 200 parts of water.

## CALCIUM FLUOSILICATE

Good results having been obtained with sodium fluosilicate, other fluorine compounds, such as calcium fluosilicate ($CaSiF_6$), were tested. This material is not at the present time produced in large quantities, so that an excessive price has to be paid for a small amount to be used experimentally. The pure calcium fluosilicate was found extremely toxic to the bean beetles, requiring but a few hours to kill them; but the plants were severely injured.

An attempt was made to make a small amount in the laboratory by adding an excess of milk of lime to hydrofluosilicic acid. The precipitate obtained did not injure the plant and did not kill as rapidly as the pure calcium fluosilicate, due possibly to the formation of inactive substances, such as calcium fluoride. When ground calcium carbonate was substituted for the lime, the resulting product showed practically as much killing power as the pure calcium fluosilicate, with but slight injury to the plant. Further research is needed to determine the action of the oxides and carbonates of calcium with hydrofluosilicic acid.

## CRYOLITE

Samples of the powdered native mineral ($Al_2F_6.6NaF$) were obtained and dusted on bean plants under cages. It was found very efficient, killing bean beetles in from 10 to 20 hours. It very likely breaks up when ingested by the insects and forms toxic products. Fluorspar, on the other hand, is much more stable and therefore much less toxic.

Mixed with 5 parts of hydrated lime, cryolite killed the beetles but also injured the bean plant. It was very evident that cryolite reacts with hydrated lime, even when used as a dust. The chemistry of cryolite-lime mixtures will not be taken up at this time, but it is certain that various toxic fluorides, aluminates, and hydroxides are formed. When cryolite was mixed with two parts of lime, the beetles were dead after 2 days, and the plant was not injured. A spray containing 2 pounds of cryolite and 4 pounds of lime to 50 gallons of water was found effective in killing the beetles within 2 days.

Cryolite is also made synthetically from bauxite. The following analysis was claimed for a sample quoted at 8 cents per pound:

| | |
|---|---|
| Aluminum fluoride | 45.70 per cent |
| Sodium fluoride | 42.60 per cent |
| Sodium fluosilicate | 11.50 per cent |
| Iron oxide | .18 per cent |

Cryolite is a white, glassy, crystalline solid, soluble in 27[illegible] parts of water. It is found in large quantities in Southern Greenland, which exports thousands of tons annually, and is used in the manufacture of aluminum, alum, and various fluorides.

## SILICA BY-PRODUCT

As mentioned previously, hydrofluosilicic acid is a by-product from the manufacture of acid phosphate. Formerly the by-product gases were allowed to pass into the atmosphere. Since even a very small percentage of fluorine gas in the air is highly injurious to plant life, many complaints were made by growers in the neighborhood of fertilizer factories. To overcome this difficulty, the gases are now passed into towers with dripping water, forming hydrofluosilicic acid and a precipitate of silica. A sample of such by-product silica gave fair results in killing adults of the Mexican bean beetle. It is obvious, since pure silica is not an insecticide, that some impurities, such as adsorbed fluorine compounds, are the active insecticidal ingredients. One other sample of silica, obtained from an entirely different source, also showed some insecticidal properties.

## ADSORBED GASES

The value of an insecticide is determined to a large extent by its physical state, it being most efficient in the form of a gas. The gases used in the late war have been tried out as poisons in various ways by many investigators,* with satisfactory results for stored-product and other insects. In the field, however, marked injury to the plants takes place when gases are used as in fumigating.

To obviate injury to the leaves, the writer conceived the idea of using charcoal impregnated with adsorbed gases which would be liberated gradually. Thus not enough gas would be present to injure the plant, while it would kill those insects which crawled over the material.

*McDonnell, C. C. "Recent progress in insecticides and fungicides." Ind. and Eng. Chem., 16: 1018. 1924.

