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THE POTATO FLEA BEETLE

By John L. Hoerner and C. P. Gillette

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THE POTATO FLEA BEETLE

By JOHN L. HOERNER and C. P. GILLETTE

The potato flea beetle, *Epitrix cucumeris* Harr., has been of economic importance in Colorado for a number of years. In 1904 the loss to the potato crop was placed at $250,000 (1) *. Since that time it has caused annual losses estimated often as over $100,000. Besides injuring the tubers, the leaves of the potato are often riddled with holes which undoubtedly cuts down the yield. The last few years, potato buyers have discriminated somewhat against the potatoes from the Greeley section because of the rough appearance due to the "worm tracks" produced by this insect on the potatoes which often put them out of first grade. (See Fig. 1.)

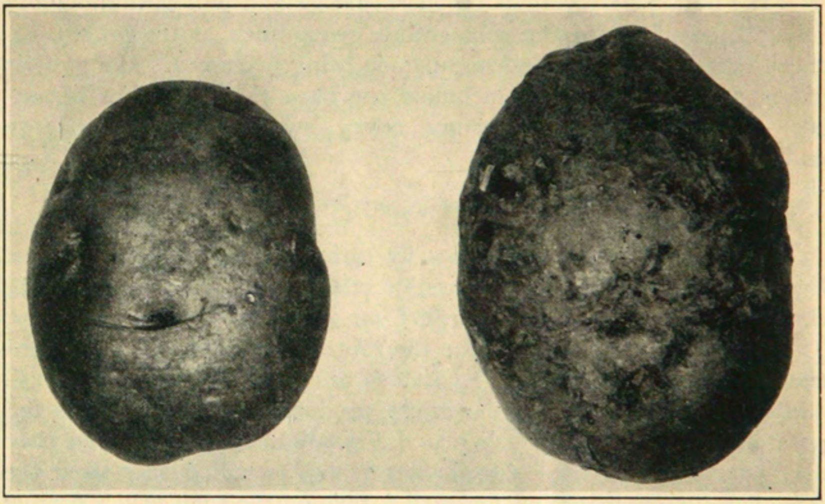

Figure 1.—Potato injured by the potato flea-beetle larvae and an uninjured potato.

COMMON AND SCIENTIFIC NAMES

The potato flea beetle gets its name from the habit of jumping like a flea when disturbed. It has also been called "cucumber flea beetle," "tomato flea beetle," and simply "flea beetle."

This insect has been referred to under the scientific names of *Epitrix cucumeris* Harr., *E. pubescens* Ill., *E. seminulum* Lec. (10), *Crepidodera cucumeris* (2), and *Haltica cucumeris* (3).

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* Reference is made by number to "Literature Cited."

HISTORY AND DISTRIBUTION

Probably because of its small size, early writers paid very little attention to the life history of this insect, and seemed to accept, without question, what another author wrote. Until 1896, it was generally accepted (4, 5, 6) that the larva was a leaf miner. At this time, Stewart (7) found the larva feeding on the underground roots and tubers of the potato, causing the so-called "pimply" potatoes which brought about a reduced price in eastern Long Island in 1894. Johannsen (8) working in Maine, and Webster, (9) in Iowa, added considerable information to the life history and habits. The distribution is quite general, the beetle having been reported in literature from practically every state.

HOST PLANTS

The potato flea beetle is a general feeder and will eat almost any foliage, the plants of the solanaceous group such as the potato, tomato, eggplant, pepper and nightshade being preferred. Many other plants are often attacked, including the bean turnip, radish, cucumber, squash, spinach, cos, lettuce, celery, sweet potato and a large number of weeds.

CHARACTER OF INJURY

The beetles injure the plants by eating the leaves full of holes. In severe cases, when the potatoes or other plants attacked are small, they may be killed. Often the leaf surface is reduced considerably. The larvae live under ground on the roots and tubers causing roughened and pitted places on the potatoes referred to as "worm tracks" and "slivers." Sometimes the injury produces a raised place on the potato called a "pimple." When the small tubers are injured they may partially outgrow it, producing a wide, winding scar from the irregular furrow made by the small larvae on the surface. A furrow eaten on the surface of a mature potato, or one just before digging time, remains as a deep furrow. Sometimes the larvae burrow into the potato almost at a right angle to the surface. These pits later are filled with corky material and are called "slivers." They may enter the potato an inch or more, but are usually quite shallow. These pits often show on the pared potato as black spots. When numerous, a second paring is necessary to remove them.

To show the loss due to the additional paring to remove the "slivers" from the potatoes when preparing them for the table, two samples of moderately pitted potatoes were weighed before and after ordinary paring. They were then pared to remove the slivers and weighed again. The loss is shown in the following table:

Table No. 1—Showing Loss from Paring to Remove "Slivers"

Sample	Weight of potatoes	Loss due to ordinary paring	Loss due to the two parings	Loss due to slivers
No. 1	48 oz.	16 percent	25 percent	9 percent
No. 2	48 oz.	14 percent	21.5 percent	7.5 percent
			Average	8.25 percent

Description of the Stages

ADULT.—The adult beetles (Plate 1, Fig. 5) are about 1/16 inch long and, due to the small size, the markings on them cannot be seen with the naked eye. Under a hand lens or binocular they are black in color with the antennae and legs brownish. The femora of the hind pair of legs are thickened for jumping. The body is covered with short hairs that give it a dull appearance.

