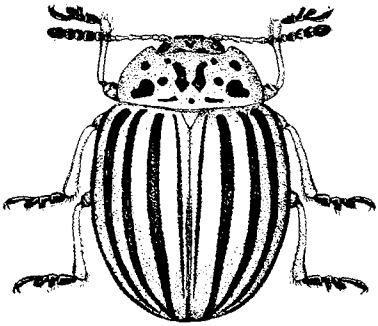
Controlling Colorado Potato Pests

Leslie B. Daniels



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Controlling Colorado Potato Pests

LESLIE B. DANIELS

COLORADO is one of the important potato-producing states of the West. In the early development of its agriculture potatoes were one of the first crops found to grow well under Colorado conditions. Soil and climate were favorable to potato culture. Potatoes have become one of the principal crops of the state. Colorado now ranks second in potato production of 10 western states. Maximum production was attained in 1925, when the total production for the state was 18,460,000 bushels from 142,000 acres.

Throughout the history of potato culture in the state there have been good and bad years. In 1911 the yield per acre for the state dropped to 35 bushels, the lowest average yield ever recorded for Colorado, while the best yields occurred in 1925 and 1930, when the average yields for the state were 195 and 190 bushels per acre, respectively.

It is significant that variation in yield has been to some degree related to outbreaks of insects. The three major insect pests of potatoes in Colorado, in the order of their importance, are the potato psyllid, the potato flea beetle, and the Colorado potato beetle. The psyllid has been one of the most important insects to affect potato culture. These tiny, jumping lice have appeared periodically in sufficient numbers to cause the epidemic condition commonly known as purple top or psyllid yellows. The disease has been responsible for serious losses in past years.

For about 30 years in certain sections the quality and saleability of potatoes has been materially affected by the potato flea beetle. Injury to the tubers by the worms has made potatoes unsightly and difficult to sell, the damage running well over $200,000 annually. Fortunately, this insect has confined most of its depredations to certain localities of the state.

Since the first potato was planted in Colorado the potato bug, more properly called the Colorado potato beetle, has been a serious menace to potato culture. The large, striped beetle has received attention in many sections of the United States and in Europe, where it has been carried by the mass movements of man.

Potato Psyllid

History

This insect, called tomato psyllid, potato psyllid, or jumping plant louse (*Paratrioza cockerelli* Sulc.), has been recorded since 1894 as a pest on tomatoes and more recently as a serious pest

on potatoes. It apparently passed unnoticed on potatoes until 1927, when the purple top or psyllid yellows condition was observed in Utah (1) and on the Western Slope (2) in Colorado. Since 1930 considerable work on the control and biology of the psyllid has been carried on by the Colorado Experiment Station.

Epidemic Years

There is little doubt that the serious potato losses in 1911 were caused largely by psyllids. Yield dropped to the lowest average since the beginning of potato production in Colorado. The losses, however, were attributed to American leaf roll, a virus condition which in its symptoms resembles psyllid yellows. The season was extremely dry, with conditions favorable for the development of a psyllid epidemic. Ninety thousand acres of potatoes were planted; the yield as given by the Colorado Year Book was 3,150,000 bushels, an average yield of 35 bushels per acre. The epidemic apparently continued into 1912. The yield for that year is reported as averaging 95 bushels per acre.

In more recent years the psyllids have caused serious losses. The past 7 years have been marked by considerable fluctuation in potato yields which may be attributed largely to a combination of drought and psyllid yellows. The two conditions appear to go hand in hand. During this period surveys have shown that there is considerable variation in the localities affected and in the incidence of the epidemic conditions. There are some sections which suffer annually from serious outbreaks of psyllid yellows. This is especially true of certain mountainous potato areas of the state.

In the open plains areas the seriousness of the psyllid condition depends largely upon the type of season. An early spring with moderately high temperatures and low rainfall is conducive to a psyllid outbreak. In the Plains Section the abundance of suitable host plants for breeding will always be a factor in building up epidemic populations of psyllids. The serious epidemic of 1931 may be attributed to a favorable spring which allowed the perennial host plants, ground cherries, to appear early in April. Psyllids began laying eggs, and by the time the early potatoes were above ground a generation or two of psyllids were ready to move into the fields. Symptoms began to show by the last week in May, and it was realized by the middle of June that Colorado was experiencing one of its worst psyllid years.

Economics

The monetary importance of psyllids in terms of value of potatoes lost through reduction in yield by the feeding of psyllids remains a debatable question. Since drought and psyllid epidemics go hand in hand, it is hard to evaluate the importance of

each under non-irrigated conditions. However, under irrigated conditions there is little doubt that psyllid yellows cause heavier losses to potato growers than any other known disease. The disease is insidious, appearing suddenly, and before control operations can be gotten under way the field is damaged beyond recovery. Such is the case in a year of serious infestation. In years of mild outbreaks the development is not so rapid, and control may be effected without too serious loss.

In terms of yield, a reduction from 190 bushels to the acre to 90 bushels, which are the average yields for 1930 and 1931, respectively, is significant. Many fields in 1931 were never dug, and the financial loss to growers in the early sections was considerable. Surveys made during the 2 years showed very definitely that the chief cause of the trouble was psyllids. Fusarium wilt and drought, since there was adequate water for irrigation, were of minor importance.

Actual value of the crop in 1931, owing to prices as low as 30 and 40 cents a bushel, makes the figures out of proportion, but at current prices the loss of 7,895,000 bushels, the difference in the yields of 1930 and 1931, cost the growers of Colorado $2,763,200. There was an increase in acreage of 15,000 for the year 1931, which makes the loss even more significant.

Biology and Habits

Description of Stages

ADULT.—The adult psyllids belong to the family of jumping plant lice (*Chermidae* Fall). They are called jumping plant lice because they have hind legs modified for leaping from one plant to another, and their feeding habits are similar to those of the true plant lice.

The mature psyllid is about 1/10 inch in length and resembles the cicada or harvest fly in body form and markings. The general color is gray, with white or yellow lines on the head, thorax, and abdomen. A white transverse band at the base of the abdomen and a somewhat Y-shaped white mark at the tip are characteristic. The wings are placed roof-like over the abdomen.

The adults are very active, and they are difficult to find unless abundant. They jump or fly upon the least disturbance.

EGGS.—The eggs of the psyllid are very small, a lens often being required to make them visible. They are yellow in color and are placed on moderately short, white stalks or pedicels. The eggs may be most readily seen by holding the edge of the leaf in strong sunlight and on a level with the eyes. They may be seen projecting like small pegs. Freshly laid eggs are of a bright yellow color, and as they advance toward hatching time they become orange.

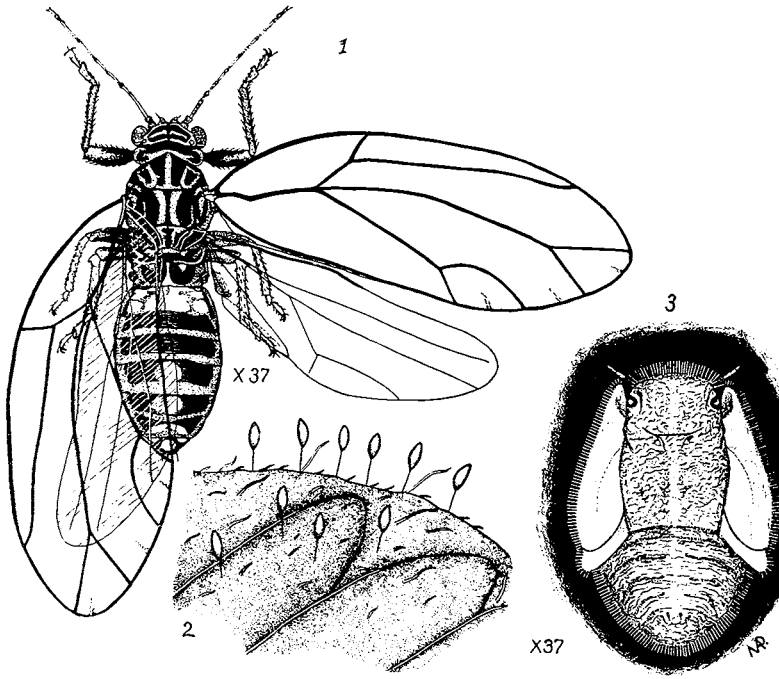

Figure 1—Tomato psyllid (*Paratrioza cockerelli* Sulc.): (1) adult, (2) egg, (3) nymph or immature form in the fourth stage of growth.