The results were gratifying, indeed, particularly with respect to the Mexican bean beetle. Mr. C. W. Exton, of the Chemical Warfare Service, supplied samples of activated and unactivated charcoal with various percentages of mustard gas (dichlorethysulfide $(ClCH_2CH_2)_2S$). This compound is a colorless, oily liquid, with a boiling point of 215°-217°C. Of all the war gases, it is one of the most toxic. It should be used with caution, since it has an irritating effect on the skin, upon prolonged exposure, in as low a concentration as 1 to 5,000,000. Amounts as small as .01 per cent of mustard gas on charcoal with a little ether proved effective in killing bean beetles in from 3 to 6 hours. When a beetle crawls over a plant dusted with impregnated charcoal, it soon becomes uneasy, tries to fly away, and starts to clean its feet. By this last operation the beetle no doubt gets some of the gases into its mouth, and death ensues within a few hours. One-tenth per cent, .6 per cent and 2 per cent nitrobenzene with .5 per cent mustard gas, without ether, proved no more effective than the .01 per cent mustard gas. Neither plant injury nor discomfort to the operator was caused by mustard gas in either of the several concentrations used.

Beetles succumbed the day after being placed on a plant that had been dusted with .01 per cent mustard gas 18 days previously, showing that the gases are active in the charcoal for several weeks.

With other insects, impregnated charcoal gave varying results. Small tobacco hornworms were killed by .01 per cent mustard gas, but the large ones were not affected.

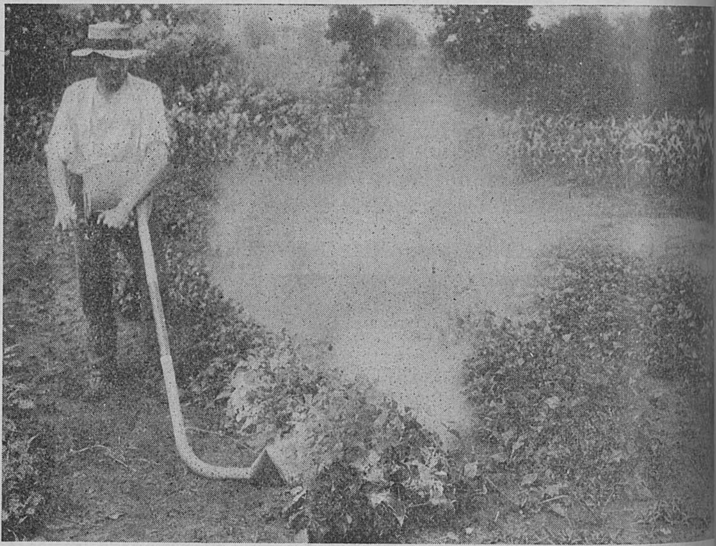
No field trials were made with the mustard gas, but one plot was dusted with wood charcoal which had been mixed with about 5 per cent liquid nitrobenzene. Good control was obtained by four weekly applications. Examination among the plants also revealed dead beetles.

Adsorbed gases were also tried against the boll weevil. In general, the results were the same as those secured against the bean beetle, but less effective control was obtained. The smaller percentages of mustard gas, such as .01 per cent, gave better control than the larger percentages, probably because the small amounts also contained ether. In many cases weevils succumbed in 4 hours after crawling over charcoal impregnated with .01 per cent mustard gas and a little ether. Others became torpid and died in from 1 to 5 days. Sixteen per cent mustard gas, by weight, did not injure the cotton plant. When a weevil crawls over impregnated charcoal it begins to rub its legs and tries to fly. After making several attempts at flying, it becomes weakened and unable to fold its wings beneath the wing covers. Wood charcoal can be obtained on the market today at less than $2.00 per 100 pounds. The cost

of impregnated charcoal should not be great when made on a lar
scale. It is possible that with further investigation a combinati
will be found that will make an effective insecticide.

## PLOT EXPERIMENTS

More than twenty 1/40-acre plots were used to determine t value of the more promising insecticides, as well as those in comm use. The experiments were carried out at the Experiment Stati farm at Knoxville and duplicated at Crossville, on the Cumberla Plateau. The following 21 varieties of beans were tested to d



**Rotary dust gun, showing manner of turning nozzle sideways to direct dust to underside of leaves**

termine any possible natural resistance to bean-beetle attack Burpee's Brittle Wax, Hodson Wax, Rustproof Golden Wax, Bu pee's Stringless Green Pod, Giant Stringless Green Pod, Extr Early Red Valentine, Black Valentine, Tennessee Green Pod, Refuge Robust Pea Bean, Red Kidney, Kentucky Wonder, Scarlet Runner Horticultural, Philadelphia Bush Lima, Burpee's Improved Bush Lima, Henderson's Improved Bush Lima, Burpee's Sunny Brook Pole Lima, King of the Garden, Carolina, and Jackson Wonder None was found resistant, although in general the lima beans ar less attractive to the beetles, and when close to garden beans wi make a crop with little or no dusting. The details of all the pl experiments are not given below. Only those are given which ar representative and bring out the points desired.