EGGS.—The eggs (Plate 1, Fig. 6) are about 1/50 inch in length, being scarcely discernible with the naked eye. They are elliptical in shape and pearly white in color. Under the microscope the surface is pitted or reticulated. Twenty eggs, measured under the binocular, averaged .496 mm. by .2 mm.; largest, .5 x .2 mm.; smallest, .45 x .2 mm.

LARVA.—The larva (Plate 1, Fig. 2) when first hatched, is very delicate and threadlike, about 1/25 inch long and white in color. The full-grown larva is about 1/6 inch long, delicate and white in color, except the head and thoracic shield which are light brown. Sometimes the anal shield shows a light-brown coloration but often is the same color as the rest of the body. The head capsule is margined with black. The head is small, sub-ovate and bent somewhat toward the horizontal; the labrum and mouth parts are reddish brown; there are three pairs of short thoracic legs; and the tenth abdominal segment is retractile with a locomotor organ.

PUPA.—The pupa is uniformly white in color when first transformed; its length is about 1/16 inch; the width across the mesothorax is about 1/20 inch; the general appearance is that of a chrysomelid; the head is bent downward; antennae are directed caudad and partly concealed beneath the first two pairs of legs; the third pair of legs is partly concealed beneath the wings; and the end segment of the abdomen bears a pair of curved appendages. (See Plate 1, Figs. 3 and 4.)

Rearing Methods

All of the life-history material was carried in the natural temperature insectary of the Experiment Station. The small size of the insect in all of its stages made work very difficult, and even with the utmost care specimens were lost.

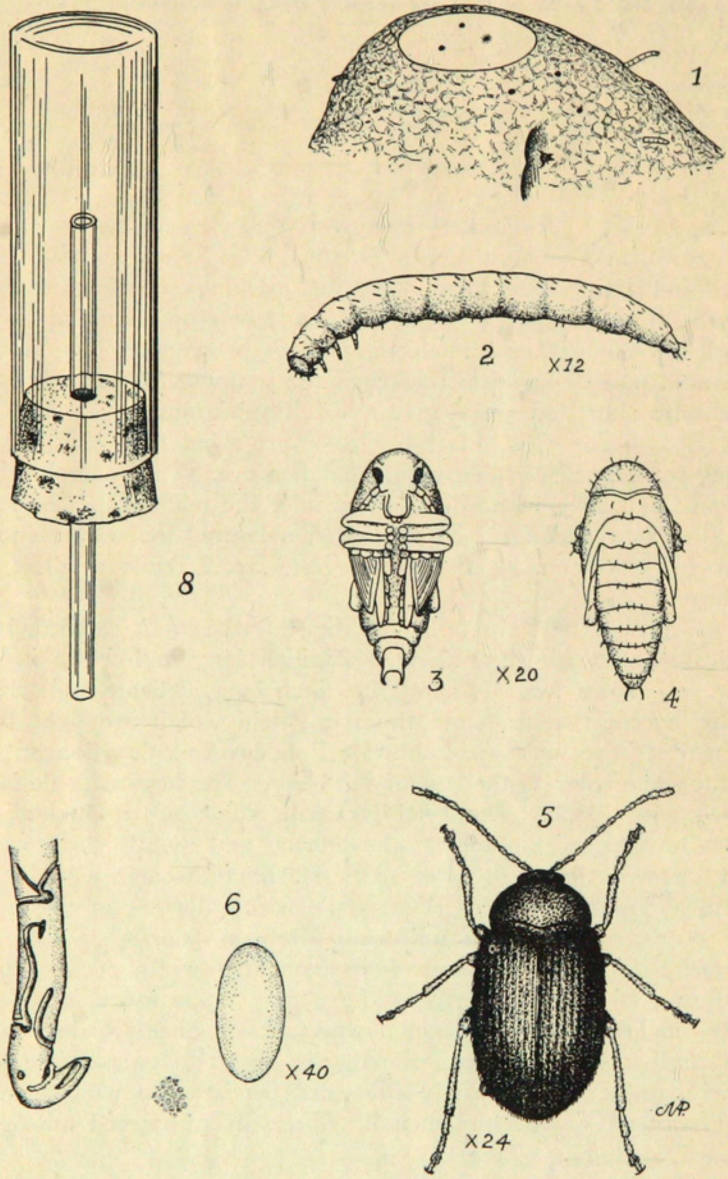

Plate I. Figure 1.—Portion of potato showing flea-beetle larvae and their punctures; 2, larvae; 3 and 4, front and back views of pupa; 5, adult beetle; and 6, egg; 7, a burrowed potato stem, all much enlarged; 8, collecting bottle with glass tube in the cork, for beetles.

Of the different methods tried for obtaining eggs, the Johannsen (11) method was the most satisfactory. The beetles were collected in the field at their first appearance and placed in lamp globes covered at both ends with cheesecloth. The lamp globes were then placed on a dark-colored blotter in contact with moist earth. The females thrust their ovipositors thru the cloth and deposited the eggs on the moist blotter where they could be easily seen and counted. It was found that some of the eggs stuck to the cheesecloth and, by using a dark-colored cloth on the bottom of the cage, work was made much easier. The cloth on the top of the lamp globe permited renewing the potato leaves on which the beetles were fed.