NYMPHS.—The nymphs are the small, scale-like, immature stages of the psyllid. Their bodies are very flat and elliptical, and they vary in color from orange-yellow to green. Color and size vary with the age of the nymph. The young, newly hatched individuals are very small, and they are orange-colored. As they feed and grow they pass through five molts, becoming larger, broader, and longer at each molt. In the late stages their color is a pale green, and they are plainly visible to the unaided eye. The last stage may be found on the under sides of the lower leaves of the potato plant. The bodies are held close to the surface of the leaf and are often so firmly attached that use of a pin is necessary to detach them. The potato grower should acquaint himself with this stage, since it is for this form that he must be continually on the watch in late May and early June.

Life History

The length of the life history of the psyllid depends upon general weather conditions. It is apparent from study of psyllid epidemics that hot, dry years favor the development and abundance of psyllids. In a favorable year there is little doubt that there may be 8 or 10 generations. The time required to develop from egg to nymph and thence to mature adult is a little over

3 weeks, the length of time depending upon temperature conditions.

In eastern Colorado in a favorable year adult psyllids appear on the available native-host plants by the middle of May, where they mate and lay their first eggs. The eggs are laid irregularly in small bunches along the edges or surfaces of the lower leaves. The average female lays about 300 eggs over a period of several weeks. The eggs hatch in from 3 to 8 days into the small, orange-colored nymphs. The young nymphs begin feeding soon after emerging.

The five stages of growth which follow vary in length, depending upon environmental conditions. The first two stages require from 4 to 5 days, the third and fourth about 6, and the fifth from 6 to 8 days. The newly emerged adult is at first pale yellow in color; after a few hours it turns to a tan, and in a few days it has the darker coloration of the mature adult. The life cycle may take place in from 15 to 30 days, depending upon weather conditions.

FEEDING HABITS.—The most injurious stage of the psyllid is the immature form. During the 2 or 3 weeks of their feeding and growing they are sucking juices from the potato plants and introducing into the plant a secretion which is apparently toxic. When psyllid nymphs are abundant, 900 to 2,000 on a plant, the effects in a field are very noticeable, and the results are soon disheartening.

The mouth parts of the psyllid nymph are two-thirds the length of the body. In structure these parts are very slender and needle-like, consisting of four stylet-like elements which serve a three-fold purpose in puncturing the delicate leaf cells, forming one tube through which the sap may be withdrawn, and forming a second through which a secretion is injected during feeding, the purpose of which is not definitely known. The mouth parts are firmly attached to the head and are controlled by long, slender muscles enclosed within the head capsule.

SYMPTOMS.—Symptoms of psyllid yellows vary with the variety of potatoes affected and the number of psyllids infesting the plant. Varieties most susceptible are Early Cobblers, Triumphs, Peach Blows (McClures), and Russet Burbanks. The least susceptible are Rurals and Brown Beauties. The varietal difference in reactions to psyllid feeding depends upon growth and soil type and upon whether potatoes are irrigated or nonirrigated. In Cobblers, Triumphs, and McClures the disease appears suddenly. The first symptom noted is an inward curling of the basal portion of the terminal leaves. The curling leaf is marked by a change from the normal green color to a yellowish-green, particularly on the edges. There is also a decided slowing

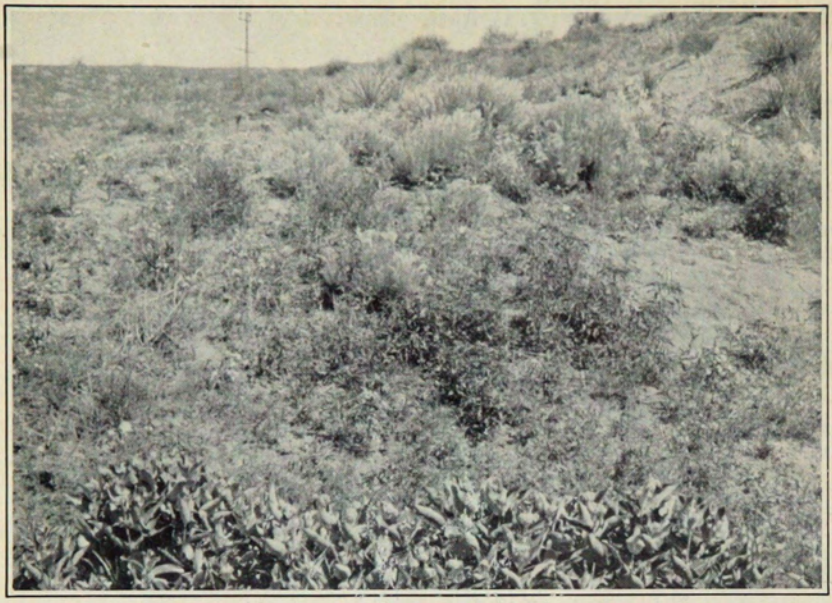

Figure 2—Typical waste land along the South Platte River, southwest of Greeley, Colo., where ground cherries are abundant. In favorable years large numbers of psyllids are propagated on such places.

up of the growth processes. As the disease advances a greater number of plants are found showing the primary symptoms, the disease continues to become more pronounced in those plants infested early, and discoloration and curling advance to a stage where many leaves are affected. The opposite edges of the terminal leaves almost meet, and the yellow discoloration changes to pink or reddish-purple. The leaves do not droop normally but are held quite rigid and stiff. The whole plant, in fact, has a most abnormal appearance because of the erect condition of the foliage.

The plants may remain in this stage for 6 or 8 weeks without showing any visible signs of growth. No amount of irrigation will retard the progress of late symptoms. Sprays at this advanced stage may give some degree of recovery. However, recovery is likely to be a prolongation of the condition over a longer period, with no advantage in tuber growth.

As the disease advances the plants change in color to yellow, and lastly to brown, as they ripen. Upon examination of underground portions of the plant a large number of small tubers, ranging in size from that of small peas up to that of marbles, are found. The tubers may be found sprouting, and if allowed to remain in the ground they produce new plants during the remaining part of the season. The rest period is shortened, and

consequently growth in the form of sprouts and new plants is the result.

Tubers from plants seriously diseased do not produce normal plants. There is serious danger in using seed from psyllid-affected fields.

The symptoms of psyllid yellows in Rurals and Brown Beauties do not develop as rapidly as in the more susceptible varieties. The disease appears in a milder form.

OVERWINTERING.—Overwintering psyllids were first found in the cedar areas of southwestern Nebraska during the winter months of 1936. The evidence obtained indicates that the insect hibernates in the adult stage in warm, dry locations in or near its preferred host-plant areas. Specimens have been taken from scattered bunches of cedars on southern exposures of sheltered ravines and arroyos near Gering, Nebr., in 1936 and 1937, and in similar locations near Lusk, Wyo. The hibernating forms appear to be selective as to a choice of habitat and restricted to the protected ravines on southern exposures.

HOST PLANTS.—The tomato psyllid has been found feeding on a wide variety of plants belonging to the potato family. Since there is an abundance of native wild hosts in the western United States, this species of psyllid finds suitable breeding grounds in many localities. The most common and widely distributed of

Figure 3—A plant from a Triumph field near Fort Collins, showing the characteristic symptoms of "psyllid yellows." Note the erect appearance and curling of the leaves in the upper portion of the plant.

the host plants are several species of ground cherries and the spiny buffalo-bur. Ground cherries, probably the preferred wild hosts, are represented by several species, of which a few are perennial. The prairie ground cherry (*Physalis lanceolata* Michx.), long-leaved ground cherry (*Physalis longifolia* Nutt.), and purple ground cherry (*Quincula lobata* Raf.) are the three most common forms. They are found harboring large numbers of psyllids annually, and large areas of these plants are undoubtedly sources for psyllids affecting potato sections. Since they are perennials and appear early in the spring, they offer suitable feeding for the first psyllids that emerge from hibernation. In a favorable season a generation or two may build up on ground cherries, and by the time the potato plants are 4 or 5 inches high large numbers of psyllids begin to migrate from ground-cherry areas into the potato fields.

The buffalo-bur (*Androsera rostrata* Rydb.) is an annual and reaches maturity the latter part of July. As a psyllid host it has not been considered as important as the perennial members of the family. However, because of its wide distribution and abundance in certain sections it must be considered a factor in psyllid propagation. The tendency of this plant to grow in the more arid locations and on heavier soils makes it possible for psyllids to propagate in sections of this soil type.

The wild tomato (*Solanum triflorum* Nutt.) has been found harboring psyllids in the San Luis Valley. This prostrate annual apparently is not a preferred host plant. Its tendency to remain close to the ground does not offer the best conditions for psyllids, although plants have been found bearing a considerable number of nymphs and eggs.

Among the cultivated solanums potato and tomato are the most common hosts. Eggplant, peppers, Jerusalem cherry, cultivated ground cherry, and matrimony vine have been found infested with psyllids.