## SODIUM FLUOSILICATE PLUS 9 PARTS OF LIME

**Plot 1.**—This plot was planted on April 8 to Early Red Valentine. The beans came up April 22, and the beetles began to make

Plot 1, where sodium fluosilicate mixture was used, showing perfect protection

Plot 2, untreated—destroyed by Mexican bean beetle

their appearance May 21. The bean leaf-beetle (*Cerotoma trifurcata*) was unusually abundant, so that an application of sodium fluosilicate plus 9 parts, by volume, of lime was made May 22. The next day dead adult bean leaf beetles were very abundant on the ground among the bean plants. The application was made wi hand-bellows duster just after the dew had disappeared. Tw minutes were required to apply one pint (½ lb.) of the mixtu the plot 18 by 60 feet. Because of rain, the application was peated May 30, and again June 4. Previous to the latter appl tion, 7 beetles to a row were counted. Two subsequent applicat were given June 14 and June 19. These last applications made with a rotary dust gun, the nozzle being turned sideway as to direct the dust to the underside of the leaves, as shown the illustration.

At no time was the patch seriously threatened, as the appl tions were made when the beetles were noticed and before laying was under way. The mixture appeared to act as a repel and a poison, for a reduction in the number of beetles was obser the day following an application. On June 10, 6 dead beetles found under the vines of one row. On June 14 a few small lar were observed in the plot. At no time was the larval infesta as much as one per cent. Complete protection was obtai whereas the check plot was very seriously infested by June (page 13).

TABLE 2—*Cost of sodium fluosilicate* treatments for the control of Mexican bean beetle, and calculated money returns*

| Plot No. | Date of application | Quantity of material per acre | Cost of materials | Time making applications | Cost of labor | Total cost per application | Yield per acre | Value | Total cost of dusting | Net [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Lbs. | | Hrs. | | | Bu. | | | |
| 1 | May 22 | 20 | $ .50 | 8 | $1.60 | $2.10 | 104 | $260.00 | $9.90 | $1[illegible] |
| | May 30 | 20 | .50 | 8 | 1.60 | 2.10 | ........ | ........ | ........ | — |
| | June 4 | 20 | .50 | 6 | 1.20 | 1.70 | ........ | ........ | ........ | — |
| | June 14 | 30 | .80 | 6 | 1.20 | 2.00 | ........ | ........ | ........ | — |
| | June 19 | 30 | .80 | 6 | 1.20 | 2.00 | ........ | ........ | ........ | — |
| Untreated | | ........ | ........ | ........ | ........ | ........ | 25 | $ 62.50 | ........ | — |

*1 part plus 9 parts hydrated lime.

The amounts of materials used and the time consumed making applications are given in Table 2. The dusted plot yie at the rate of 104 bushels per acre, while the check plot yie 25 bushels. The market price of green beans was from two three dollars per bushel. At $2.50 per bushel the dusted would have returned $260 per acre. The total cost of the applications was $9.90, giving a net return increase due to dus of $187.60 per acre. This large net return was obtained on of an acre, and indicates what is possible with a heavy bean be infestation, and the high prices which result when the pest is uncontrolled.

Plot 9.—The effect of sodium fluosilicate with 9 parts, by volume, of lime was given a trial later in the summer, when the beetles were very abundant. Tennessee Green Pod and Black Valentine varieties were planted July 1. Half of the plot was left untreated and the remaining half was dusted July 17, 21, and 25, and August 5 and 9. Just before the first application there were about 50 beetles to the row. Eggs were also present. The next day a count revealed only 4 beetles to the row on the dusted half and 30 to the row on the untreated half. On July 21, the beetles were extremely numerous—80 to the row—on the untreated portion. On August 7, full-grown larvae were present on the check plot, and by August 12 the patch was completely infested. On the other hand, good protection was obtained in the treated portion of the plot as long as the plants were kept covered with dust. After

Treated with sodium-fluosilicate-lime mixture — Untreated

the crop was made, the beetles multiplied so rapidly in the untreated half that they attacked the treated half, as it was no longer being protected. By September 3 both halves were destroyed.