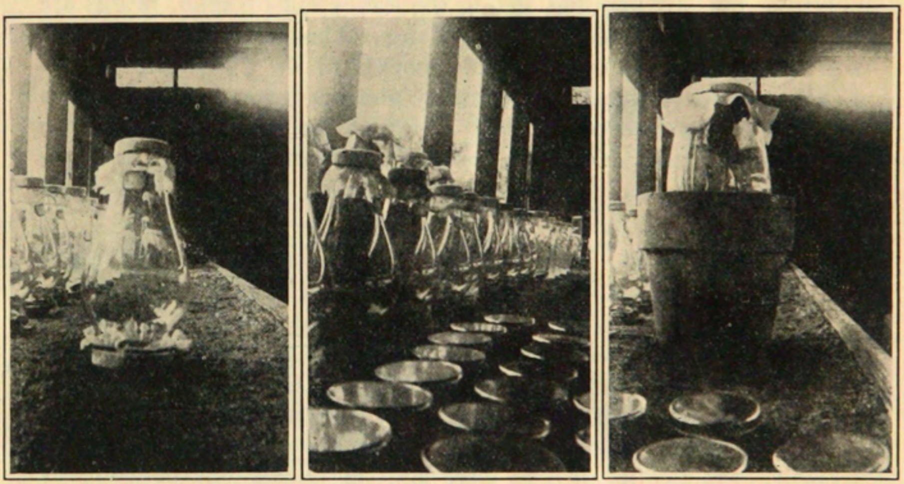

Fig. 1 Fig. 2 Fig. 3

Plate II. Figure 1.—Lamp-globe cage for cbtaining eggs; 2, lamp-globe cages and salve boxes used as breeding cages; 3, potted potato plant in cage for rearing beetles.

After the eggs were deposited on the blotter, they were placed, with the blotter, in small tin salve boxes and kept moist by adding, daily, a few drops of water. Daily examinations were made and records kept of the incubation period.

As the larvae hatched, they were removed daily with a small brush and placed on small potatoes or on a slice of potato known to be free from any larvae or eggs. When the larvae were full grown and left the potato, moist, sifted dirt was added. This seemed to be necessary for normal pupation.

The pupae were removed and placed in tin boxes with moist earth until the adults appeared.

Beetles were also enclosed over potted potato plants for a few days and removed so that the time of egg laying could be determined within a few days. These pots were examined at regular intervals and compared with the life-history material. The potted material, and also field material, compared very closely with that carried in the insectary.

SUMMARY OF LIFE HISTORY

The winter is passed as beetles, in the ground. When the weather warms up in the spring, the beetles leave their hibernal quarters and become active, feeding on most any plant, preferably on plants of the potato or mustard families, eating the leaves full of holes. Eggs are laid in the soil around the potato plants. They hatch in a few days and the larvae feed on the small rootlets or on the potato tubers. In about 25 days they reach maturity and pupate in small oval cells beneath the surface of the soil. After about 9 days they emerge as adults and start feeding. There are indications of a partial second brood but laboratory results seem to show that it is of little importance.

THE EGGS.—The eggs are deposited at a depth of 1/2 to 2 inches in the moist soil close around the base of the plant.

Eggs were first found in the soil around potted plants which had beetles caged over them for a few days. In one pot 30 beetles had been inclosed with the plant for 8 days. Here eggs were found in the loose moist soil to a depth of 3/4 of an inch. Some of the eggs touched the main plant stem, others were out a little distance from it. Practically all eggs were laid singly and only occasionally touched each other. One teaspoonful of soil contained 52 eggs.

On several different occasions eggs were found in the field. The first six eggs were found July 10, 1922, around potato plants and about 1 to 1 1/2 inches below the surface and not over 3/8 inch from the plant stems. Two empty egg shells and a small larva were also found at a depth of 3/4 inch. On two other occasions eggs were found around the potato plants in the field. One egg was fully 2 inches below the surface. Three eggs were found around a tomato plant in about the same location as around potato plants.

The Number of Eggs Laid.—The number of eggs deposited by females varied greatly. In 1922, the average for 16 females was 120, and for 1923, 21 females averaged 96 eggs, the average for the 2 years being 108 for each female. The largest number obtained from 1 female in 24 hours was 28; for 1 season, 245, deposited from June 4 to August 8.

The females start depositing eggs soon after emerging from hibernation and continue over a period of about 2 months.

Influence of Moisture.—Moisture appeared necessary for deposition of eggs. Females in cages oviposited very readily on moist blotters. Dry blotters under the cages retarded egg laying. All the eggs found in the field or around potted plants were in moist soil. Moisture was also necessary for the eggs to hatch. Eggs kept dry did not hatch, while those kept moist hatched quite well. Moisture also affected the length of the incubation period of the eggs. When eggs were kept dry for several days and then moistened, the incubation period was lengthened many days. The results are shown in the following table:

Table No. 2—Showing Influence of Moisture on Egg Incubation

No. of eggs	Date deposited	Date moistened	No. of eggs hatched	Date hatched	Length in days of incubation period	Percent hatched
33	6-12	6-21	7	6-27	15	
			3	6-28	16	30.30
20	6-14	6-21	1	6-29	15	5.00
23	6-21	7-5	1	7-16	25	4.34
52	6-27	7-9	15	7-17	20	36.53
			4	7-18	21	
45	6-28	7-8	6	7-18	20	
			9	7-19	21	42.42
			4	7-20	22	
8	6-8	Kept dry	None hatched			
19	6-16	Kept dry	None hatched			0
10	6-19	Kept dry	None hatched			0
8	7-19	Kept dry	None hatched			0
12	7-22	Kept dry	None hatched			0
607 eggs kept moist, 425 hatched						70.01

Average incubation period for 425 eggs kept moist, 9.82 days, max. 13 days, min. 5 days.