Control

History

The first control work on the psyllid was done by Dr. C. P. Gillette (3) of the Colorado Experiment Station in 1904, when the lime-sulfur treatment was first tried and recommended for tomatoes. In 1911 Dr. George M. List (4), also of this station, did further work with lime-sulfur on tomatoes and recommended the use of 1 gallon of liquid lime-sulfur to 40 or 45 gallons of water. The outbreak of serious psyllid trouble in 1929 brought about a project at Greeley in which this station cooperated with the Colorado Potato Experiment Station of the U. S. Department of Agriculture.

A project in which Dr. Walter L. Sackett, formerly station

bacteriologist, and L. A. Schall, junior pathologist, Colorado Potato Experiment Station, cooperated with the writer, provided a detailed study of psyllid-yellow diseases. The seriousness of the condition demanded that an efficient and satisfactory control be found as soon as possible. Preliminary field tests were run in 1930. Favorable indications of control were obtained, and further intensive control work was done during the seasons of 1931, 1932, 1933, and 1934 (6).

Spraying

Lime-sulfur has been found to be the most satisfactory insecticide to control psyllids. Many other materials have been tried under field tests, with none showing the effectiveness of lime-sulfur spray. Control results were based on increase in yield

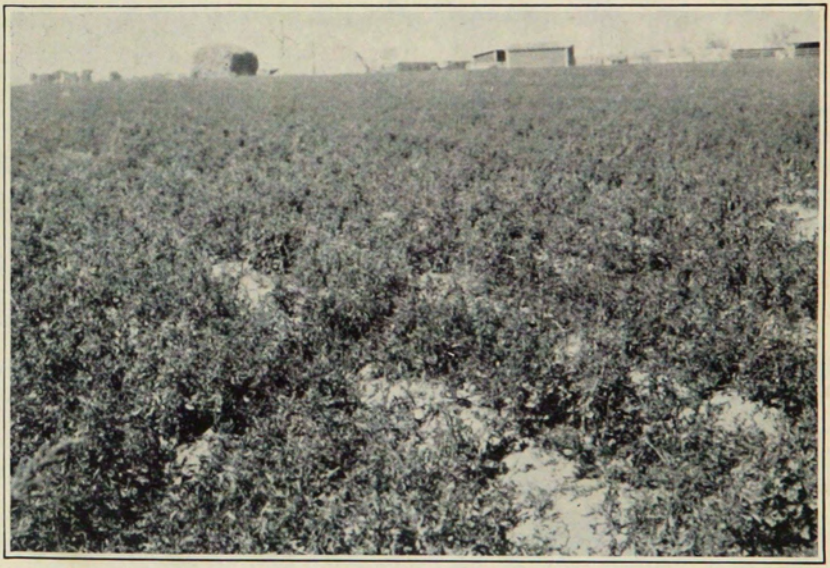

Figure 4.—Field of potatoes in the Gilcrest section near Greeley, Colo., seriously affected by psyllids. This field was never dug.

and actual retarding of development of the disease in the field. Lime-sulfur is sold in either liquid or dry form. Dry lime-sulfur is the powdered residue which remains after the water is removed from liquid lime-sulfur. In using the dried material, water must be added and the material brought back into solution. From 4 to 5 pounds of the dry form is needed to equal a gallon of the liquid form.

The control of psyllids on potatoes requires thorough and complete spraying of plants with a solution of 1 gallon of liquid lime-sulfur, or from 4 to 5 pounds of dry lime-sulfur, to 40 gallons of water.

The spray must be applied to the upper and lower surfaces of all the foliage, particularly of the lower leaves. Many nymphs are found on the under sides of leaves. It has been necessary to recommend sprayer equipment that will develop pressures of from 250 to 300 pounds, with pumps that will deliver adequate amounts of material to cover each plant thoroughly. For these reasons power sprayers are most desirable. Sprayers powered by separate motors, or sprayers designed to obtain their power from tractors, will meet the needs for psyllid control.

Liquid lime-sulfur is more generally used. It mixes easily with water, going into solution almost immediately. The dry lime-sulfur is frequently used in areas remote from a supply of liquid lime-sulfur. Freight rates into mountainous potato sections give dry lime-sulfur a distinct advantage. From control tests it was found that liquid lime-sulfur gave a little better psyllid kill than did the dry.

A good standard brand of lime-sulfur should be used. Standards which must be considered in the purchase of lime-sulfur are a high polysulfide content, a Baume test of 32 degrees, and absence of sludge. These factors determine the effectiveness and efficiency of controlling psyllids with lime-sulfur. In a uniform standard product the manufacturer attempts to produce a lime-sulfur which meets all these requirements. The polysulfide content determines the amount of vaporized sulfur that will be liberated after the spray is applied to foliage. Vaporized sulfur is

Figure 5—A Cobbler field near Fort Morgan, Colo., sprayed for psyllids in 1934. Other fields in the neighborhood were never dug. This field averaged more than 200 sacks to the acre.

the killing agent, and it is important that a lime-sulfur spray produce as much as possible of this lethal factor. The specific gravity test, Baume hydrometer test, gives an index to the concentration of the liquid spray material. The standard which most manufacturers try to meet is a test of 32 degrees Baume. If the material is known to test lower than 32 degrees, a dilution table (5) must be used, since the lower the Baume test the more lime-sulfur required to bring it up to the requirements of the concentration in a solution of 1 gallon of lime-sulfur, 32 degrees Baume, to 40 gallons of water.

In early recommendations for psyllid spraying, the presence of 25 percent of diseased plants in a field was considered the critical stage to which a field might be affected before it was necessary to spray. Recent work has shown that a field must be sprayed before symptoms begin to appear; thus the grower must be continually alert, watching for appearance of psyllids or taking the other alternative, and probably the safer, which is to put on the first spray when the plants are from 6 to 8 inches high. It is a well-known fact that to some extent lime-sulfur repels the adults from sprayed plants, preventing egg laying. Spray applied at the right time wards off psyllids migrating in from surrounding breeding areas. Thus it has become a part of good farm practice for the potato grower to spray annually when plants are from 6 to 8 inches above ground.

A second spray is advisable every year, and in some seasons a third may be needed. The second application is made from 2 to 3 weeks after the first. The interval depends upon general weather conditions and upon the thoroughness with which the

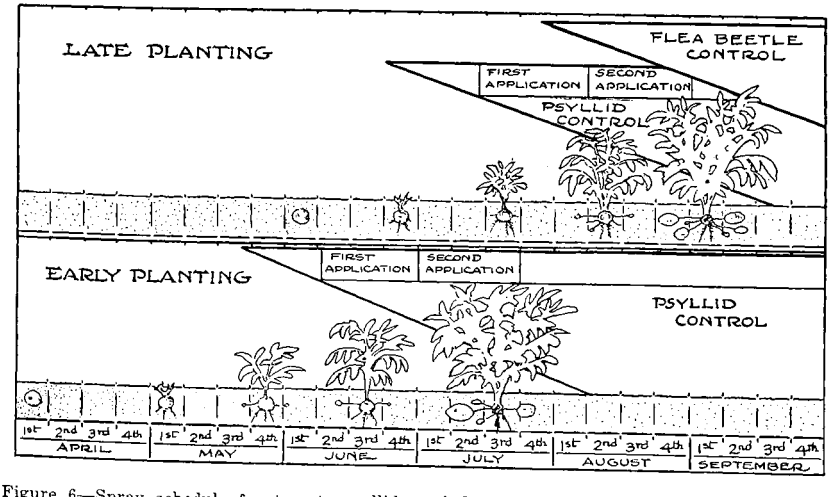

Figure 6—Spray schedule for tomato psyllids and flea beetles. It is important to time the spray to obtain the maximum protection and to reduce the danger of losses from mild psyllid infestations.

first spray was applied and its effectiveness in controlling psyllids. If symptoms begin to show after the first spraying, it is advisable to follow immediately with a second spraying, since the first has apparently failed to control.

Favorable weather conditions, such as existed in 1931, may bring about so great an abundance of psyllids that before the grower realizes it he is faced by a serious condition that may be very difficult to handle. It is possible that the Colorado Experiment Station will be in position to forecast psyllid years, and, if so, this information may be obtained through county agents in the various potato areas of the state.

Summary

1. The years of 1911 and 1931 were the worst psyllid years in Colorado.

2. Psyllids are most injurious during dry, hot years.

3. The green, scale-like nymphs are the direct cause of the disease.

4. In a favorable year there may be from 8 to 10 generations.

5. The number of psyllids on a plant determines the extent to which it is diseased.

6. Patches of wild native ground cherries are the early season breeding grounds for psyllids.

7. A power sprayer is necessary for the most satisfactory control.

8. For psyllid control a sprayer should develop from 200 to 300 pounds pressure and deliver material at a rate sufficient to thoroughly cover the plant.

