AN EVALUATION OF A BORDER SPRAY CONTROL PROGRAM AS A PREVENTIVE MEASURE AGAINST INSECT MIGRATION FROM BORDER FIELDS TO CROP AREAS

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AN EVALUATION OF A BORDER SPRAY CONTROL PROGRAM AS A PREVENTIVE MEASURE AGAINST INSECT MIGRATION FROM BORDER FIELDS TO CROP AREAS

by

JOHN GARY BRADY

AN ABSTRACT

Submitted to the College of Science and Arts
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Entomology

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ABSTRACT

The primary purpose of this study was to determine the effectiveness of a border spray control program in preventing the movement of the potato leafhopper, *Empoasca fabae* Harris, and the six-spotted leafhopper, *Macrosteles fascifrons* (Stål), from bordering areas to cultivated crops. The arrival dates and seasonal fluctuations in populations of these leafhoppers were also determined.

A second objective of this program was the evaluation of insecticidal spray materials for control of insect pests on potatoes, carrots, beans, and celery. Thiodan and Sevin were compared with the standard DDT - parathion recommendation.

The Michigan State University Muck Experimental Farm, Clinton County, Michigan, was chosen as the location for this study. Nine sampling stations were established. Six stations were in the bordering fields, two were in the border spray area, and one was a plot inside the border which was planted to grass but was not sprayed. Beginning 10 April, 1958, and lasting for a period of twenty-three weeks, sweep-net samples were taken weekly from each of these locations. To determine the effectiveness of the border spray control program, twelve plots were chosen

inside the border on which insecticide trials were being conducted. The insecticides being tried were Thiodan, Sevin, and a combination of DDT - parathion. The insecticide trial plots included six plots of potatoes on which all three materials were being applied on one or more plots, two plots of celery on which DDT - parathion and Sevin were used, two carrot plots on which these same two materials were used, and two plots of beans on which Thiodan and Sevin were applied.

The results were as follows:

1. The first potato leafhopper was collected on 8 May, 1958. One specimen was taken on this date.
2. The first six-spotted leafhopper appeared in the sample taken 15 May, 1958 when two specimens were collected.
3. The border spray program proved effective in slowing the movement of *M. fascifrons* from the border fields to the cultivated areas. A total of 458 specimens were taken outside the border and 120 inside the border.
4. The border spray control program did not prove successful in preventing movement of *E. fabae* from the border fields to the crop area. A total of 89 potato leafhoppers were collected outside the border and 133 inside the border.

5. The DDT - parathion mixture was found to be the most satisfactory of the materials against the insect pests involved in this study. There were, however, indications that this mixture was not effective against adult spittlebugs on carrots.
6. Sevin at 2 pounds of 50 per cent wettable powder was effective against leafhoppers, particularly M. fascifrons. Sevin gave no control of the green peach aphid. There were indications that this material was less effective against flea beetles and spittlebug adults than the other materials.
7. Leafhopper populations were abnormally low during the entire 1958 season.
8. Thiodan at two quarts of 25 per cent emulsion was effective against all insects. Thiodan at one quart of 25 per cent emulsion did not prove effective against the green peach aphid. There were indications that this material was not as effective against E. fabae as Sevin and the DDT - parathion mixture.

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INTRODUCTION

In Michigan, the potato leafhopper, *Empoasca fabae* Harris, and the six-spotted leadhopper, *Macrosteles fascifrons* (Stål), are serious pests of many vegetable crops. The potato leafhopper, by its feeding, causes injury known variously as "tipburn" and "hopperburn." The six-spotted leafhopper transmits the virus which causes the aster yellows disease. Many of the crops grown on muck soil are important hosts of these leafhoppers.

It has been assumed that spring build-ups of populations occur in the border fields prior to attainment of sufficient growth of cultivated host plants to support insect populations. If the migrating insects could be prevented from moving from the border areas to the crops, the damage caused by their feeding could be greatly reduced. For this reason, a standard recommendation, especially in muck farming areas, has been that a border spray control program be followed.

This study was therefore undertaken to determine: (1) the effectiveness of a border spray control program in preventing movement of these insects into the crop areas, (2) the arrival dates and seasonal fluctuations in population of the potato leafhopper and the six-spotted leafhopper at the Muck Experimental Farm, (3) the effectiveness of two new insecticides, Thiodan and Sevin, as compared to the standard DDT - parathion recommendation.

LITERATURE REVIEW

General Biology

Potato Leafhopper, *Empoasca fabae* Harris.

Disagreement exists in the literature regarding the life history of the potato leafhopper, *Empoasca fabae* Harris.* In Iowa, Fenton and Hartzell (1920) conducted greenhouse experiments on the life history of *E. fabae* and compared their results with field experiments. These findings indicated that the potato leafhopper overwintered in the adult stage and became active in April. At this time the adults were found on various weeds and remained there until June. This first generation migrated to early planted potatoes where the females laid eggs on the vines. These adults died in July. The first nymphs appeared in late June and early July. By August these nymphs had matured into adults and were able to lay eggs which hatched in late August and early September. At the time of the first frost all immature stages and summer brood adults were killed. The second generation adults matured in late August but did not lay eggs. They remained on the vines until frost. These adults then flew to weeds and

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* Note: for convenience, the specific name with priority, *fabae*, is used in place of *mali* when the latter was used by the author being cited.

remained there until the weeds were frosted at which time they entered hibernation. In April and May, 1919, *E. fabae* was found on common yellow dock, *Rumex crispus* L., which seemed to be the preferred host. Potted potato plants were placed among the weeds but were not infested by the leafhoppers. On the morning of 6 July, 1919, the leafhoppers suddenly left the weeds and migrated to early planted potatoes. Fenton and Hartzell deduced that this sudden migration was correlated with temperature and humidity as well as sexual maturity of the insects. Ripe eggs were found for the first time following this migration. In addition to this spring migration there was a summer migration from early-planted to late-planted potatoes. This second migration differed from the first flight in that it occurred over a longer period of time.

In order to determine whether a complete generation could be reared on some of the plants on which *E. fabae* had been found, Hartzell (1921) conducted experiments using curly dock, Carolina poplar, pigweed, and broadleaf plantain. All of these plants gave negative results except curly dock which produced a complete generation. Hartzell stated the potato leafhopper had been bred on apple, bean, and potato. De Long (1928) found that *E. fabae* was able to complete its life cycle on a number of wild and cultivated plants. Included among these hosts were common dock, bean, potato, egg plant, rhubarb, clover, alfalfa, apple, and several ornamentals. In Ohio, bush bean appeared to be the preferred early host. Eggs were laid as early as 20 May on beans. The adults migrated to potato about a month later. In 1926 and 1927, DeLong found four distinct generations. One mating was sufficient for the life of a female.

Smith (1931) studied the feeding habits of some leafhoppers of the genus Empoasca. When E. fabae was confined on tender stems and petioles, wilting of the plant parts above the point of feeding occurred. When the leafhopper was confined to the lower surface of the leaflet, the midvein and lateral veins became lighter in color and wilting took place in one or two days. When there was less feeding, wilting did not take place but the typical symptoms of "tipburn" or of reddening or yellowing of leaves appeared after a longer period of time. Smith made microscopic examinations of sections through the leaves and found that the cells of the phloem were frequently punctured. These cells were torn and distorted or were partially or completely filled with leaf sheath material.