## SODIUM FLUOSILICATE PLUS 15 PARTS OF LIME

Plot 8.—To determine whether sodium fluosilicate could be diluted still more, it was mixed with 15 parts, by volume, of lime. In this plot Tennessee Green Pod was planted May 6. Applications were made June 4, 10, 14, and 19. The protection obtained was not so good as with the mixture of one to nine, yet the infestation was reduced to 30 per cent. Two and one-half bushels of beans were obtained from this plot.

## CALCIUM ARSENATE PLUS 9 PARTS OF LIME

**Plot 4-A.**—To compare the results of the new chemicals te with those of the present methods, several plots were used. plot treated with calcium arsenate plus 9 parts of lime was pla to Black Valentine May 6. Applications were made June 5, 10, and 19, and on June 25 infestation was only 10 per cent.

The Crossville plots treated with calcium arsenate plus 9 p of lime developed a 20 per cent larval infestation. Five appl tions were made, June 17 and 25 and July 3, 8, and 23.

## MAGNESIUM ARSENATE

**Plots 3 and 5.**—Recently N. F. Howard, of the United St Bureau of Entomology, has obtained good results with magnes arsenate as a wet spray, using 1 pound to 50 gallons of wa This material was tested on plot 3, planted May 6 to Burp Improved Bush Lima, and plot 5, to pole beans, such as Kent Wonder, Carolina, or Sieva, and Sunny Brook Pole Lima. Ap cations were made June 5, 10, 14, and 19 to both plots.

Plot 3 remained free of larvae and beetles as long as the sp ing was continued. As no applications were made after June the beetles subsequently became numerous, so that by Augus there was a 100 per cent infestation. The bean yield was not terially reduced, however, for the earlier protection had ena the plants to develop a good crop.

The pole beans received an additional application July 17. infestation never exceeded 1 per cent, and an excellent crop beans was secured. Howard* does not recommend the growin pole beans where the beetles are numerous, but this experi indicates that pole beans can be grown in Tennessee, even th the pods are matured slowly and are produced over an exte period of time.

Plots were also planted to bush beans in late summer sprayed with magnesium arsenate 5 times. Adequate prote was again obtained, the results of the treatments being aide hot, dry weather.

## CAL-SULPHUR

**Plot 4.**—One part of calcium arsenate and 1 part of sul to 4 parts of lime was used on plot 4 at Knoxville, planted to nessee Green Pod May 6. The first application was made Ju On June 3 the beetles were very numerous, averaging 65 to row. Subsequent applications were made June 10, 14, and 19, on June 25 less than 5 per cent infestation was observed. By 27 a yield at the rate of 110 bushels per acre had been obta "Cal-sulphur" also gave good control at Crossville.

*Bull. 1243, U. S. Dept. Agr., p. 49. 1924.

## DISCUSSION OF THE PRACTICAL CONTROL OF THE MEXICAN BEAN BEETLE

One reason why many gardeners fail to keep the Mexican bean beetle in check is that the familiar principles of control for the potato beetle are applied to the bean beetle. The rule followed in the control of the potato beetle is to apply an arsenical when the grubs are conspicuous. Since the young of the potato beetle eat the entire leaf, they can be very easily poisoned. With the bean beetle, however, feeding takes place almost altogether on the underside of the leaf, so that poison applied in the ordinary manner fails to kill them. Furthermore, when the spray or dust is applied to the underside of the leaves, it is difficult to coat them evenly and thoroughly, and many of the larvae escape.

In our experiments it was found to be much easier to drive away or to kill the active adult beetles than to kill the larvae, particularly when sodium fluosilicate was used as a dust. It was observed that the beetles are very sensitive to any dust on the plants, such as lime or wood ashes, and can be literally "scared" out of a patch when it is kept thoroughly covered with such materials. For this reason, much better success can be had if control measures are directed against the adult beetles when they first make their appearance. The remark is sometimes heard that the bean beetle is not as bad as it was two or three years ago. Investigation usually shows that some material such as wood ashes, lime, road dust, or some such material, is being applied. Much better control would be obtained, however, if sodium fluosilicate were mixed with hydrated lime.