Influence of Temperature.—Temperature was also an important factor in egg incubation. Eggs deposited in June and kept moist hatched in about 10 days; in July, when the temperature ran considerably higher, about 7 or 8 days. Then time increased again in September to 11 or 12 days. The average incubation period for 425 eggs over a period of 3 years was 9.82 days, the longest period 13 days, the shortest 5 days. Eggs deposited on the same day varied as much as 3 days in the length of incubation period.

THE LARVA.—The most difficult stage to study was the larval period. The larva is very frail and feeds largely out of sight inside the small rootlets or tubers. It was very difficult to remove it without injury from the material on which it was feeding and the molts or instars were omitted.

Larval Emergence From Egg.—Several times a larva was watched with a binocular while emerging from the egg. In one egg observed, the larva was seen moving inside for fully 2 minutes before one end of the egg showed a slight protrusion on one side. This protrusion enlarged until it included the whole end of the egg. Then the back of the head broke thru the eggshell as tho it had been broken by muscular force. The larva slowly crawled out leaving the almost transparent shell partly collapsed. The time from the appearance of the head thru the shell until the larva was out was about 8 minutes. The newly hatched larva was all white and 1 mm. long. The egg from which it hatched measured .5 mm. long. In about 1 hour the mandibles started to darken. In 2 hours this had spread to the margins of the head capsule and thoracic shield.

Habits.—The newly hatched larvae wander actively in search of food. In the laboratory, when placed on a piece of potato or small root, they rapidly burrowed beneath its surface. (In the field they probably work their way thru the soil until they find a small root or tuber to feed on.) Only once was a small free larva found in the field and it had probably just hatched, as two egg-shells were found close by. The habit of feeding beneath the surface, when small, would account for not finding larvae in the fields.

When full grown, the larvae left the feed material in the rearing cage and, when given moist soil, would build an earthern cell and pupate. In the potato fields large larvae, or those almost full grown, were often found. It some cases they were found feeding on the tubers with the body partly buried and the abdomen projecting at an angle from the surface. (Plate 1, Fig. 1). Some of the small roots were girdled and almost cut in two. This girdling was probably the work of the large larvae. In the laboratory the larvae were seldom seen, once they had burrowed beneath the surface of a potato, until they left it to find a place to pupate.

Length of the Larval Period. — Temperature appeared to be quite an important factor in determining the length of the larval period. The average larval period for 60 larvae was 25.74 days; minimum 19, and maximum 45 days.

When full grown, the larvae enter the moist soil and make a small cell in which to pupate.

PUPA.—When first transformed, the pupa is about the size of the adult and white in color. It gradually darkens until the adult appears. Temperature, and probably moisture, are quite important in determining the length of the pupal period.

The average pupal period for 20 individuals was 9.72 days. The minimum was 6 and the maximum 16 days. Pupae were found around the bases of plants 1 1/2 to 2 inches below the surface in the moist soil. In flower pots in the laboratory, they were found 1 to 4 1/2 inches below the surface, being most numerous 2 and 3 inches down.

THE ADULT.—For a short period after transformation from the pupa, the adult is light in color. It gradually becomes dark and, by the time it has worked its way to the surface, it can seldom be distinguished from overwintering beetles.

Feeding Habits.—The beetles, after emerging from the soil the latter part of May and the first part of June, soon start feed-

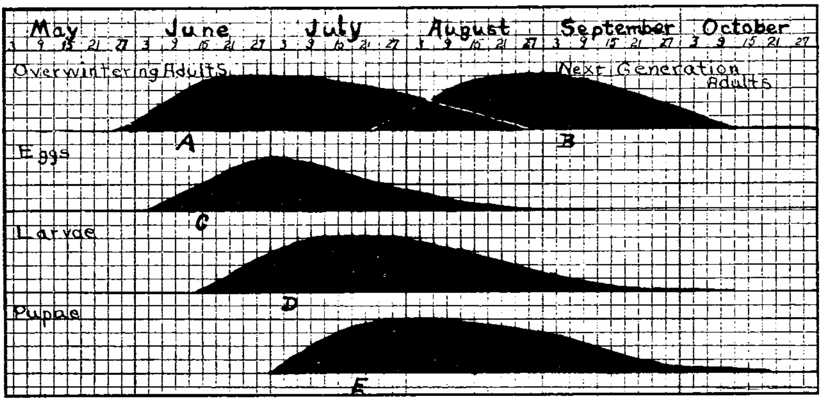

Figure 2.—Life-history chart showing duration and relative numbers of the different stages cf its development thruout the year. A shows the rise and fall of the abundance of the over-wintering beetles until all have died off by the 25th of August; B gives the increase in the next generation of adult beetles beginning about July 25 and decreasing in numbers on the plants after about September 1 as they go into the ground for hibernation. Nctice that they have all disappeared by about October 10. C, D and E give the rise and fall of the eggs, larvae and pupae.

ing on almost any green plant at hand. The writer has observed them after emerging from hibernation in the soil of a potato field, feeding by the hundreds on the sunflower, red root, lambs quarter, alfalfa and morning glory. If potatoes are at hand, they will feed readily on them. If no potato plants are close at hand, they will soon migrate from the weeds or other plants and go to the potato fields.

The greatest migration occurred in the Greeley section, in 1927, from June 10 to 25.