DeLong (1931), in studies on the distribution of the potato leafhopper, found E. fabae to be an important pest throughout the eastern and southern United States. Studies in western states showed that E. fabae occurred westward to the Rocky Mountains in Colorado. At high elevations (3500-4500 feet) it occurred in small numbers. It occurred in California, also in small numbers. In no place in the western states were populations large enough to cause economic injury. No specimens were found in the high inter-mountain area between the Rocky Mountains and the Sierra Nevadas. Three other economically important species were found to replace E. fabae in the higher altitudes and the arid regions of the west. Empoasca filamenta DeL. was abundant throughout western Colorado, Utah, Idaho, Nevada, Oregon, Wyoming, and southern Montana on potatoes, beans, and sugar beets. Two other species, E. abrupta DeL. and E. arida DeL., were found to be the most important on truck crops in California. E. abrupta obtained its greatest development on the cucurbit group of plants, especially squash, cucumber, watermelon, and cassaba and honeydew melons. Potatoes, beans, parsnips, sweet potatoes, okra, and celery were also preferred hosts. E. abrupta was found in Texas, Arizona, Oregon, and occasionally in Colorado.

Beginning in 1927, DeLong and Caldwell (1935) made attempts to find, or recover, E. fabae in winter quarters under natural conditions in Ohio. These attempts were unsuccessful. This is in disagreement with the work done in Iowa by Fenton and Hartzell. DeLong and Caldwell found the earliest records of *E. fabae* for Columbus, Ohio, were in late May with the main migration occuring in the middle of June. A detailed search in the field during the early season for a period of eight years upon all types of host plants failed to yield any positive proof that *E. fabae* overwintered in the egg stage. In view of these findings, DeLong and Caldwell concluded that in all probability the potato leafhopper passes the winter in the south. Material taken in Florida and the Gulf states showed that *E. fabae* breeds on alfalfa and similarly growing crops.

Six-spotted Leafhopper, *Macrosteles fascifrons* (Stål).*

As is the case with the potato leafhopper, there are many points concerning the life history of the six-spotted leafhopper, *Macrosteles fascifrons* (Stål), upon which there is disagreement.

One of the early studies on the life history of *M. fascifrons* was conducted by Osborn (1916). This worker found that the six-spotted leafhopper was a very widely distributed species occuring in Europe and North America

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*Note: for convenience, the name with priority, *Macrosteles fascifrons* (Stål), is used in place of *Cicadula sexnotata*, *Macrosteles sexnotata*, and *Macrosteles divisus* when the latter were used by the authors being cited.

from Alaska to Florida. In Maine, Osborn found adults of _M. fascifrons_ plentiful in late June and early July. There was a well-marked brood occuring in July. Adults were found to lay eggs in the leaf sheath and at the base of the leaf blade of oats and other grasses. There appeared to be three generations per year. One generation occurred in grasslands before 1 July. A later generation was found between 15 July and 15 August. An autumn generation occurred between 15 August and 1 October. This generation deposited eggs which overwintered. Beckwith and Hutton (1924) found adult six-spotted leafhoppers on cranberry bogs in New Jersey in May and early June. It was concluded that _M. fascifrons_ overwintered as adults. The food was not definitely determined but was believed to be grass.

Kunkel (1926) kept _M. fascifrons_ in culture for three years. These leafhoppers produced twenty-five generations. It was observed that females of one generation were still depositing eggs when females of the next generation began to deposit. The average age reached when the temperature was kept between 70 and 75 degrees Fahrenheit was about one hundred-twenty days. This age was reached when only a few leafhoppers were kept in a cage. When large numbers were kept in a cage, they lived not more than sixty days. Eggs hatched in from ten or eleven days to three weeks under ordinary greenhouse conditions. Eggs were deposited under both the lower and upper epidermis of aster leaves. Some females deposited eggs in leaf petioles and even in small branches and the main stem. The favored hosts were found by Kunkel to be aster, lettuce, sow thistle, great ragweed, daisy fleabane, English plantain, dandelion, wheat, oats, rye, barley, calendula, and daisy. Some plants which were not preferred were tobacco, potato, tomato, peach, begonia, and alsike clover.

Relying on the fact that *M. fascifrons* transmits the virus that causes aster yellows, Linn (1940) made surveys in New York state during April covering most of the weeds bordering farms. These surveys showed that the common plantain, *Plantago major* L., was the principal, if not the sole, weed that overwintered the yellows virus on Staten Island. Experiments suggested that *M. fascifrons* did not overwinter in the egg stage. Because of the presence of yellows infected plantain, it was concluded that some of the leafhoppers found in the spring should have been viruliferous if they had overwintered in the bordering weeds. Three hundred fifty adults captured in the spring were caged over lettuce seedlings in the greenhouse. At the end of five weeks none of these plants had developed symptoms of yellows. This indicated that none of the leafhoppers were viruliferous when they first appeared and none of these individuals had fed on diseased weeds prior to collection.

Hervey and Schroeder (1947), noting the confusion in the literature as to overwintering in the northern latitudes and the question as to whether M. fascifrons overwintered in the region at all, conducted experiments designed to find the answer. In November, 1945, near Geneva, New York, large numbers of six-spotted leafhoppers were observed in a field of winter barley adjoining a carrot field that had a high population early in the summer. In March, 1946, ten clumps of barley plants were dug from this field, placed in the greenhouse and caged. Within ten days, newly hatched nymphs appeared. An average of eighty-five insects were reared to maturity from each of the ten cages. The field was again examined in late April and a few newly hatched nymphs were observed. A cage measuring four by eight feet was erected over the barley. This cage yielded 1350 adults between 13 June and 26 June. Collections made in May and June indicated nymphs on wheat, rye, barley, and grasslands. On the basis of these observations it appeared obvious that the six-spotted leafhopper overwintered in the area and strongly suggested that it must overwinter in the egg stage. No eggs were found however.

Chemical Control

Potato Leafhopper, *Empoasca fabae* Harris.

Dudley (1920) experimented with three chemicals and an entomophagous fungus to obtain control of the potato leafhopper, *Empoasca fabae* Harris. A 10 per cent kerosene emulsion was applied to Early Ohio and Green Mountain potatoes. Three applications were made with no control of the insect. Nicotine sulfate and fish oil soap gave no control with four applications. Bordeaux mixture 4-4-50 was also applied four times. This material gave no control until the middle of July. From this time on control was good. Dudley also experimented with an entomophagous fungus, *Entomophthora sphaerosperma*. Results showed that this fungus attacked both adults and nymphs and greatly reduced the population.

DeLong, Reid, and Darley (1930) experimented with copper sulfate to control *E. fabae*. Dilutions to and including 1:6500 gave a high degree of control. A wettable powder formulation of copper sulfate was used. This was mixed with a 5 per cent sugar solution or with tap or distilled water. Nymphs lived for an average of twelve days on the sugar solution and three days on tap or distilled water. The roots of bean plants were placed in different dilutions of copper sulfate solution and the leafhoppers allowed to feed. A high rate of mortality of E. fabae was observed and copper was found in the plant juices of the leaves. Other bean plants were sprayed with solutions of copper sulfate and of calcium hydroxide. Nymphs were then placed on these plants. Copper sulfate caused 50 per cent mortality while the calcium hydroxide was not toxic to E. fabae.

McDaniel (1936) used Lethane 440, Lethane dust, 4 per cent nicotine dust, Loro, and Pyrethrum "A" dust on dahlia. Of these materials, the 4 per cent nicotine dust proved to have very good repellant value but produced only very slight kill. Lethane 440 spray was found to kill by contact as was Loro. The other materials had very little or no value either as repellants or as contact poisons. None of these materials exhibited any phytotoxicity.