9. It is important to reach the under sides of the lower leaves.

10. A standard grade of liquid lime-sulfur is most satisfactory.

11. Liquid lime-sulfur should have a high polysulfide content and a specific gravity of 32 degrees Baume, and should be low in sludge.

12. Dry lime-sulfur may be substituted for liquid, but the grower should be well informed as to its disadvantages.

13. The formula for control of psyllids on potatoes is 1 gallon of liquid lime-sulfur, or from 4 to 5 pounds of dry lime-sulfur, to 40 gallons of water.

14. Two applications of lime-sulfur spray are necessary.

15. The first application should be made when plants are from 6 to 8 inches high. The second application should be made from 2 to 3 weeks after the first.

Potato Flea Beetle

History

The potato flea beetle, because it feeds both on the foliage and the tubers, is considered the second most important pest of potatoes in Colorado. This small, jumping beetle appears in injurious numbers in the potato areas of Weld, Morgan, and El Paso Counties of the Eastern Slope, and in Mesa, Delta, and Montrose Counties of the Western Slope of Colorado. Recently the flea beetle has been reported in the potato areas of southern Colorado. Serious injury to the quality of tubers has made it necessary for the Colorado Experiment Station to study the problem.

The first records of the injurious nature of potato flea beetles in Colorado were obtained in 1904 by S. A. Johnson (7). Larvae of the beetles were observed feeding on tubers, and their damage was estimated. Work with Bordeaux sprays by Johnson (8) in 1910 was the first attempt to control flea beetles in Colorado. More recent work of Hoerner and Gillette (9), 1928, added much to the knowledge of life history and control. The present flea-beetle investigation has been continued to date since 1929 (10). Cooperation with the Colorado Potato Experiment Station, U. S. Department of Agriculture, Greeley, has made possible an intensive study of control.

Economics

Injury to potatoes from flea beetles varies with seasonal conditions. A favorable season of excessive precipitation during July and August causes an increase in the amount of "worm tracks" on tubers. Abundant moisture is necessary to the welfare of growing flea-beetle larvae. The injury by the larvae in eating through epidermal layers of tubers under conditions of high moisture allows soil organisms (10) to enter, materially increasing the damage. Flea beetles and potato diseases occur in a most injurious combination. Injury from flea beetles allows scab and other organisms to enter the tubers through the injured skin, where they combine to cause serious roughness and discoloration, affecting quality and marketability of potatoes. Because larval injury and disease go more or less together, the importance of flea beetles is increased.

Johnson (7) estimated that flea-beetle larvae cause a financial loss to growers of Colorado of $250,000 annually. In 1931 it was estimated that the loss amounted to $436,603 (10). In years of more serious infestation the damage will run much higher.

Biology and Habits

There are several flea beetles that feed upon potatoes in this state. The common form is the potato flea beetle (*Epitrix cucumeris* Harris.) The striped flea beetle (*Systena taeniata* Say) occasionally occurs in large numbers. It is marked by distinct white horizontal stripes on a background of black and is much larger and less common than the potato flea beetles. The western potato flea beetle (*Epitrix parvula* Fab.) occurs in Colorado on the Western Slope. It is very similar to the Eastern Slope species in size and form. The two forms are so closely related that to distinguish them would require the services of an expert. However, geographical distribution serves to designate the species for the present. All flea beetles belong to the same family (Chrysomelidae) and are characterized by having the hind pair of legs modified for jumping.

Description and Stages

ADULT.—The body of the potato flea beetle is oval and small, measuring 1/16 inch in length. The color is a dense black, with the legs and antennae of a lighter brown shade. The surface is covered with a rather dense growth of short hairs.

EGGS.—The eggs are so small that they are difficult to see with the unaided eye. These small, rather elongated eggs are of a pearly white color and about 1/20 inch in length. Under a lens the surfaces are somewhat marked by pits and lines which give the eggs a characteristic appearance.

LARVA.—The larval forms are rather slender, white, delicate-bodied worms varying in length with the stage of development. The newly hatched form is about 1/50 inch in length. When the larvae reach maturity they are about 1/6 inch in length.

PUPA.—The pupa is white and about the size of the adult, being 1/10 inch in length and resembling the adult in form.

Life History

Flea beetles make their appearance from hibernation late in May and early in June. They begin the early season activities by feeding on available wild solanums and various early garden crops. Mating takes place and egg laying begins and continues over a period of from 6 to 8 weeks. The females go into the soil around the base of the plant to a depth of an inch or more to lay their eggs. The average female lays about 100 eggs. Moisture is the vital factor in incubation and larval development. Dry soil conditions cause a high mortality in eggs and larvae.

The eggs under favorable conditions hatch within a week into the larval form. The small, delicate-bodied worm crawls onto the roots of the host plant and begins to feed. As the larva

grows and becomes stronger it goes deeper into the soil to a depth of 5 or 6 inches, where it feeds upon the developing tubers. Moisture conditions in the vicinity of tubers grown under irrigation are ideal for larval growth and development. Feeding takes place over a period of from 3 to 4 weeks. After maturity is reached the larva makes a small cell in the soil and transforms into the pupa. The pupal or resting stage lasts a little over a week, when the adult flea beetles begin to crawl to the surface. The newly emerged adult is a light brown color, and as bright sunlight strikes the body the brown changes into the jet black of the mature forms.

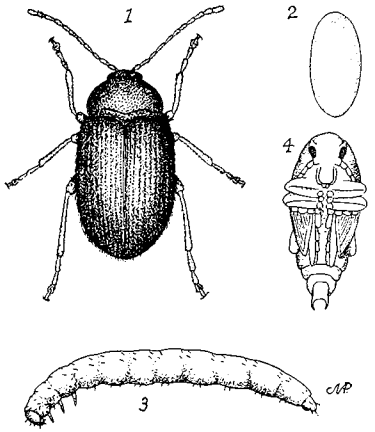

Figure 7—Potato flea beetle (*Epitrix cucumeris* Harris): (1) adult, magnified 18 times; (2) eggs, magnified 30 times; (3) larva, magnified 9 times; (4) pupa, magnified 18 times.

The time necessary for the flea beetle to pass through its life history from egg to adult varies with conditions in the soil. The average period is 6 weeks, but it may be extended to 8 or 9 weeks. There is ordinarily only one brood, but in a favorable year a second brood may occur. Years of a second brood are especially serious, since the larvae feed on the more mature tubers, thus allowing greater numbers of soil organisms to enter and making the tubers very rough.

FEEDING HABITS.—Both the larval forms of flea beetles have mandibulate or chewing mouth parts. The adults feed upon the leaves and foliage, making small round holes. Frequently the injury becomes so serious that it affects the growth of the plant. When this occurs the yield is affected. However, flea beetles do not often become this abundant in Colorado.

The larvae are the most destructive. The young forms begin by feeding on the delicate parts of the roots. As they continue to grow they feed on the corky epidermis in a rather serpentine fashion, making the so-called worm tracks. The more mature larvae have a tendency to go deeper into the potato, often to ¼ inch. Pits thus made are especially bad from the viewpoint of disease, as the flea-beetle larvae inoculate potato tubers with scab, and the infection is carried deep into the tissue of the tuber.

Control of flea beetles lowers the amount of disease on the tubers to some extent. Feeding habits determine the type of control required. It has been necessary to obtain a spray that

will kill the adults as they feed on the foliage and to determine by experiment the proper time of application to reduce the number of larvae that feed during the tuber-forming period.

OVERWINTERING.—Hibernation of flea beetles has been studied in Colorado by Hoerner (9). More recent experimental work has demonstrated that the adults go into the soil to overwinter. Considerable evidence has been accumulated to show that the mature larvae pupating in the fall remain in this condition for some time and pass into the pupal form during the winter. Adults emerging in the fall apparently burrow into the soil to a depth of 4 or 5 inches or more. Experiments with adults have shown that those exposed on the surface in plant debris die during the winter, while those placed at depths of 6 or 12 inches survive. Because of hibernation in the soil there is little that can be done toward extermination at this period other than to burn the vines as soon as possible after digging is completed.

MIGRATION.—It has been demonstrated by experiments that potato flea beetles migrate. In the early part of the season they are found feeding on available host plants, such as early potatoes, radishes, cabbage, and ground cherries. As the late potatoes appear there is a very definite migration into the fields. Very high populations occur on small patches of potatoes and ground cherries at the beginning of the season. A decrease in numbers has been observed as soon as the late plantings of potatoes are available. Flea beetles in their movements fly low, from 2 to 4 feet from the ground, having a tendency to follow prevailing winds as much as possible. Their ability to jump undoubtedly aids them in migration.