## RECOMMENDATIONS FOR THE CONTROL OF THE MEXICAN BEAN BEETLE

### DUSTS

When the beetles appear, apply immediately a dust mixture of sodium fluosilicate plus 9 parts, by volume, of hydrated lime, at the rate of 15 to 25 pounds of the mixture per acre, depending on size of plants and degree of infestation. Care should be exercised to obtain as light a sodium fluosilicate as possible, as some firms are putting out a heavy product. If sodium fluosilicate cannot be obtained, a dust of calcium arsenate plus 9 parts of lime, or a dust consisting of 1 part of calcium arsenate, 1 part of fine dusting sulphur, and 4 parts of hydrated lime may be used.

Care should be exercised to apply the materials to the underside of the leaves, as shown in the illustration on page 12. From 15 to 25 pounds of the mixture, consisting of 1 part of sodium fluosilicate and 9 parts, by volume, of lime, should be used per acre, the quantity depending on the size of the plants and the severity of the infestation. For small patches and gardens a hand-bellows duster is satisfactory. For larger f the rotary dust gun or knapsack-bellows duster will cover ground in shorter time.

Good results may be obtained with the rotary fan duster turning the nozzle sideways and blowing the dust to the under of the leaves, as shown in the illustration. Where the infest is heavy the nozzle may be directed vertically over the bean p and dragged along over the tops in such a manner as to turn leaves over. In this way the dust may be applied to the under of the top leaves, where the adults frequently feed.

The first dust applications should be made as soon as beetles appear in the patch and before egg-laying is under Ordinarily the second application is given in about a week. I rains occur and the beetles are not numerous, the second app tion may be delayed 10 days or more. If rains wash the mate off and the beetles are abundant, it is advisable to dust again or five days after the first application. Where beetles are numerous, one or two applications may suffice. Usually three four will be necessary, a week or ten days apart, until the cro about made. For pole beans and other late varieties, five or applications may be necessary.

## SPRAYS

Although dusts are becoming more popular, because of of handling and rapidity of application, good results in the co of the bean beetle may be had with liquid sprays, such as ma sium arsenate, applied at the rate of 2 pounds to 100 gallons water, to the underside of the leaves. For pole beans, a li spray has the advantage of not forming a cloud of dust at level of the nose of the operator.

When calcium arsenate is to be used as a spray it is advis to make the mixture in the following proportions:

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| Hydrated lime | 3 lbs. |
| Calcium arsenate | 1½ lbs. |
| Water | 100 gallons. |

The lime is used to prevent "burning." Arsenate of lea considered unsafe to use on bean foliage.

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*Farmers' Bull. 1407, U. S. Dept. of Agr. 1924.

## SUMMARY

1. The experimental work showed that many of the fluorine compounds were effective in destroying the adult Mexican bean beetles. Sodium fluosilicate, calcium fluosilicate, and cryolite have considerable insecticidal value when mixed with hydrated lime in the proper proportions.

2. Sodium fluosilicate is a contact as well as a stomach poison. Because of its irritating effect, the beetle attempts to clean its feet in its mouth. Enough of the chemical thus enters the mouth to cause death.

3. Sodium fluosilicate has these advantages over the arsenicals: (1) It is cheaper, (2) it acts as a contact as well as a stomach poison, (3) it kills more rapidly, (4) it is less poisonous to people, and (5) it is effective against a variety of insects, such as chicken lice, roaches, tobacco hornworms, flea-beetles, and potato beetles.

4. The density of sodium fluosilicate, as obtained in the market to-day, is high, but work is being carried out to remedy this defect.

5. Cotton boll weevils were killed with sodium fluosilicate without lime in from 4 to 30 hours.

6. Gases adsorbed on charcoal gave good results as insecticides. Charcoal containing .01 per cent mustard gas with a little ether was dusted on plants, and bean beetles were killed in from 3 to 12 hours. Nitrobenzene on charcoal was also effective in destroying the beetles.

7. The above gases killed boll weevils in from 6 hours to 5 days.

8. When used as a dust, sodium fluosilicate mixed with 9 parts, by volume, of hydrated lime gave excellent control in the field against the bean beetle.

9. When mixed with 9 parts of hydrated lime, and properly used, sodium fluosilicate showed a net return as high as $187.60 per acre, at a time of the season when the bean beetles were very abundant.