Lewis (1942) observed that E. fabae had become an important pest of citrus in the San Joaquin Valley of California. Injury to ripening fruit was caused by the leafhoppers puncturing the rind of the fruit causing a blemish. A whitewash composed of hydrated lime and zinc sulfate was used in an attempt to control this insect. This material was applied at the rate of 33.3 pounds of hydrated lime plus 5 pounds of zinc sulfate, 0.67 pounds of casein spreader or 1 pint fish oil per 100 gallons of spray. This material gave satisfactory control of E.

<u>fabae</u>. Lewis also found that any white dust or spray sediment discouraged the feeding of the leafhoppers.

Poos (1945) used a DDT spray of 252 grams of 10 per cent DDT in pyrophyllite added to one gallon of water, a 2 per cent DDT dust in pyrophyllite, and a pyrethrum-sulfur dust containing 0.1 per cent of pyrethrins. The spray was applied at the rate of 27 gallons per acre and the dusts at 25 pounds per acre. Two applications of each material were made. Good control of the potato leafhopper was obtained with all three insecticides. No nymphs developed in the areas where DDT was applied. The pyrethrum-sulfur dust soon lost its effectiveness and nymphs began developing within a comparatively short time.

Mitchner (1950) compared wettable powder formulations of five chemicals with calcium arsenate. These five were 50 per cent DDT, 25 per cent aldrin, 25 per cent dieldrin, 40 per cent toxaphene, and 50 per cent chlordane. The rates per fifty gallons water in actual material were 24 ounces chlordane, 2 and 1 ounces aldrin, 2 and 1 ounces dieldrin, and 8 and 4 ounces toxaphene. The plots were sprayed on 30 June at the rate of 72.5 gallons per acre and on 27 July at 145 gallons per acre. The amount of spray was doubled for the second application because of the increase in the amount of foliage to be covered. Of these insecticides, only DDT destroyed potato leafhoppers. A possible exception was toxaphene at 8 ounces which gave some control but not the complete control obtained with DDT.

Six-spotted Leafhopper, *Macrosteles fascifrons* (Stål).

Pepper and Haenseler (1939) used seven combinations of various materials in 1936. The combinations were (1) rotenone-pyrethrum-sulfur, (2) copper plus lime dust, 25-75, (3) derris marc plus sulfur, (4) derris root plus talc sulfur (0.75 per cent rotenone), (5) nicotine sulfate (1-600) plus Aresket, (6) nicotine sulfate (1-600) plus soap, and (7) Bordeaux mixture 3-5-50. Rotenone-pyrethrum-sulfur and derris root plus sulfur dusts gave a significant reduction in leafhopper nymph populations and a slight decrease in diseased plants. All the other combinations gave practically no control of the disease or of *M. fascifrons*. In 1937, Pepper and Haenseller used seven dust combinations. These were (1) pyrethrum, (2) pyrethrum plus sulfur, (3) derris root plus pyrethrum plus sulfur, (4) pyrethrum plus varying amounts of activators, (5) pyrethrum plus neutral copper, (6) pyrethrum plus 1 per cent Santomerse, and (7) derris root plus sulfur. The pyrethrin content of the pyrethrum dusts was 0.3 per cent. The rotenone content of the derris root was 0.75 per cent.

The pyrethrin-rotenone contents of the derris root plus pyrethrum plus sulfur was reduced to one-half normal. When sulfur was used, the content was 25 per cent. There were five applications made at ten-day intervals starting when the plants were approximately ten days old. The pyrethrum dusts containing sulfur, the derris root plus sulfur, and derris root plus sulfur dusts gave the best control of M. fascifrons and yellows while pyrethrum plus activator gave good control of the leafhoppers but failed to give any appreciable reduction of diseased plants.

Linn (1940) suggested the eradication of weeds bordering crop areas was perhaps the best means of control. Several herbicides were tested including sodium chlorate crystals, sodium chlorate, Atlacide, Sinox, Sinox Special, and Elgetol solutions. The results showed that sodium chlorate crystals gave the best control.

Hoffman (1952) conducted border spray experiments in 1951 using DDT, parathion, and a DDT-parathion mixture. When used as a mixture, parathion was used at one pound of 15 percent wettable powder and DDT at two pounds 50 percent wettable powder per 100 gallons of water. This mixture was applied at 25 gallons of water per acre. When used alone, parathion was mixed at 1 pound of 15 percent wettable powder per 100 gallons of water and DDT at one and one-half pints 25 percent emulsifiable concentrate per 100 gallons water. These sprays were also applied at 25 gallons per acre. Hoffman concluded that the border spray resulted in a definitely lower incidence of yellows infected plants than would have been observed had no border sprays been applied.

Chiykowski and Chapman (1958) found that DDT at two pounds per acre and parathion at one-half pound per acre gave good control of the six-spotted leafhopper when applied every three days. When the interval between sprays was increased to nine days, only DDT gave good control. Tests conducted in 1956 and 1957 indicated that malathion at one-half pound every three and one-half days gave the best control.

Insect Migration

There are, as has been presented, some gaps between the observed habits, life history, and abundance of leafhoppers. These discrepancies are at least partially resolved by a brief account of the knowledge of insect migration in general and of leafhoppers in particular.

Williams (1957) defined migration as the movement of animals in a direction and for a distance over which they have control and which results in a temporary or permanent change of habitat. The minimum distance an animal must move in order to constitute a true migration is extremely difficult to determine. By definition, a migration results in a change of habitat. What determines a change in habitat is a factor which must be arbitrarily determined by the observer. This could possibly be a few feet or many miles. There actually is no upper limit. A migration may extend up to a thousand miles or more. The number of individuals in a single movement may range from a few hundred up to thousands of millions.

Evidence that migrations of insects do occur may come from several sources. Observations of large numbers of insects flying steadily in a definite direction lends credence to the idea that insects do migrate. Shannon (1916) observed Monarch butterflies and dragonflies habitually traveling westward along the southern Long Island shore in an apparent attempt to reach the mainland and an overland route to the south. Another evidence that migrations exist is the sudden appearances of winged insects in an area where they were not known to be previously present and with no evidence of local breeding or emergence. Knight (1936) noticed Ozarkian forms arriving in central Iowa after the drought of 1930. The boxelder bug, Leptocoris trivittatus Say, and the chinch bug, Blissus leucopterus Say, which were rather scarce in the period 1925 to 1930, increased greatly in numbers during 1930. Species that were known previously as normal to the southern half of Missouri also began to appear. During this same period, Bird (1937) noted *L. trivittatus* in Manitoba where very large swarms had congregated for hibernation in the autumn. A third evidence of insect migration is the presence of flying insects at sea or on oceanic islands. Stearns and MacCreary (1938) reported a collection of leafhoppers from light traps on four lighthouses on Delaware Bay. These lighthouses had beams visible from a distance of 14.9 miles. Over a period of 144 days, 3466 specimens representing 33 genera and 50 species of leafhoppers were captured. Of this total, 106 were the potato leafhopper, *Empoasca fabae* Harris. This total included fifty males and fifty-six females. The lighthouses were at distances of three, six, nine, and ten miles from shore. At the three mile light, 37 *E. fabae* and 60.1 per cent of all the leafhoppers were taken. At six miles, 29 *E. fabae* and 26.9 per cent of the total were taken. The nine mile lighthouse yielded 23 *E. fabae* and 7.2 per cent of the total. At a distance of ten miles, 17 potato leafhoppers and 6.2 per cent of the total were captured. The other leafhoppers were, for the most part, non-economic forms. Leafhoppers were present on ninety-two of the one hundred forty-four days collections were taken. Nights on which leafhoppers were not trapped occurred usually in groups in which there was a definite interference with activity by the weather. This interference included low temperature, cloudiness, strong winds, and rainfall. Peak flights were definitely associated with the following combination of factors: a high mean temperature, a clear night, and a light to moderate wind.