On the potato, the beetles feed on the under and upper surfaces of the leaves, eating them full of holes, or eating thru the leaf to the epidermis; which later dries and breaks. While potatoes are preferred, they will feed on a large number of cultivated plants and weeds. The beetles sometimes collect around the edge of potato blossoms and feed there.

In the fall the new beetles feed upon the potato foliage until the first killing frost, and even after that may be found in large numbers feeding on the green stems of the potato vines. Later they feed upon alfalfa or any green plant not killed by frost, until the latter part of October, when they seek hibernating quarters. Adults have been found feeding as late as October 19.

Mating.—Mating was observed to take place at all times of the day in the fall, but rarely after emergence in the spring. Each female and male appeared to mate several times with different individuals.

Dispersion.—Flying is the most important means of spreading. Potato fields 1/2 mile from fields of the year before are sometimes heavily infested. The insect is such a general feeder it may develop on weeds or other plants.

When disturbed, the beetles jump and then feign death for some time. This makes them very difficult to find after they have jumped from the plant.

Length of Life.—The average length of life of this flea beetle, after emerging from hibernation was about 2 months. A few beetles in the rearing cages lived as long as 92 days, but this was unusual.

Number of Broods.—Laboratory results showed one generation and a partial second, altho the second brood was so small that it is not important. One year only five eggs were obtained from 31 second-brood beetles. Another year (1924), 38 eggs were obtained from 106 beetles.

Hibernation.—The winter is passed as adults in the moist soil about 3 to 5 inches deep. Often the beetles will collect underneath a pile of old potato vines and then enter the soil in large numbers underneath the vines. Until the winter of 1927, much time was spent looking under rubbish and in the soil for the hibernating adults without success, except for a few dead beetles. On November 25, 1925, Mr. George S. Langford found a live adult in the shucks of an ear of sweet corn adjoining a potato field, and the writer on this same date found six beetles under a burlap sack in an irrigation ditch. The beetles hibernating in these places did not survive the winter.

In 1927, the writer made use of screen sieves for finding the adults in the soil. By sifting the soil thru a series of screens having 8, 14, 18 and 32 meshes to the inch, respectively, the adults were quite easily obtained. The beetles passed thru the 18-mesh screen but were caught by the 32 mesh and were quite readily seen. These screens also aided in finding the larvae and pupae.

NATURAL ENEMIES

In our experiments with this flea beetle, no parasites have been found associated with it.

Forbes (12) reports a Hymenopterous parasite, probably one of the *Braconidae.* Chittenden (13) reports a parasite on the adult beetles taken at Washington. Cameron (14) records *Perilitus epitricis* Viereck as a parasite on the beetles.

PREVENTIVE AND CONTROL MEASURES

In looking over the available published accounts one finds that a great variety of materials have been tried and recommended for this insect. These recommendations vary all the way from stomach poisons and repellents to tanglefoot traps. The material recommended most is Bordeaux mixture as a repellent.

DESTROYING HIBERNAL QUARTERS.—Clean culture along with early burning of the dead vines and weeds along fence rows and ditch banks to destroy hibernating places, will aid considerably.

CROP ROTATION.—Crop rotation will undoubtedly help in the control of this insect, especially if carried out on large enough units of land. Some fields 1/2 mile from potato fields of the year before, have been heavily infested. The flea beetle is such a general feeder that good control cannot be expected by this means.

TIME OF PLANTING.—Some of the growers say that they can avoid the worm tracks by late planting, and if they do not plant until the middle or latter part of June, the young tubers will not start to set until about the middle of August and will not be injured. By this means they can largely avoid injury as most of the eggs are laid in June and early in July and the larvae mature before the tubers set. However, a few eggs are laid in August and even as late as early September. Late plantings will not escape injury from these.

TYPE OF SOIL AND MOISTURE.—Severe injury, in most cases, has been on the heavier types of soil, especially when rains or irrigation has kept the ground unusually moist. The greatest injury in any field usually occurs at the ends of the rows or in low places where drainage is not good.

VARIETIES.—The smooth-skinned varieties of potatoes show the injury much more than the russet varieties.

MECHANICAL CATCHERS.—Due to the difficulty experienced in poisoning the beetles, two mechanical catchers were tried out in 1926. A Burlin Aphidozer was used on one field, but it was found to be too cumbersome for the rough soil that exists under irrigated conditions. This machine, in a "once-over," collected 2,509 beetles on 1/10 acre which would make over 25,000 per acre.

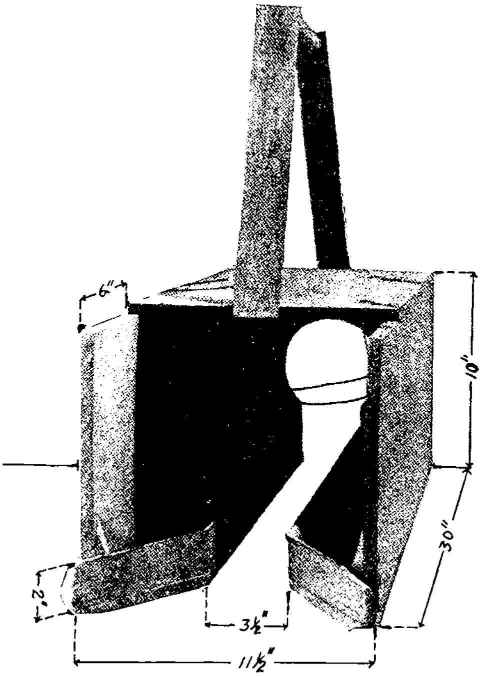

Figure 3.—Box-trap showing detail of construction.