HOST PLANTS.—Host plants of the potato flea beetle adults are varied. The beetles are quite general feeders early in the spring, and as the season advances they become more selective. Early season feeding seems to favor the crucifers, such as cabbage, radishes, and turnips. The flea beetles may become quite serious pests in early cabbage fields, where frequently they require control. By mid-season they confine their depredations largely to the members of the potato family (Solanaceae), cultivated and wild. Among the cultivated forms potato, tomato, peppers, eggplant, petunias, and ground cherries are injured. Native hosts include all the common wild solanums. The several species of ground cherry (Physalis) and nightshade (Solanum) are fed upon by the adults. Buffalo-bur (*Androcera rostrata* Rydb.), an annual, serves as a host plant wherever it grows.

Host plants of the larvae require further study. The potato, because of its economic value, has received the greatest attention. There are other plants which serve as food for the larvae. The ground cherries are known to support a large number of flea-beetle larvae on their roots. Examination of soil from around

buffalo-bur and nightshade has indicated in various seasons an abundance of flea-beetle larvae. Weeds such as these serve as breeding plants for flea beetles and should be eliminated.

Control

History

In 1910 Johnson (8) used Bordeaux spray as a control for flea beetles in Weld County, Colo. Later Hoerner (9) recommended the use of calcium-arsenate spray, 3 pounds to 150 gallons. In 1933 Daniels (10) advised the use of calcium-arsenate dust, 1 pound to 8 pounds of hydrated lime, and a zinc-arsenite spray, 2 pounds to 100 gallons of water. The studies up to the present on control of flea beetle in Colorado indicate that zinc-arsenite spray is the most satisfactory. The fact that potato growers are having to spray for psyllids makes it advisable to combine the lime-sulfur spray for psyllid with the zinc-arsenite spray for flea beetles. A series of tests started in 1932 and carried to date has shown that this may be done with excellent results.

Spraying

Control of flea beetles, like control of psyllids, demands application of materials carefully and thoroughly at the proper time. Foilage of plants must receive coverage on both the upper and lower surfaces. To obtain the desired coverage it is necessary to have equipment that will develop pressures adequate to deliver material to thoroughly cover the foliage.

To obtain maximum protection against the feeding of flea-beetle larvae on tubers, sprays or dusts must be applied very soon after tuber setting begins. It is necessary to obtain control of the egg-laying females at the time the tubers begin to form, since it is the larvae from the eggs laid by these females that are responsible for heavy damage late in the season. Tuber-forming and growth periods must be considered by the grower in order to time sprays properly for control of flea beetles (fig. 6). Ordinarily, the first application on late potatoes is made during the first and second weeks in July, since this allows about 2 weeks for the spray to reduce the number of adult flea beetles in the field before tuber setting has reached an advanced stage.

The time required for eggs to hatch and larvae to develop to the stage where they are a menace is about 3 weeks. The larvae in their late stages of growth do the heaviest damage. The entire objective in spraying for flea beetles in Colorado is to reduce the adult flea-beetle population at mid-season, so that as few larvae as possible will be in the soil during the time the tubers are forming and growing.

The time of the second application of spray depends entirely

on the efficiency of the first spray and the weather which followed the first application. The efficiency of the first spray in killing and reducing the population is determined by the relative abundance of adult flea beetles observed 2 or 3 days after spraying. If the plants have been thoroughly sprayed, adult flea beetles will be reduced in numbers. Weather conditions are always factors in spray programs. Wet weather reduces effectiveness of the spray. Under dry conditions an arsenite spray will remain active for several weeks. The second spray is ordinarily applied about 2 or 3 weeks after the first.

Liquid sprays, because of their general use and the fact that spray equipment is available, are more acceptable to the grower than dust controls. The solution recommended for flea-beetle control consists of 2 pounds of zinc-arsenite diluted in 50 gallons of water. Zinc-arsenite mixes well and forms a satisfactory solution. It should be mixed with water before pouring into the spray tank. Lumps and foreign material may be eliminated by allowing the solution to pass through a screen before entering the tank. A good grade of zinc-arsenite should have very little foreign material in it.

This spray is ordinarily applied at the rate of from 100 to 125 gallons per acre. Where vine growth is heavy these amounts are adequate, but in cases where plants are from 6 to 8 inches high there may be some waste. The amount applied may be controlled by adjusting the pressure of the sprayer and controlling the speed of the team or tractor.

Dusting

In dusting for the flea beetle on potatoes, a mechanical duster, power or traction, is needed. The duster should be equipped with a self-mixer, so that it will not be necessary to do the extra handling which is necessary in equipment built without mixing attachments.

Calcium arsenate, mixed at the rate of 1 pound to 8 pounds of hydrated lime, has been found to be the most effective and economical dust to use for controlling the flea beetle. Applied at the rate of from 25 to 30 pounds per acre, with suitable equipment, it will afford control.

A most satisfactory dust material for control of the flea beetle on potatoes is available in commercial mixtures of cryolite, one of the natural fluo-silicate compounds. Several reliable companies are putting this dust on the market. However, the cost makes its use prohibitive in commercial potato growing. The dust is applied with a mechanical duster at the rate of from 10 to 15 pounds per acre.

Combination Spray

The Colorado Experiment Station has been successful in

controlling the three major insect pests by use of a combination spray consisting of 1 gallon of liquid lime-sulfur, 2 pounds of zinc arsenite, and 40 gallons of water. This concentration has been found to work admirably in areas in Weld and Morgan Counties, where the psyllid, flea beetle, and Colorado potato beetle are seriously injurious to potatoes. The spray has been used since 1934 in experimental tests. Its extensive use in 1936 and 1937 by growers has added further to knowledge of its value to the potato industry of the state.

Commercial growers make the first application when plants are from 6 to 8 inches high. The first application completely controls the Colorado potato beetle, psyllids present are either killed or repelled from the plants, and migrating beetles which are arriving are kept under control. The greatest numbers of flea beetles appear later in the season; consequently, second and third applications of spray are necessary.

Because it is less expensive, calcium arsenate has been used instead of zinc arsenite by some growers. Results of use of calcium arsenate spray show some control, but it is not usually as complete as in the case of zinc arsenite.

Summary

1. Flea beetles have caused annual loss in northeastern Colorado of $436,603.

2. The larval forms are responsible for the heaviest damage.

3. The average length of the life cycle is 6 weeks.

4. There is ordinarily only one brood; however, in a favorable season there are two.

5. Flea beetles overwinter in the soil.

6. There are local migrations of flea beetles from one field to another.

7. All native wild members of the potato family, as well as other weeds, serve as host plants to the adult beetles. Ground cherries and buffalo-bur are known to serve as hosts to the larvae.

8. Control consists of applying to the foliage of the potato plants a solution of 2 pounds of zinc arsenite to 50 gallons of water. A thorough spraying is required.

9. A combination spray of 2 pounds of zinc arsenite, 1 gallon of lime-sulfur, and 40 gallons of water will control psyllids, flea beetles, and Colorado potato beetles.

Colorado Potato Beetle

History

This pest, known since potato culture was first begun in the state, has occupied a position of considerable importance as a potato pest. The name "Colorado potato beetle" was given to it from the beginning, because it was first found in Colorado Territory. The insect was recorded and described by Thomas Say in 1824. From this early date there began a movement of this insect from the western plains through the United States. Cultivation of potatoes made it possible for the insect to distribute itself through the country. It became one of the most important insect pests to potato growers. Paris green was found to kill it, and although a factor in potato production, it does not at present occupy the important position as a pest that it held in the past.

Economics

Injury to the potato crop by this insect is difficult to determine, since in sections where it is a major pest the fields are sprayed annually. The best way to arrive at a value would be to consider the amount spent annually for control in the state. In 1928 some 10,000 acres of potatoes in eastern Colorado were sprayed for Colorado potato beetle with paris green costing from 35 to 40 cents per pound. The amount of material sprayed to the acre varied from 2 to 6 or 8 pounds. Such a practice is faulty, it is true, but a number of instances have been observed during different seasons where these extremes were actually the case. The average of 3 pounds would make the cost of material $1.05 per acre. The cost of materials for the section of the state would run well over $10,500. This does not include spraying equipment, time, labor, etc. There is little doubt that in a year favorable to the Colorado potato beetle the early potato crop and much of the late crop would be damaged to an extent of several thousand dollars if fields were not sprayed.