Williams (1957) lists several factors as suggested external guides to orientation. Some of these factors are the sun, wind, temperature gradients, moisture, barometric pressure and the earth's magnetic field. As insects have no sense of time, the sun and moon can probably be ruled out. Insects are, however, able to perceive light and the sun would therefore have an effect as far as providing light.

Temperature has an effect on the migration of insects. Carter (1930) observed the result of a mass migration on the night of 17 September at Rocky Ford, Colorado. On the day of the flight an unusual and sudden drop in temperature of between 20 and 30 degrees F. was experienced. This caused a flight of insects, mostly Hemiptera, into the town of Rocky Ford where they covered the streets. One sample examined by Carter totaled 3,666 insects. Of this total, 3,094 were members of the family Cicadellidae.

Linn (1940), in experiments to determine the dispersion of the six-spotted leafhopper, _Macrosteles_ *fascifrons* (Stål), stated that the distance the leafhoppers jump or are carried by air currents and the frequency of jumps are determined by (1) wind velocity and direction, (2) temperature, humidity, and rainfall, (3) preference of the leafhoppers for the particular plant on which it attempts to feed, and (4) number and frequency of cultivations and overhead irrigations. In experiments with dyed leafhoppers, Linn traced the dispersal of *M. fascifrons*. Winds were from the northwest, north, and northeast for a total of 63 per cent of the test period. Seventy-four percent of the dyed leafhoppers were collected southeast, south, and southwest of the dusted area. The dye used was a dust consisting of one part methyl-violet 3B concentrated powder and nine parts wheat flour. This was applied to an area approximately three hundred square feet. Insects have been observed flying against the wind. Williams (1957) states that locusts have been observed to alter their body axis during a side gust so that their direction of movement relative to the ground was kept constant.

Smith and Allen (1932) found that the spotted cucumber beetle, *Diabrotica duodecimpunctata* Fabr., regularly migrates northward during the spring and early summer. The offspring migrate back to the south during fall with none surviving the winter north of central Missouri. No true hibernation takes place in the south.

Fulton (1940) developed a method of determining the distance the beet leafhopper, Circulifer (= Eutettix) tenellus (Baker), migrates by measuring the chloroform soluble components as a measure of the reserve energy of the leafhopper. Sex ratios of adults also proved useful in some localities since the females move farther than the males. Sweep net collections and chloroform extractives were, in general, greatest nearest the breeding area and decreased progressively with the distance from the breeding area.

Hervey and Schroeder (1947) reported a migration of the six-spotted leafhopper from a barley field, where they had evidently overwintered, to a field of carrots. These two fields were separated by a beet field 300 feet wide. The migration took place during a period from 20 May to the end of June. The approaching maturity of the barley appeared to hasten the migration. Movement of the leafhoppers from the carrots to winter grains took place in early October or as soon as these crops emerged. Adult M. fascifrons were found on wheat, barley, and rye.

PROCEDURE

Description of the Area

The Michigan State University Muck Experimental Farm is located approximately eleven miles northeast of East Lansing in Clinton County. The total area of the farm is 320 acres. Forty acres are currently being used for crop production. The outbuildings and housing for farm personnel take up six acres. One-hundred twenty acres, purchased during fiscal 1957-58, are presently being seeded to bluegrass, *Poa* spp. Before being purchased by Michigan State University, this area was used for the production of mint and corn. The remaining 154 acres are border fields and roads and are not being used for crop production. Since the Muck Experimental Farm is maintained for experimental use by Michigan State University, there is no major crop occupying a majority of the land area. The crops are not limited to those normally grown on muck soil. Included are crops indigenous to other soil types. The crops include onions, celery, cabbage, carrots, corn, sugar beets, potatoes, snap beans, soy beans, cauliflower, red beets, mint, and broccoli.

Many of the experiments are associated with fertilizer and variety trials. There are also chemical control experiments. These include disease, weed, and insect control work. In addition to this, the Muck Experimental Farm in cooperation with the Entomology Department of Michigan State University carried out an extensive border spray control program in 1958.

Methods

On 10 April, 1958, seven sampling stations were established. Of these, five were outside and two were in the border spray area. These sites were given letter designations, A through G. Stations A, B, D, E, and G were outside the border area. Stations C and F were in the border area. The approximate location of each of these stations is shown in figure 1. The plant types at each of these stations are shown in table 1. A total of twenty-three weekly samples were taken from each of these stations beginning 10 April, 1958, and continuing until 11 September, 1958. All of these locations, except stations A and C, were on level terrain.

Stations A and C were on ditch banks. Station A was located at the extreme southeast corner of the new section of the farm on the bank of a drainage ditch. Station B was located in an open field approximately midway between station A and section A of the farm. Station C was on the bank of a drainage ditch which runs north and