The writer constructed and used a small wooden box-trap modeled after Metcalf's tanglefoot trap (16). Instead of tanglefoot, a small pan containing cyanide dust was used. (See photograph, Fig. 3). While this arrangement did not catch quite as high a percentage of the beetles, as Metcalf reported, the cyanide dust was easily removed and renewed. This trap was tested out 3 hours later on the same area as the Burlin Aphidozer, and collected 3,231 beetles on 1/10 acre. It would undoubtedly have caught more if used before the Burlin Aphidozer. After removing the beetles from this area in the two tests at the rate of 57,000 per acre, there were still many beetles on the plants.

Attempts to place the box-traps on wheels failed, but they were arranged with a yoke over the shoulders so that a man could carry one on each side and cover two rows as fast as he cared to walk.

Several treatments would greatly reduce the number of beetles, but it would not be possible to prevent all injury by this method.

NICOTINE DUST.—The nicotine dusts, when applied in sufficient amounts, knocked many beetles to the ground where practically all recovered, unless they chanced to fall in a spot where there was considerable nicotine dust. The recovered beetles, when placed in cages, fed normally and deposited eggs the same as those in the control cage. Road dust and wood ashes dusted on the plants repelled the beetles and gave a little protection.

CYANIDE DUST.—Calcium cyanide dust (40 to 50 percent calcium cyanide) used at the rate of 25 pounds per acre, applied under a 25-foot canvas canopy, with a hand duster, gave about 75 percent control. The infestation of this plot was unusually heavy. After dusting, 106 apparently dead beetles were picked up on the ground and on the leaves of one small hill about 10 inches high and composed of seven shoots. There still remained 33 live beetles on the plant. None of the 106 beetles recovered. A heavier application of dust, or one applied under a longer canopy, may prove more effective. Better results can be expected from a power duster than from a hand duster. No burning of foliage resulted from the application of 25 pounds per acre.

SPRAYING.—Until 1927, the results of sprays applied for the adult beetles were obtained by examining the tubers for injury. This proved unsatisfactory, as little or no difference could be seen in the many different tests that were made. During the past season (1927) the sweeping method was used to determine the number of adults in the field before and after spraying. By this means the difference in the efficiency of the sprays was readily obtained.

Preliminary to field tests a number of tests on caged beetles were made. Of the materials tried, calcium arsenate used at the rate of 3 pounds to 100 gallons of water gave the best results. Sodium fluosilicate also gave good results but burned the potato foliage quite severely. Table 3 shows the results secured in this work.

It is the opinion of the writer that the calcium arsenate is less objectionable than arsenate of lead to the beetles and they feed more readily on it, resulting in a higher kill.

A 2-acre plot sprayed July 7, 1927, with 3 pounds of calcium arsenate and 3/4 of a pound of calcium caseinate to 100 gallons of water, reduced the beetles 85 percent in 5 days, and 95 percent in 11 days. Later in July, when the next brood of beetles appeared, they again became quite numerous on this plot.

Unfavorable weather prevented a second application of spray until too late to be of much value.

SUMMARY

The potato flea beetle is a serious pest to the potato in the infested sections of Colorado. This insect is a general feeder, eating the foliage of a large number of cultivated plants and weeds. The larvae feed on the underground roots and tubers of potatoes, causing characteristic injuries which are known as "worm tracks," "slivers," and "pimples."

The insect winters as an adult in the soil. The adults appear from hibernation the latter part of May and early June.

In the sections around Greeley and Fort Collins, there is one complete generation, and a partial second brood. From laboratory results the second brood appears to be of little importance.

Potatoes planted late on the lighter types of well-drained soil are the least liable to be injured. The beetles avoid sprayed foliage and are very difficult to control by the ordinary applications of insecticides.

CONTROL.—Arsenate of calcium used at the rate of 3 pounds to 100 gallons of water has given the best control. It should be applied as soon as the beetles become numerous upon the potatoes, which is usually between the 15th and 25th of June in the Greeley section. Make the treatment thoro and repeat in about 10 days. If, for any reason, a third application is needed, it should be made about 10 days after the second.

LITERATURE CITED

(1) Jchnson, S. Arthur
1904. Unpublished Notes.

(2) Slingerland, M. V.
1896. Rural New Yorker. 15 Aug. 545.

(3) Walsh, B. D.
1867. Prac. Eng., August, Sept. V. 2; 120.

(4) Harris, J. W.
1862. Insects Injurious to Vegetation. 127.

(5) Riley, C. W.
1869. Mo. Rep. Sta. Ent. 1; 101.

(6) Packard, A. S.
1875. U. S. Geol. and Geog. Surv. of Colorado and Adjacent Territory. 732.

(7) Stewart, F. C.
1896. N. Y. Bul. 113, New Ser. Dec.

(8) Johannsen, O. A.
1913. Maine Exp. Sta. Bul. 211.

(9) Webster, R. L.
1915. Iowa Bul. 155: 367.

(10) Leng, Chas. W.
1920. Catalcgue of Coleoptera of N. A.

(11) Johannsen, O. A.
1921. Jour. Econ. Ent. V. 14, No. 6: 511. Dec.

(12) Forbes, S. A.
1900. 21 Rept. State Ent. Ill.; 117.