Biology and Habits

Descriptions and Stages

ADULT.—The adult beetle, called the potato bug, potato beetle, or Colorado potato beetle, belongs to the family of leaf-eating beetles, the Chrysomelidae. Its scientific name is *Leptinotarsa decemlineata* Say. The adult form is a stout, oval, convex beetle ⅜ inch long and ¼ inch wide. The black and yellow lines, five on each wing cover and running lengthwise, are characteristic. The adults have mandibulate or chewing mouth parts.

EGGS.—The eggs are orange-yellow, laid in masses of 10 to 12 on the under sides of leaves. They are readily observed with the naked eye.

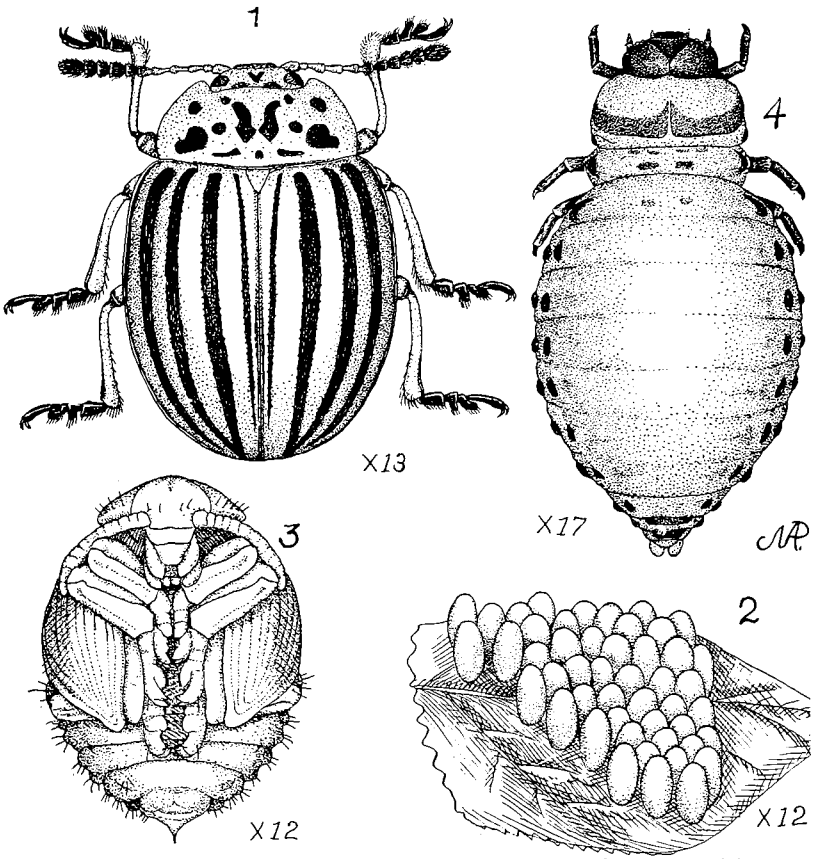

Figure 8—Colorado potato beetle (*Leptinotarsa decemlineata* Say): (1) adult, (2) egg mass, (3) larva, (4) pupa.

LARVA.—The small, newly hatched larval forms are of a dark-red color. As they grow and increase in size the color changes to orange. Along each side are two conspicuous rows of black spots which, with the black head on the orange-colored body, make a striking contrast. Mouth parts of the larvae are for chewing.

PUPA.—The pupa found in the soil is about 3/8 inch in length and a yellowish-orange in color. The legs and wings are encased in a pupal skin.

Life History

The adult beetles overwinter in the soil, going to depths of 10 or 12 inches. The depth to which they may go is more or less controlled by the frost line. In the spring they crawl to the surface. In late April and May they begin feeding on their available host plants, the ground cherries and potatoes. Early plantings of potatoes are seriously damaged by the emerging beetles.

Mating and egg laying begin soon after the beetles emerge. The females lay several batches of eggs over a period of several weeks. Eggs usually are laid on the under sides of leaves, where they are protected from direct sunlight. Each female lays about 300 eggs. At first the eggs are a brilliant yellow color, and as they advance towards incubation they become much darker.

The newly hatched larvae are very small and are usually observed feeding in the vicinity of the empty egg shells. Feeding begins very soon after hatching. In about 3 or 4 days the second stage of growth begins. The larvae in the second stage are larger and more active, although they remain red in color. This stage lasts for another 3 or 4 days, when a moult takes place and the third stage appears. The dark color changes to a reddish-orange.

The fourth stage is a decided orange color. The body has become greatly enlarged, from 60 to 70 times the size of the newly hatched larva. During larval development, which may last from 12 to 18 days, growth is rapid. To have such rapid growth, large quantities of food must be consumed. As maturity approaches the larvae become sluggish in their movements. They descend from the plant, crawling into a suitable crack or burrowing into soil to a depth of about 2½ inches, where they pupate. Transformation requires 10 days or 2 weeks, after which new adults may be seen emerging from the soil. The entire life cycle from egg to adult takes place in about 30 days. Since the eggs are laid over a period of several weeks, the first generation extends over a period of 2 months and the second generation up until the late harvest begins. There is a very definite first generation in Colorado, the second being only partial in most years.

FEEDING.—Both larvae and adult Colorado potato beetles have mandibulate or chewing mouth parts. The mouth parts are strong, suitable for shearing and crushing the delicate tissues of the leaf. Food requirements of the developing larvae make them feed extensively, devouring all the leaf, with the exception of the heavier midribs and stems. The young larvae have a tendency to skeletonize the leaf, while the older, more mature larvae eat the leaf more completely.

The adults, particularly the newly emerged, overwintering forms, feed extensively. Early plantings of potatoes are severely injured by both adults and larvae. The initial attack comes when the plants are 4 or 5 inches high, and plants may be completely destroyed at this stage if control is withheld. The late plantings escape the depredations of this insect. Abundant host plants and unfavorable mid-season conditions for development of the Colorado potato beetle result in reducing injury to the late crop.

OVERWINTERING.—Hibernation of Colorado potato beetles is complete. They burrow well into the soil, below the frost line, where they remain until spring. A light soil with good drainage

appears important in successful overwintering of Colorado potato beetles. Heavy soils with poor drainage are fatal to the insect. Irregular distribution in the state seems to coincide with variations in soil types and with variations in conditions for overwintering.

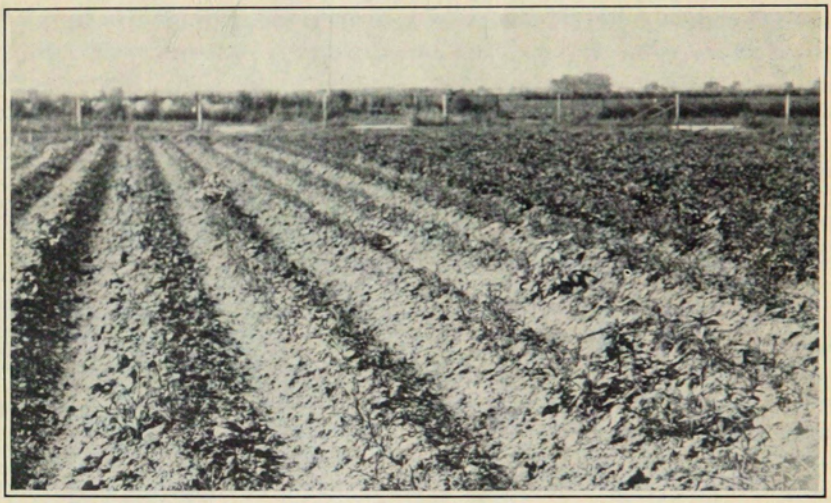

Figure 9—A field near Peckham, Colo., seriously injured by Colorado potato beetle. The plants are entirely defoliated. The rows to the right were sprayed with calcium arsenate spray.

HOST PLANTS.—Several common solanums serve as host plants to these insects. The most widely distributed and probably the preferred host plant is the spiny arid annual, the buffalo-bur (*Androsera rostrata* Rhyd.). This plant is widely distributed and is quite generally infested with Colorado potato beetles. The ground cherries serve as host plants in the early part of the season.

Control

Use of paris green as a control for Colorado potato beetles was recommended in 1854 and has been generally used for the past 60 years. It has become the common farm practice to spray potatoes with paris green. The familiar green poison finds a place in every intelligent farmer's list of necessary materials. A dilution of from 1 to 2 pounds of paris green to 50 gallons of water will kill the adults and larvae when applied properly to the foliage.

The use of zinc arsenite in the proportion of 2 pounds to 50 gallons of water will control the Colorado potato beetle in this state. Use of the combination spray, 1 gallon of liquid lime-sulfur, 2 pounds of zinc arsenite, and 40 gallons of water, is adequate for psyllids, flea beetles, and Colorado potato beetles.