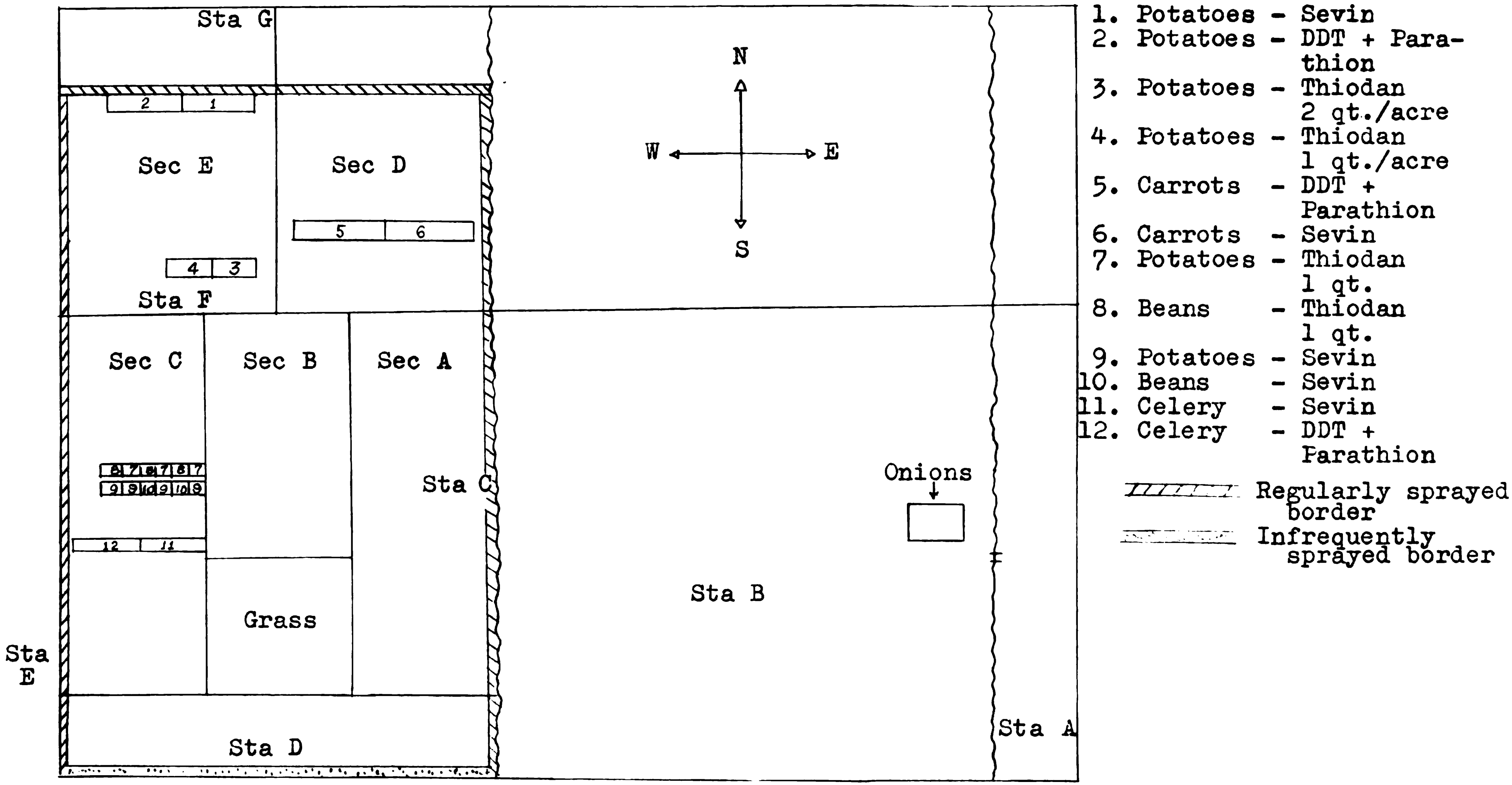


Figure 1. Locations of sampling stations outside, inside, and in border and crop locations inside border at the Muck Experimental Farm.

TABLE 1

List of Weeds at Sampling Stations
at Muck Experimental Farm

Station A	
Cruciferae	species not determined
Curled Dock	Rumex crispus
Downy Bromegrass	Bromus tectorum
Other grasses	species not determined
Station B	
Wild Lettuce	Lactuca spicata
Aster	Species not determined
Goldenrod	Solidago graminifolia var. nuttallii
Goldenrod	Solidago rugosa
Boneset	Eupatorium sp.
Ragweed	Ambrosia artemisiifolia
Peppermint	Mentha piperita
Sedge	Carex sp.
Beggar Tick	Bidens coronata
Station C	
Broom Sedge	Andropogon virginicus
Spear Grass	Poa annua
Station D	
Goldenrod	Solidago altissima
Meadow-sweet	Spireae alba
Station E	
Thistle	Cirsium sp.
Aster	Aster azureus
Agrimony	Agrimonia parviflora
Goldenrod	Solidago rugosa
Meadow-sweet	Spireae alba
Brome	Bromus commutatus
Station F	
Bluegrass	Poa sp.
Station G	
Reed-canary grass	Phalaris arundinacea
Grass	
Broom Sedge	Andropogon virginicus

south along the east side of the cultivated area of the farm. Station D was at the extreme south end of the farm midway between the east and west boundaries of the cultivated area. Station E was at the southwest corner of section C of the farm, approximately fifty yards west of the crop area. Station F was on a border strip of grass which runs east and west between sections C and E of the farm. Station G was at the northwest corner of section E.

On 5 June, 1958, an eighth station was added. This was a plot of onions with which in-row applications of insecticides were being evaluated. A total of 14 samples were taken from this station beginning on 5 June, 1958, and ending 5 September, 1958. At this time the onions were harvested. The ninth sample location was added 7 July, 1958. This was an area which was planted to grass. It included most of the southern half of section B of the farm. This station, while technically inside the border, was considered as being outside the border area. The border to the south of this area was sprayed infrequently and the plot itself was sprayed only once. For these reasons, this station was considered as being outside the border.

To obtain data from inside the border spray area, five plots were chosen on which insect control experiments were being conducted. These plots included four crops; celery, beans, carrots, and potatoes. The spray dates and rates of application inside the border are shown in table 3. The locations of these plots are shown in figure 1.

For purposes of sampling, a standard 12-inch diameter sweeping net was used. A sample consisted of ten double sweeps. The samples were put in one-half pint mason jars. A paper tag giving the site designation, the number of the sample, and the date was placed in each jar. In April and early May, one-quart calcium cyanide killing jars were used. When the plants became green, these cyanide jars were replaced with plain glass jars. This change was necessitated by the presence of green plant parts in the jars. Because of respiration by these plant parts, moisture was condensed on the jars. This made recovery of the specimens difficult. This difficulty was largely eliminated by the use of the plain jars. Carbon tetrachloride was used as the killing agent. From the field, these samples were taken to the laboratory for killing, separating, and counting. The separation was done in a porcelain pan. The samples were emptied onto the pan and the plant parts discarded after the insects were removed from them. The insects were then counted and the numbers recorded on the analysis sheet for each location. The specimens were then placed in 2 3/4 inch pillboxes. These containers were lined with tissue paper to absorb any moisture which might have been present. The tag which had been placed in the jar in the field was also placed in the pillboxes as a means of identifying the sample.

For the border spray program, the standard DDT-parathion mixture was used. The rates of application for these materials were DDT one-quart of 25 percent emulsion and parathion one pint of 25 per cent emulsion. This was added to 150 gallons of water and applied at 150 gallons per acre. A John Bean model 8RC Air Crop mist blower was used. This sprayer has a 200 gallon tank and delivers 14.27 gallons per minute at 400 pounds pressure. This sprayer was used for most of the spraying on the plots inside the border also. On windy days, however, a boom sprayer was used. This was a John Bean model 70-TG boom sprayer. This sprayer has a 150 gallon tank and delivers 7 gallons per minute at 400 pounds pressure. All of the spraying was done by personnel of the Muck Experimental Farm. During June, the border was sprayed every day except Saturday and Sunday. During July and August the interval between applications was increased to three to five days.

Table 2

Dates of Application of Border Sprays

Month:	May	June	July	August
Day:	30	2	2	1
		3	7	4
		4	11	8
		5	14	11
		6	18	13
		9	31	15
		10		18
		11		22
		12		
		13		
		16		
		17		
		18		
		19		
		20		
		23		
		24		
		25		
		26		
		27		
		30		

Table 3

Spray Dates and Rates of Application on Crops Inside Border of Muck Experimental Farm

Crop:	Potatoes					
Material Rate and Formulation	Sevin 2 # 50 WP	DDT 1 quart 25% Emul. Parathion 1 pint 25% Emul.	Thiodan 1 quart 25% Emul.	Thiodan 2 quarts 25% Emul.	Sevin 2 # 50 WP	Thiodan 1 quart 25% Emul.
Date:	July 2	July 2	July 2	July 2	July 2	July 2
	8	8	8	8	8	8
	15	15	15	15	15	15
	22	22	22	22	22	22
	30	30	30	30	30	30
	Aug. 5	Aug. 5	Aug. 5	Aug. 5	Aug. 5	Aug. 5
	12	12	12	12	12	12
	19	19	19	19	19	19
	Sept. 2	Sept. 2	Sept. 2	Sept. 2	Sept. 2	Sept. 2

Table 3. Continued.