(13) Chittenden, F. H.
Bul. 19 Div. of Ent. U. S. D. A.

(14) Cameron, Alfred E.
1914. N. J. Rpt. 375-381.

(15) List, George M.
1921. Bul. 271. Colo. Agr. Expt. Sta.

(16) Metcalf, C. L.
1915. Jour. Econ. Ent. 240.

TABLE 3.—GIVING POISON TESTS WITH THE POTATO FLEA BEETLE IN CAGES

Cage No.	Insecticide used	Strength of poison lbs. to gal.	Dates	Beetles and Eggs	Record of length of life in days and number of eggs laid each day														On 31st day		
					1	2	3	4	5	6	7	8	9	10	15	20	25	30	Beetles alive	Total Eggs	% Dead Beetles
1.	Calcium arsenate spray	3 to 100	7-29	B'tl's 22		3		6		12				1					0		100
				Eggs	5	1		1		1									0	8	
2.	Calcium arsenate spray	3 to 100	8-3	B'tl's 20		7	8		4		1								0		100
				Eggs					1											1	
3.	Calcium arsenate spray	3 to 100	7-27	B'tl's 10		1	5		4										0		100
				Eggs		3			1											4	
4.	Calcium arsenate spray	3 to 100	7-29	B'tl's 39	3		18		16		2								0		100
				Eggs	2															2	100
5.	Calcium arsenate spray	3 to 100	7-9	B'tl's 29		24		5											0		100
				Eggs				7												7	
6.	Calcium arsenate spray	3 to 100	7-2	B'tl's 69	21	35	9	1	2	1									0		100
				Eggs					1											1	
7.	Calcium arsenate spray	3 to 100	7-8	B'tl's 44	2		17		23					2					0		100
				Eggs																0	
8.	Calc. arsenate spray with casenate	3 to 100	7-7	B'tl's 26	3	6		12		5									0		100
				Eggs																0	
9.	Calc. arsenate spray with casenate	4 to 100	6-25	B'tl's 25		10		13		2									0		100
				Eggs		1														1	
10.	Calc. arsenate spray with casenate	4 to 100	7-2	B'tl's 25	2	5	5	6	1	1			6		2	1			0		100
				Eggs	4		8	4	6	5			1		8					36	
11.	Calcium arsenate alone	6 to 96	7-29	B'tl's 26	9		14		2		1								0		100
				Eggs																0	
12.	Calcium arsenate alone	6 to 96	7-13	B'tl's 73	29	12				32									0		100
				Eggs																0	
13.	Calcium arsenate alone	6 to 96	7-21	B'tl's 34	2	11		17	4										0		100
				Eggs					1											1	
14.	Calcium arsenate with casenate	6 to 96	7-21	B'tl's 45	13	19		13											0		100
				Eggs																0	
15.	Calcium arsenate with casenate		7-21	B'tl's 47	10	16		16	4		1								0		100
				Eggs																0	

TABLE 3.—GIVING POISON TESTS WITH THE POTATO FLEA BEETLE IN CAGES—(Continued)

Cage No.	Insecticide used	Strength of poison lbs. to gal.	Dates	Beetles and Eggs	Record of length of life in days and number of eggs laid each day: 1	2	3	4	5	6	7	8	9	10	15	20	25	30	On 31st day: Beetles alive	Total Eggs	% Dead Beetles
16.	Calcium arsenate	Straight	7-29	B'tl's 4	1		3												0		100
	dust,			Eggs 5			2													7	
17.	Calcium arsenate	Straight	7-22	B'tl's 16	2		12		1		1								0		100
	dust,			Eggs			3				1									4	
18.	Calcium arsenate	Straight	7-20	B'tl's 29	6	12	9		2										0		100
	dust,			Eggs																0	
19.	Calcium arsenate	1 to 9	7-20	B'tl's 18			4		7		4			2	1				0		100
	and lime			Eggs																0	
20.	Calcium arsenate	1 to 9	7-20	B'tl's 31		2			3		6		4	2	13	1			0		100
	and lime			Eggs	7	5	8		4											24	
21.	Calcium arsenate	3 to 96	7-7	B'tl's 38				23		13	2								0		100
	Bordeaux (com'l)	6 to 50		Eggs																0	
22.	Calcium arsenate	3 to 96	7-11	B'tl's 8			3	1				4							0		100
	Bordeaux mixture	6 to 100		Eggs			5													5	
23.	Calcium arsenate	4 to 100	6-25	B'tl's 23		16		4		2	1								0		100
	Bordeaux mixture	4- 4- 50		Eggs				1												1	
24.	Calcium arsenate	4 to 100	7-2	B'tl's 23	1	11	1		2	1					4	1	1		1		95
	Bordeaux mixture	4- 4- 50*		Eggs						1										1	
25.	Control		6-25	B'tl's 15		2								1					12		20
				Eggs		13		3		13	15	13	14	17	15	27	65	80		275	
26.	Control		7-1	B'tl's 12	1											2			9		25
				Eggs	3	9	3		4	11	5			45	5	6				91	
27.	Paris green	1 to 96	6-27	B'tl's 22		5		7	2	2	1	1	2		2				0		100
	and casenate			Eggs		5		4	3	1		5	3		1					22	
28.	Paris green	1½ to 96	7-9	B'tl's 39		23		13	1	1				1					0		100a
				Eggs																0	
29.	Paris green	1 to 9	7-20	B'tl's 28	8	6	7		5		1				1				0		100
	lime dust			Eggs																0	
30.	Paris green	1 to 50	6-25	B'tl's 13		7		5			1								0		100
	and Boreaux	4- 4- 50		Eggs																0	