Summary

1. The Colorado potato beetle is the earliest known potato pest.
2. Both adults and larvae feed upon foliage of potato plants.
3. Early plantings are most seriously injured.
4. The life history requires about 30 days.
5. The beetle feeds quite generally on solanums.
6. Control of the Colorado potato beetle may be obtained by using paris green, 1 pound to 50 gallons of water; or zinc arsenite, 2 pounds to 50 gallons of water; or the combination spray, 2 pounds of zinc arsenite, 1 gallon of liquid lime-sulfur, and 40 gallons of water.

Sprayers and Dusters

The advent of various new and more efficient methods of insect control has brought to the grower highly specialized equipment which is more thorough and effective in its operation in controlling insects. The psyllid and flea-beetle problems have brought into use the powered and high-pressure sprayer.

Many failures in insect control experienced by growers in the past have been due to large extent to methods of application. Low-pressure traction equipment is inadequate to cover the plants completely and to such an extent that complete control is obtained. It has been a common practice to increase the concen-

Figure 10—A low-pressure traction sprayer in operation. This type of machine is being replaced by the power sprayer in controlling potato insects.

trations unreasonably in the hope that low-pressure equipment would be effective. The lower concentrations when properly applied to all the foliage of a beet or potato plant will give good control. A machine that will develop sufficient pressure and deliver adequate material to cover all the foliage is an important requirement.

Dusting and spraying machinery is finding a very important place in the fields of various crops in the state. Growers of truck crops such as celery, lettuce, and cauliflower, and of field crops such as potatoes and beets, are finding that their success depends upon how well they can control injurious insects. It has seemed advisable to include in this bulletin information on dusters and sprayers, that growers may know what equipment to purchase.

The size of the machine, whether it be duster or sprayer, depends upon the acreage of the fields to be treated, the type of crop, and the method of control to be used.

Dusters and sprayers may be divided into two well-defined groups: the small garden equipment and the crop, orchard, or field equipment. Information on the former class of equipment has been widely distributed. Seed stores, hardware stores, poultry-supply houses, and other merchandising establishments handle this type of equipment. Dissemination of information on the smaller type of equipment is quite general, and it has no place in a bulletin of this kind. Field equipment has not been so

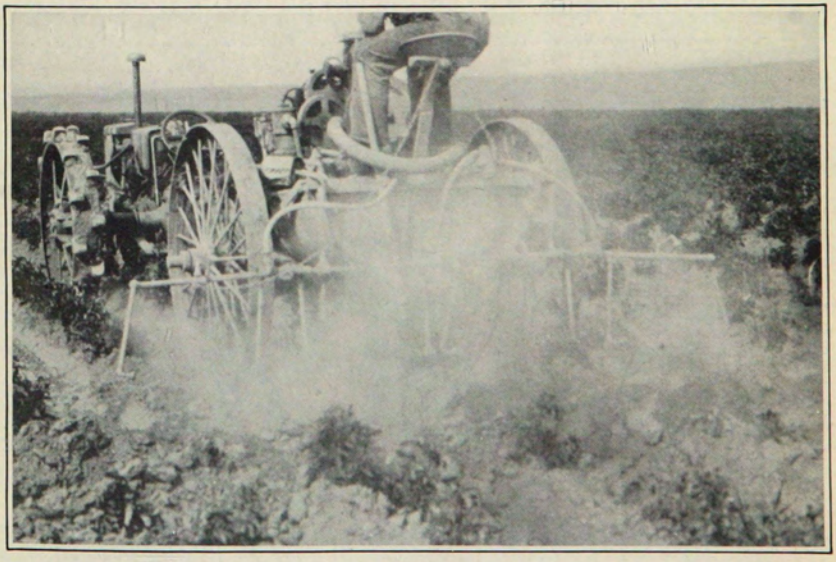

Figure 11—Power sprayer being pulled by a tractor near Mesita, Colo. This is a good example of the larger type of equipment being used in Colorado. Such a machine is more efficient and economical than the low-pressure sprayer pictured in figure 10.

generally advertised, and many growers are having their first experiences with crop dusters and sprayers.

Crop Dusters

The power or traction duster has had limited use in Colorado, that use being confined to the more specialized crops, such as lettuce, cucumbers, celery, onions, and cauliflower. The insecticides are applied in a diluted dust by means of the duster machine, which varies in construction, depending upon its manufacturer. The machines are all similar in principle, each consisting of a hopper into which mixed or unmixed materials are placed, an agitator, a feed to control the amount of dust going into the air blast, a fan, and a boom with flexible conduits and nozzles to direct the dust upon the plants. The fan and agitator are driven either by traction from the wheels or by gasoline motor.

Dusters are very practical and most efficient for the control of cabbage loopers (*Autographa brassicae* Riley), cabbage worms (*Pieris rapae* Linn.), flea beetles spp., and aphid spp. Dusts are especially advantageous where contact insecticides such as tobacco, pyrethrum, rotenone, and other "non-poisonous" controls are required. These materials can be used more effectively when applied as dusts.

In potato growing the duster may be used very successfully in control of flea beetles. Use of calcium arsenate and fluosilicate

Figure 12—A power duster at work in experimental plots at the Colorado Potato Experiment Station, Greeley, Colo.

dusts (10) has been found very satisfactory. Power dusters seem to have little advantage over the traction type, except possibly in the mixing. Most dusters are light, since dust mixtures are not so heavy as are the water solutions for sprays, and consequently, the disadvantages of traction sprayers do not apply to traction dusters. Ordinarily, there is sufficient traction, even under irrigated conditions, to power this equipment. Power requirements of dusters are not nearly so great as those of sprayers. Care of the duster is quite simple. Lubrication and keeping the equipment dry are the most important considerations. Most dusts absorb moisture from the air, if allowed to stand. If the machine is not cleaned after operation, there is a tendency for dust mixtures left in the hopper to cake, often causing trouble. It is always advisable to remove extra material from the machine before allowing it to stand or before putting it in storage for winter. Cleaning metal conduits is especially important. The use of a wooden bludgeon is often required to jar loose the cake along the sides of the conduits. The cake may affect the efficiency of the machine. Dusters should be stored for the winter in the driest part of the machine shed.

Sprayers

Commercial Equipment

Crop sprayers are not of recent development, and because of experiences with beet webworms Colorado growers have considerable knowledge about this type of equipment. The beet sprayer is a traction machine developing low pressures adequate for con-

Figure 13—Drifting cloud of dust, indicating satisfactory dusting conditions for controlling potato flea beetle.

trol of webworm. However, sprayers of this type are not suitable for insect control on potatoes; consequently, the more efficient, powered, high-pressure sprayers have become important implements to potato growers. This expensive specialized machinery is new to most farmers, and it seems important to outline the points that should be considered in the purchase, use, and care of this type of equipment.

In purchasing a sprayer that will meet requirements of the average potato grower in the state, several points must be considered. First, the machine should be sturdy and well built, but not too heavy. Irrigated fields, because of their corrugated condition, are extremely wearing on equipment. Second, the grower must decide between traction and power types of sprayer.

Traction sprayers under irrigated conditions are at times impracticable. To obtain the power needed to maintain a constant high pressure is difficult when the rows are moderately wet. The machine powered by its own motor is very efficient and is the most satisfactory machine for the average grower. It has the advantage of being more economical in operation and valuable as a complete unit for extra farm work. A farmer may use it in orchard spraying, car washing, or barn or poultry house spraying.

The machine used on a tractor and powered from the tractor

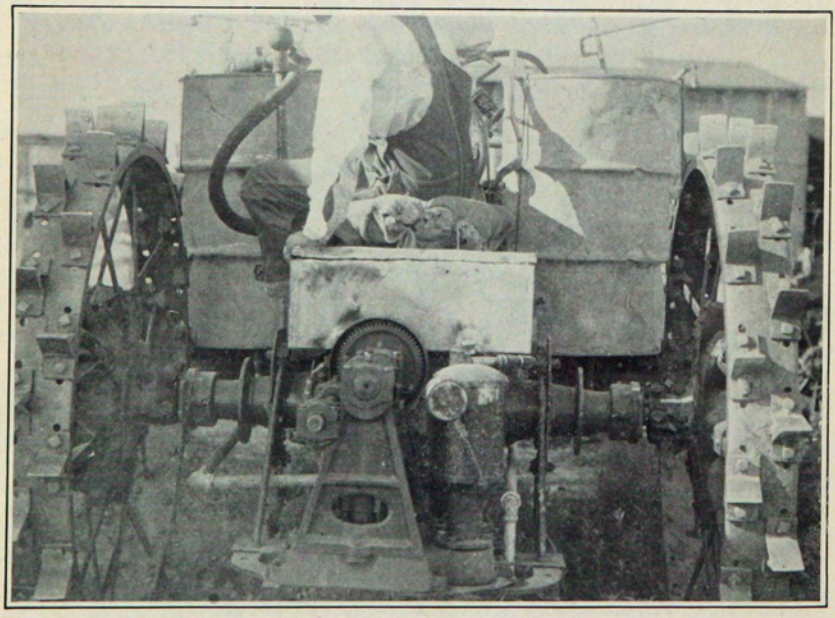

Figure 14—A sprayer built on a tractor for controlling a serious outbreak of psyllids near Mesita, Colo., in 1933. The pump was placed at the rear and driven direct from the power "take off."

has a number of enthusiastic users. The sprayer consists of the tank and chassis and pumps which are powered from the "take off" on the tractor. Such units are often larger, having six-row booms, 150- to 200-gallon tanks, and larger pumps, which makes it possible to spray larger acreages very efficiently in less time. Growers who own tractors can save money by purchasing the sprayer adapted for the tractor.