Crop:	Carrots		Beans		Celery	
Material Rate and Formulation	Sevin 2 # 50 WP	DDT 1 quart 25% Emul. Parathion 1 pint 25% Emul.	Thiodan 1 quart 25% Emul.	Sevin 2 # 50 WP	Sevin 2 # 50 WP	DDT 1 quart 25% Emul. Parathion 1 pint 25% Emul.
Date:	July 2	July 2	July 2	July 2	July 2	July 2
	8	8	8	8	8	8
	15	15	15	15	15	15
	22	22	22	22	22	22
	30	30	30	30	30	30
	Aug. 5	Aug. 5	Aug. 5	Aug. 5	Aug. 5	Aug. 5
	12	12	12	12	12	12
	19	19	19	19	19	19
	Sept. 2	Sept. 2	Sept. 2	Sept. 2	Sept. 2	Sept. 2

PRESENTATION AND DISCUSSION OF DATA

The first samples on the crop area were not taken until after the first spray application. Spraying was begun on 2 July and the first sample taken 7 July. Sampling was started in the border area prior to the first spray application. The first samples were taken on 10 April. The first spray application was on 30 May. The total number of specimens taken, especially of leafhoppers, was abnormally low. The reasons for the low populations could not be definitely ascertained. The total number of *Empoasca fabae* Harris* from all collecting stations was 182 and of *Macrosteles fascifrons* (Stål) 509. These totals are less than some workers have collected in a single sample. These low totals could possibly have been caused by the cool weather which prevailed throughout most of the spring. Williams (1957) stated that temperature gradients might serve as a means of orientation for migrating insects. Assuming that this is correct, it is possible that the bulk of the leafhoppers did not reach Michigan but

*Determinations of *E. fabae* were made according to published information. Recent investigations by H. H. Ross of the Illinois Natural History Survey indicate that what is now known as the potato leafhopper may actually be a complex of species. This information is as yet unpublished.

stopped somewhere south of this state where temperatures were more favorable. Another possibility was that subnormal temperatures in the breeding areas prevented or hindered reproduction and subsequent population buildups. This would tend to decrease the number of migrating insects. Williams (1957) also stated that the prime instigator of migratory flights was thought to be overpopulation. If breeding in southern areas were hindered, this population pressure would not exist thereby reducing the number of leafhoppers migrating northward.

The first specimen of E. fabae was collected on 8 May and three more were collected on 15 May. All of these leafhoppers were adults. This is somewhat in advance of the usual date of arrival of the potato leafhopper. Medler (1957) listed the usual date of arrival in the north-central states as 23-27 May. Medler added, however, that the potato leafhopper had been recorded as early as April and as late as June in the north-central area. The six-spotted leafhopper was first collected on 15 May when two adult specimens were collected. Tables 4 through 12 show the results of collections from all stations outside the border area. It was from these stations, specifically stations A and F, that these first arrivals were collected.

Figure 2 shows the fluctuations in population of E. fabae. This figure represents the total number of

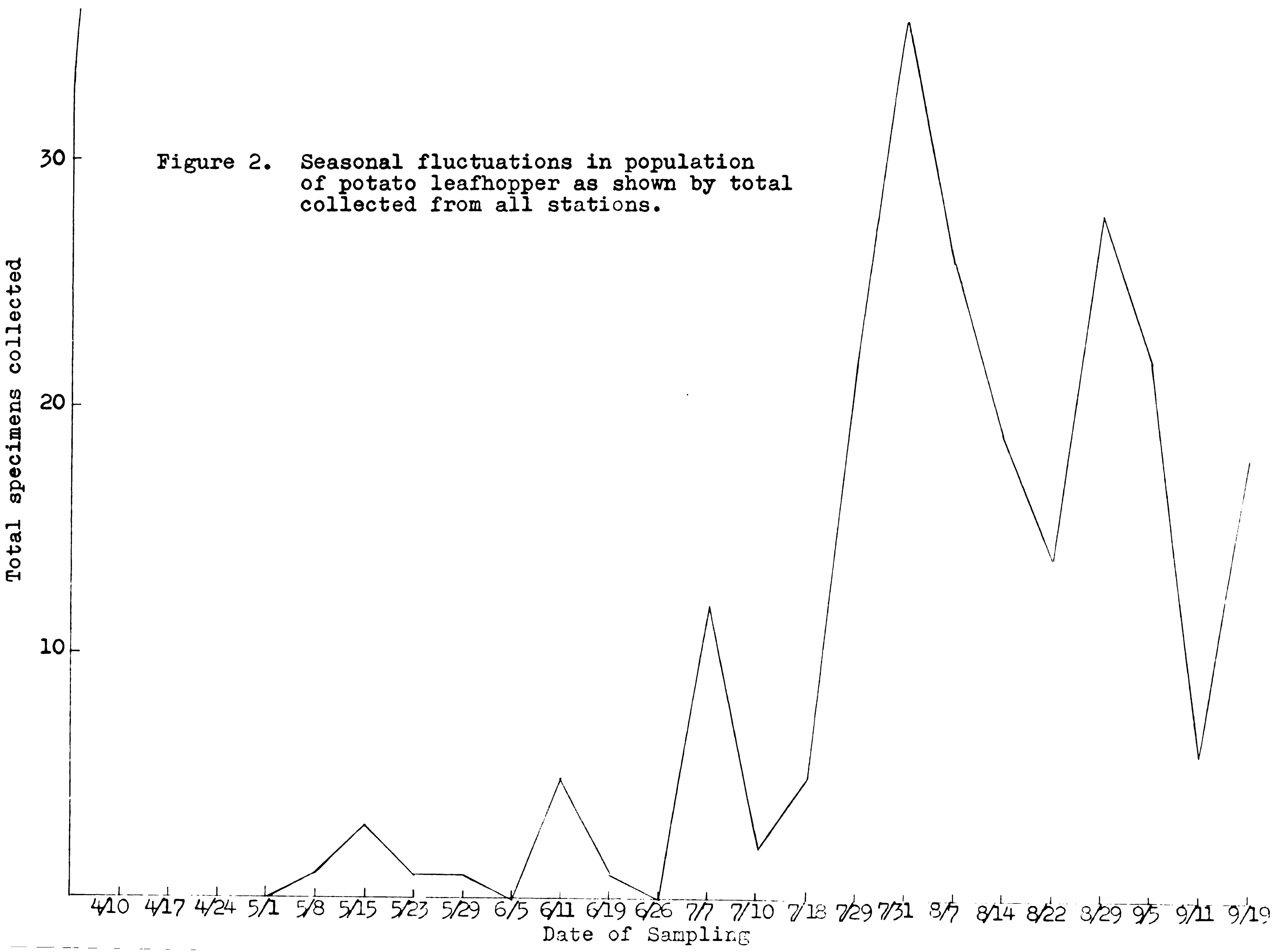


Figure 2. Seasonal fluctuations in population of potato leafhopper as shown by total collected from all stations.

TABLE 4

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM STATION A LOCATED OUTSIDE BORDER AREA

Date		Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April	10	0	0	0	0	0	0
	17	0	0	0	0	0	0
	24	0	0	0	0	0	0
May	1	0	0	0	0	0	0
	8	1	0	0	0	0	0
	15	1	0	0	0	0	0
	23	0	1	0	0	0	0
	29	0	0	3	0	0	0
June	5	0	1	0	2	0	2
	11	2	0	2	0	0	1
	19	0	3	7	0	0	1
	26	0	0	2	3	0	0
July	7	0	0	12	50	2	5
	10	0	0	2	0	2	1
	18	2	0	11	1	9	0
	29	0	2	6	0	6	10
	31	22	6	10	4	4	13
Aug.	7	0	3	9	0	9	5
	14	0	0	2	0	9	0
	22	0	5	10	5	11	0
	29	2	0	3	0	25	0
Sept.	5	0	1	3	5	3	2
	11	0	0	1	0	0	1
	19	4	0	0	0	5	0
TOTALS		34	22	83	70	76	45

TABLE 5

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE
FROM STATION B LOCATED OUTSIDE BORDER AREA

Date	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April 10	0	0	0	0	0	0
17	0	0	1	0	0	0
24	0	0	0	0	0	0
May 1	0	0	0	0	0	0
8	0	0	0	0	0	0
15	0	0	0	0	0	2
23	0	0	0	0	0	0
29	0	0	0	0	0	2
June 5	0	4	0	0	0	0
11	0	2	4	0	0	2
19	0	3	5	0	0	5
26	0	2	7	7	0	7
July 7	1	0	18	0	0	0
10	0	0	10	13	0	2
18	2	0	46	0	1	0
29	8	2	16	7	4	10
31	3	1	21	0	0	1
Aug. 7	0	1	18	0	2	6
14	0	3	21	0	3	0
22	0	1	13	2	1	0
29	0	2	7	2	2	1
Sept. 5	0	0	5	0	1	1
11	0	0	0	0	0	0
19	0	0	0	0	0	0
TOTALS	14	21	192	31	14	44