TABLE 3.—GIVING POISON TESTS WITH THE POTATO FLEA BEETLE IN CAGES—(Continued)

Cage No.	Insecticide used	Strength of poison lbs. to gal.	Dates	Beetles and Eggs		Record of length of life in days and number of eggs laid each day														On 31st day		
						1	2	3	4	5	6	7	8	9	10	15	20	25	30	Beetles alive	Total Eggs	% Dead Beetles
31.	Paris green	1 to 50	7-2	B'tl's	10	3	6	1												0		100
	and Boreaux	4- 4- 50*		Eggs																	0	
32.	Paris green	1 to 9	7-22	B'tl's	26	10		12		3					1					0		100
	and lime (dust)			Eggs																	0	
33.	Zinc arsenite	2 to 50	6-29	B'tl's	33		21	6	2	2		1				1				0		100
	and casenate	1 to 100		Eggs			3		1				1								5	
34.	Zinc arsenite	3 to 96	7-7	B'tl's	37		7		22		7	1								0		100
				Eggs																	0	
35.	Lead arsenate	3 to 96	7-1	B'tl's	32		2	15	8	2	1	2	2							0		100
	Casenate	1 to 96		Eggs			1														1	
36.	Lead arsenate	3 tc 96	7-7	B'tl's	17			1								14	1	1		0		100
				Eggs						1						15					16	
37.	Lead arsenate	2 to 50	7-1	B'tl's	28		4	12	6	1		1	1			1	2			0		100
	Casenate	1- 100		Eggs			1	3		2											6	
38.	Lead arsenate	2 to 50	7-1	B'tl's	25		4	3	5	1		1	2		6	1	2			0		100
				Eggs			1														1	
39.	Lead arsenate	Straight	7-20	B'tl's	24		3	8		3		3		2	1	2	2			0		100
	dust			Eggs																	0	
40.	Lead Bordeaux	6 to 50	7-7	B'tl's	24		2		5			2	5			10				0		100
				Eggs																	0	
41.	Lead Bordeaux	6 to 50	6-25	B'tl's	23		2		6		2	2	2	3	1	4	1			0		100
				Eggs			3				3					2					8	
42.	Magnesium arsen-	3 to 96	7-7	B'tl's	17		4		2							2	7	2		0		100b
	ate			Eggs					3			2				2		6			13	
43.	Magnesium arsenate	2 to 50	6-29	B'tl's	22		10	6	1	1	1	2						1		0		100
	Casenate	½ to 50		Eggs					1												1	
44.	Manganar	3 to 96	7-7	B'tl's	71	1	1		31		16	15				6	1			0		100
				Eggs							4					1					5	
45.	Manganar	2 to 50	7-1	B'tl's	18	1	9	3	2	2					1					0		100
	Casenate	½ to 50		Eggs		1															1	

TABLE 3.—GIVING POISON TESTS WITH THE POTATO FLEA BEETLE IN CAGES—(Continued)

Cage No.	Insecticide used	Strength of poison lbs. to gal.	Dates	Beetles and Eggs	Record of length of life in days and number of eggs laid each day														On 31st day		
					1	2	3	4	5	6	7	8	9	10	15	20	25	30	Beetles alive	Total Eggs	% Dead Beetles
46.	Sodium floride	2 to 50	6-29	B'tl's 19		12	3		2	1			1						0		100
	Casenate **	½ to 50**		Eggs																0	
47.	Sodium floride	2 to 50	7-8	B'tl's 36	7		26		2						1				0		100b
				Eggs	1					1										2	
48.	Sod. fluosilicate	2 to 50	6-29	B'tl's 20		17			1	1	1								0		100
	Casenate **	½ to 50**		Eggs																0	
49.	Sod. fluosilicate	2 to 50	7-7	B'tl's 41	29	9		3											0		100
	Casenate **			Eggs																0	
50.	Sod. fluosilicate	3 to 96	7-1	B'tl's 23			2		3	2	3	1	6		3		1		2		91
				Eggs														3		3	
51.	Sod. fluosilicate	1 to 9	7-20	B'tl's 38		4		5			5		5	6	13				0		100
	with lime			Eggs									4	1						5	
52.	Sod. fluosilicate	1 to 9	7-22	B'tl's 26	4				1		2		4		15				0		100
	with dust lime			Eggs	26				3		1		3		1					34	
53.	Calcium floride	3 to 96	7-7	B'tl's 26												1			25		3.8
	and Casenate	1 to 96		Eggs		1		4		7	1				26	59	3			101	
54.	Flurocide (double)	Dust	7-20	B'tl's 43	8	6	8		11		7		1	1	1				0		100
	dust			Eggs																0	
55.	Flurocide	Dust	7-20	B'tl's 41		10	8		2		4		7	4	4	2			0		100
	(single)			Eggs									3							3	
56.	Iron Arsenate	3 to 96	7-7	B'tl's 34		1					1				5	8			19		44.1
				Eggs				14		16	2	2			11	7	3			55	
57.	Iron Arsenate	3 to 96	7-7	B'tl's 31											3	8			19		38.3
	Casenate	1 to 96		Eggs				2		10					3	11				26	

(*) One untreated leaf put in. (**) Foliage badly burned. (a) Two beetles lost (b) One beetle lost