Third, mechanical construction of the sprayer needs close attention. Construction of the pump should be carefully considered. Capacity, the amount of material delivered per minute, should be given serious attention. Delivery should be adequate for the boom. To obtain the most satisfactory coverage with a four-row boom on potato plants two-thirds grown, a pressure of from 250 to 300 pounds should be maintained, and pumps should be delivering from 10 to 12 gallons per minute. To spray six rows, the delivery should be from 16 to 18 gallons per minute. Pressure is important, since all the foliage must be covered to obtain the best results. Pressures from 250 to 300 pounds are the most satisfactory. The machine should not have to labor to produce these pressures.

The average grower buys a machine with the intention of using it over a period of years. Parts which wear on the sprayer are the pumps, the bearings, the valves, the filter screens, and the discs. Pumps should be of such construction that they will stand up under the high pressures necessary. Bearings should be of construction and material adequate to withstand the effects of grit and sand which are a menace in spraying under field con-

Figure 15—A front view of the sprayer shown in figure 14, showing the six-row boom.

ditions. Valves, filter screens, and discs receive a great deal of abuse when ditch water is used for spraying. Discs wear out in a short time; frequently a day's run of 12 hours will enlarge disc openings until they are uneconomical and wasteful. Filter screens corrode and wear out in about a season and should be renewed. Adequate filtering, effective sediment wells, and additional screening are distinct advantages in any machine. Machines without adequate sediment wells give a great deal of trouble, necessitating frequent stops to wash and clean the nozzles.

The life of a sprayer depends upon its original construction and the care it receives after purchase. The average well-built machine has all the essential features of good construction and with reasonable care can be depended upon to remain in operation for a long time. The careful and thrifty farmer will realize that a good sprayer must be properly cared for during the winter. Protect it by draining, ascertaining that all parts are well lubricated to prevent rusting. Loosen the valve covers, pour old crankcase oil into the valve chambers, and remove the nozzles. Metal parts of the nozzles should be placed in oil to prevent corrosion.

Home-Made Equipment

A number of ingenious farmers during the past few years have constructed sprayers. Some machines have been built at very small cost and have served quite successfully in saving potato crops. Most of the growers were hard pressed financially or had such small acreages that it would not be economical to

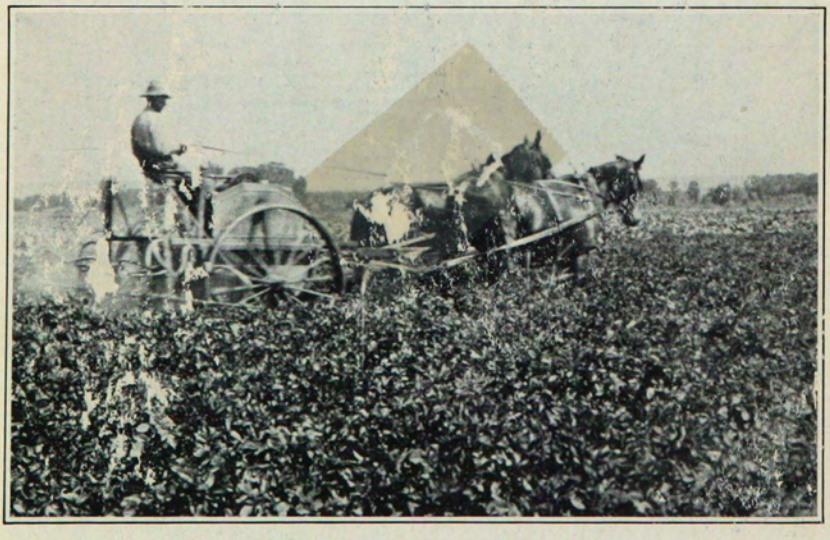

Figure 16—A four-row power sprayer in the San Luis Valley doing a good job of spraying. The foliage in this field was very heavy, but with high pressures and sufficient delivery capacity the field was thoroughly sprayed and psyllids were controlled.

purchase a machine, so they did the next best thing and constructed sprayers to meet the emergency.

Machines made were of two types: large tractor sprayers and small one-row sprayers. The larger sprayers were built around tractors. Pumps were mounted at the back end or on the side, and power obtained from the tractor. The tanks consisted in most cases of 55-gallon oil barrels, two or four of which were mounted on the sides of the tractor. No agitators were used, since they are hardly necessary when lime-sulfur is used. The boom was mounted on the front of the tractor, being manipulated by elevators worked from the driver's position. The outfits were equipped with four- and six-row booms.

Construction of this type of sprayer involves the purchase of a pump, material for a boom, and barrels for solutions. Separate pumps can be purchased from any reliable sprayer company for a price very much less than that of the complete sprayer. In these cases growers have obtained pumps of larger capacities, capable of developing higher pressures, with the advantage of doing more efficient and thorough spraying than was possible with the regular horse-drawn sprayers.

The booms were made according to plans furnished by the Colorado Experiment Station and can be made by the grower at a cost of about $40. Growers interested in construction of their own booms can obtain blueprints by writing to the station.

Several growers in the state have resorted to the small, one-

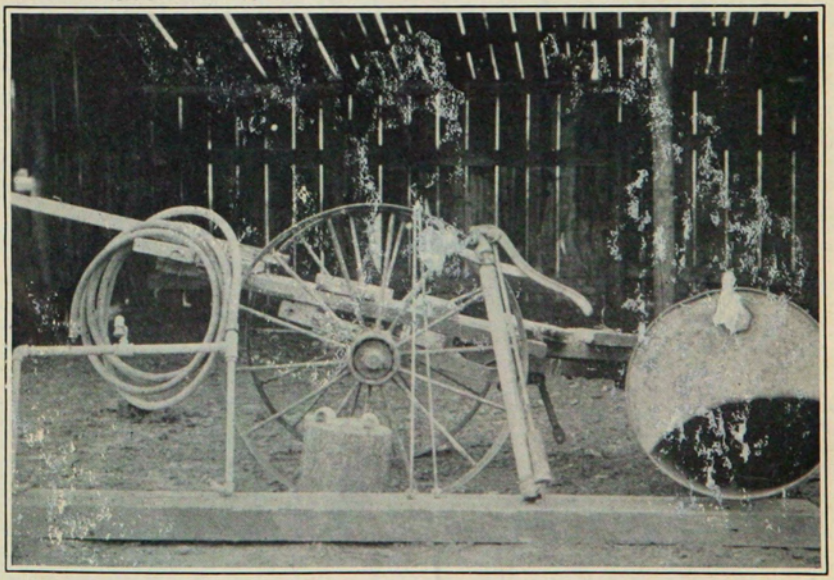

Figure 17—Parts of a home-made sprayer used by Fred Hermann near San Acacio, Colo. This machine, simple in construction, aided materially in saving a potato crop.

row sprayers. Small hand-sprayer pumps were purchased from hardware stores, seed dealers, or mail-order houses. The type ordinarily purchased was the barrel sprayer pump, simple in construction and capable of developing from 85 to 100 pounds pressure.

The spray tank consisted of a 55-gallon barrel into which the pump was inserted; the whole was mounted on a two-wheeled cart drawn by a team. A spray hose from 15 to 20 feet long was wound around the barrel and connected to the one-row boom at the rear end. The length of hose aided in maintaining constant pressure as the operator worked the pumps while the machine was driven through the field.

It is significant that these machines are makeshift affairs, constructed only to prevent serious loss of a paying crop. It is important that in fields sprayed by these machines a partial control was obtained, which justified their construction. Many growers with small, scattered fields through the mountainous areas of Colorado could save a great portion of their potatoes by use of such a sprayer.

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