TABLE 6

TOTAL NUMBER OF INSECTS COLLECTED PER COLLECTION DATE FROM STATION C LOCATED IN BORDER AREA

Date		Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April	10	0	0	0	0	0	0
	17	0	0	0	0	0	0
	24	0	0	0	0	0	0
May	1	0	0	0	0	1	0
	8	0	0	0	0	1	0
	15	0	0	0	0	1	4
	23	0	0	0	0	0	4
June	5	0	0	0	0	0	0
	11	0	0	0	0	0	0
	19	0	0	0	0	0	0
	26	0	0	0	0	0	0
July	7	0	0	0	1	0	0
	10	0	0	8	6	0	0
	18	0	0	3	6	0	0
	29	0	0	4	8	1	0
	31	0	1	5	11	0	0
Aug.	7	0	0	6	0	0	0
	14	0	0	11	0	0	0
	22	1	1	4	0	0	0
	29	0	0	0	0	0	0
Sept.	5	0	0	0	0	0	0
	11	0	0	0	4	0	0
	19	0	0	0	0	0	1
TOTALS		1	2	42	36	4	10

TABLE 7

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE
FROM STATION D LOCATED OUTSIDE BORDER AREA

Date		Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April	10	0	0	0	0	0	0
	17	0	0	0	0	0	0
	24	0	0	0	0	0	0
May	1	0	0	0	0	0	0
	8	0	0	0	0	1	0
	15	1	0	0	0	0	0
	23	1	0	0	0	0	0
	29	0	0	0	0	0	3
June	5	0	5	2	0	0	3
	11	2	11	0	0	1	0
	19	1	7	1	0	0	2
	26	0	1	0	0	0	0
July	7	0	2	7	0	2	0
	10	0	0	7	14	2	0
	18	1	2	17	20	4	0
	29	0	0	18	143	6	0
	31	0	8	26	65	7	0
Aug.	7	0	7	8	0	0	0
	14	0	1	5	0	0	0
	22	2	4	4	0	5	0
	29	1	3	4	0	1	0
Sept.	5	0	0	1	0	1	0
	11	0	0	0	0	0	0
	19	1	0	0	0	0	0
TOTALS		10	51	100	242	30	8

TABLE 8

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM STATION E LOCATED OUTSIDE BORDER AREA

Date		Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April	10	0	0	0	0	0	0
	17	0	0	0	0	0	0
	24	0	0	0	0	0	0
May	1	0	0	0	0	0	0
	8	0	0	0	0	0	0
	15	1	0	0	0	0	0
	23	0	0	0	0	0	2
	29	1	2	0	0	0	0
June	5	0	0	3	0	0	0
	11	1	2	0	0	0	0
	19	0	25	0	0	0	1
	26	0	1	1	0	0	0
July	7	5	0	15	0	0	4
	10	0	0	22	9	0	4
	18	0	0	28	20	0	3
	29	4	5	12	0	0	2
	31	5	8	22	46	5	0
Aug.	7	4	1	16	11	1	1
	14	0	0	19	0	6	0
	22	0	1	15	0	4	1
	29	3	0	13	0	11	0
Sept.	5	0	0	8	10	1	0
	11	0	0	9	5	2	0
	19	1	0	1	0	3	0
TOTALS		25	45	165	101	33	18

TABLE 9

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM STATION F LOCATED IN THE BORDER AREA

Date		Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April	10	0	0	0	0	0	0
	17	0	0	0	0	0	0
	24	0	0	0	0	0	0
May	1	0	0	0	0	0	0
	8	0	0	0	0	1	9
	15	0	2	0	0	5	5
	23	0	0	0	0	0	0
	29	0	2	0	0	0	2
June	5	0	0	0	0	0	0
	11	0	0	0	0	0	0
	19	0	0	0	0	0	0
	26	0	0	0	0	0	0
July	7	0	1	0	0	0	0
	10	0	0	0	0	0	0
	18	0	0	2	1	0	0
	29	0	0	7	0	0	0
	31	0	9	2	0	0	0
Aug.	7	0	1	0	3	0	0
	14	0	0	0	0	1	0
	22	0	0	0	0	0	0
	29	0	1	9	0	0	0
Sept.	5	2	17	5	3	0	2
	11	0	3	0	2	2	1
	19	1	0	0	0	0	2
TOTALS		3	36	25	9	9	21

TABLE 10

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM STATION G LOCATED OUTSIDE BORDER AREA

Date		Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April	10	0	0	0	0	0	0
	17	0	0	0	0	0	0
	24	0	0	0	0	0	1
May	1	0	0	0	0	0	1
	8	0	0	0	0	0	0
	15	0	0	0	0	0	5
	23	0	0	2	0	0	9
	29	0	3	0	0	0	1
June	5	0	3	2	0	0	0
	11	0	3	1	4	0	0
	19	0	7	2	0	0	0
	26	0	0	0	0	0	0
July	7	0	1	36	0	0	0
	10	0	0	17	21	0	0
	18	0	0	6	0	3	0
	29	0	0	7	0	0	0
	31	1	20	24	0	0	1
Aug.	7	0	16	19	0	0	0
	14	0	12	11	0	0	5
	22	0	1	9	0	4	0
	29	0	1	4	1	0	1
Sept.	5	0	11	2	0	0	3
	11	0	0	0	0	0	0
	19	0	0	1	0	0	9
TOTALS		1	78	143	26	7	36

TABLE 11

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM STATION G LOCATED OUTSIDE BORDER AREA

Date	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
April 10	0	0	0	0	0	0
17	0	0	0	0	0	0
24	0	0	0	0	0	1
May 1	0	0	0	0	0	1
8	0	0	0	0	0	0
15	0	0	0	0	0	5
23	0	0	2	0	0	9
29	0	3	0	0	0	1
June 5	0	3	2	0	0	0
11	0	3	1	4	0	0
19	0	7	2	0	0	0
26	0	0	0	0	0	0
July 7	0	1	36	0	0	0
10	0	0	17	21	0	0
18	0	0	6	0	3	0
29	0	0	7	0	0	0
31	1	20	24	0	0	1
Aug. 7	0	16	19	0	0	0
14	0	12	11	0	0	5
22	0	1	9	0	4	0
29	0	1	4	1	0	1
Sept. 5	0	11	2	0	0	3
11	0	0	0	0	0	0
19	0	0	1	0	0	9
TOTALS	1	78	143	26	7	36

TABLE 11

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM ONION PLOT LOCATED OUTSIDE BORDER AREA

Date	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
June 5	0	8	0	0	1	0
11	0	0	0	0	0	0
19	0	4	0	0	0	0
26	0	1	0	0	0	0
July 7	0	0	0	0	1	1
10	0	0	2	0	1	0
18	0	1	1	1	2	0
29	0	12	1	0	0	0
31	0	20	1	1	0	1
Aug. 7	0	20	3	0	0	0
14	0	31	3	0	1	3
22	0	0	1	0	0	0
29	0	2	0	0	0	3
Sept. 5	0	2	0	1	1	0
TOTALS	0	101	12	3	7	7

TABLE 12

TOTAL NUMBERS OF INSECTS COLLECTED PER COLLECTION DATE FROM GRASS PLOT LOCATED OUTSIDE BORDER AREA

Date	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
July 7	0	4	5	0	1	0
10	0	0	0	0	0	0
18	0	5	32	0	3	0
29	0	17	14	0	5	0
31	0	32	12	0	11	0
Aug. 7	1	14	3	0	1	0
14	0	8	6	0	3	4
22	0	10	15	0	0	4
29	0	5	6	0	0	0
Sept. 5	0	4	0	0	3	3
11	0	1	0	0	0	0
19	0	1	0	0	0	0
TOTALS	1	101	93	0	27	11

TABLE 13

SUMMARY OF TOTALS SHOWN IN TABLES 4-12 SHOWING TOTALS AND AVERAGE PER STATION FOR STATIONS OUTSIDE AND INSIDE BORDER AND AVERAGE PER PLOT FOR PLOTS INSIDE BORDER

Station	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Aphids	Tarnished Plant Bug	Flea Beetles
Totals Outside Border						
A	34	22	83	70	76	45
B	14	21	192	31	14	44
D	10	51	100	242	30	8
E	25	45	165	101	33	18
G	1	78	143	26	7	36
Onions	0	101	12	3	7	7
Grass	1	101	93	0	27	11
Average Per Station	12	59.8	112.5	67.5	27.7	24.2
Totals in Border						
C	1	2	42	36	4	10
F	3	36	25	9	9	21
Average Per Station	2	19	33.3	22.5	6.5	15.5
Average Per Plot Inside Border	9.8	1.07	50.9	63.5	20.3	11.7

potato leafhoppers collected from all sampling stations outside and inside the border and in the border area. As mentioned above, tables 4 through 12 show the results of collections outside the border. Of these, tables 6 and 9 are the two stations in the border area. Table 13 shows the results of sampling from the plots inside the border. It should be again pointed out that the number of leafhoppers was abnormally low. As shown by figure 2, the population of E. fabae remained low until 10 July. For the next three weeks there was a gradual build-up until a peak population was reached on 31 July. This peak was followed by a gradual decrease until 22 August. A second peak was reached the following week as shown by the collections of 29 August. After this second peak, there was another drop in population. A comparison of populations inside and outside the border and in the border spray area are shown in figure 3. As discussed previously, a peak population was reached 31 July. This peak occured mainly in the fields outside the border spray area. This peak was followed by a decrease in population in the bordering fields. This decrease was accompanied by an increase in population inside the border spray area. This drop outside the border and the accompanying increase inside the border indicated that there was probably a movement of E. fabae from outside to inside the border. The decrease in

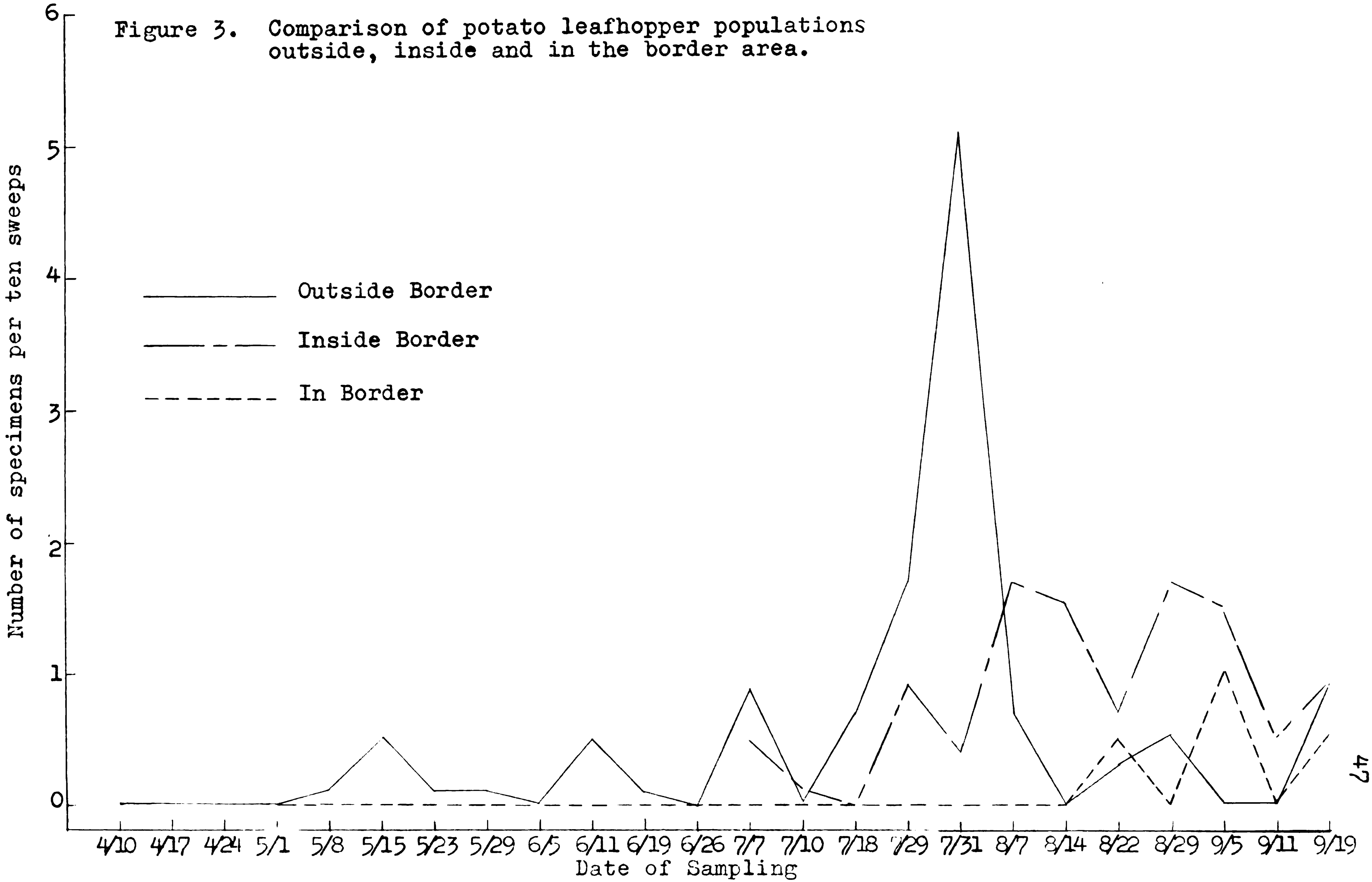


Figure 3. Comparison of potato leafhopper populations outside, inside and in the border area.

population between 29 August and 11 September probably were caused by killing frosts which occurred during this period.

Figure 4 shows the fluctuations in population of M. fascifrons. Two noticeable peaks were indicated. The first was reached on 19 June and the second on 31 July. These two peaks in population were probably indications of two generations although no nymphs were found. Osborn (1916) found indications of three generations per year, the last being overwintering eggs. Figure 4 tends to support the findings of Osborn. Figure 5 shows a comparison of six-spotted leafhopper populations outside and inside the border and in the border spray area. The two peaks discussed previously are shown by figure 4 to have occurred mainly in the fields outside the border. The first peak occurred entirely in the bordering fields. The samples taken in the border area showed no M. fascifrons during this period. The second peak occurred simultaneously in all areas. A peak was reached 5 September in the border area. This occurred after border spraying was stopped. Following this peak there was a rapid decrease in numbers. This decrease was probably caused by frost destroying the host plants.

The seasonal fluctuations in population of the potato flea beetle, Epitrix cucumeris (Harris), are shown in

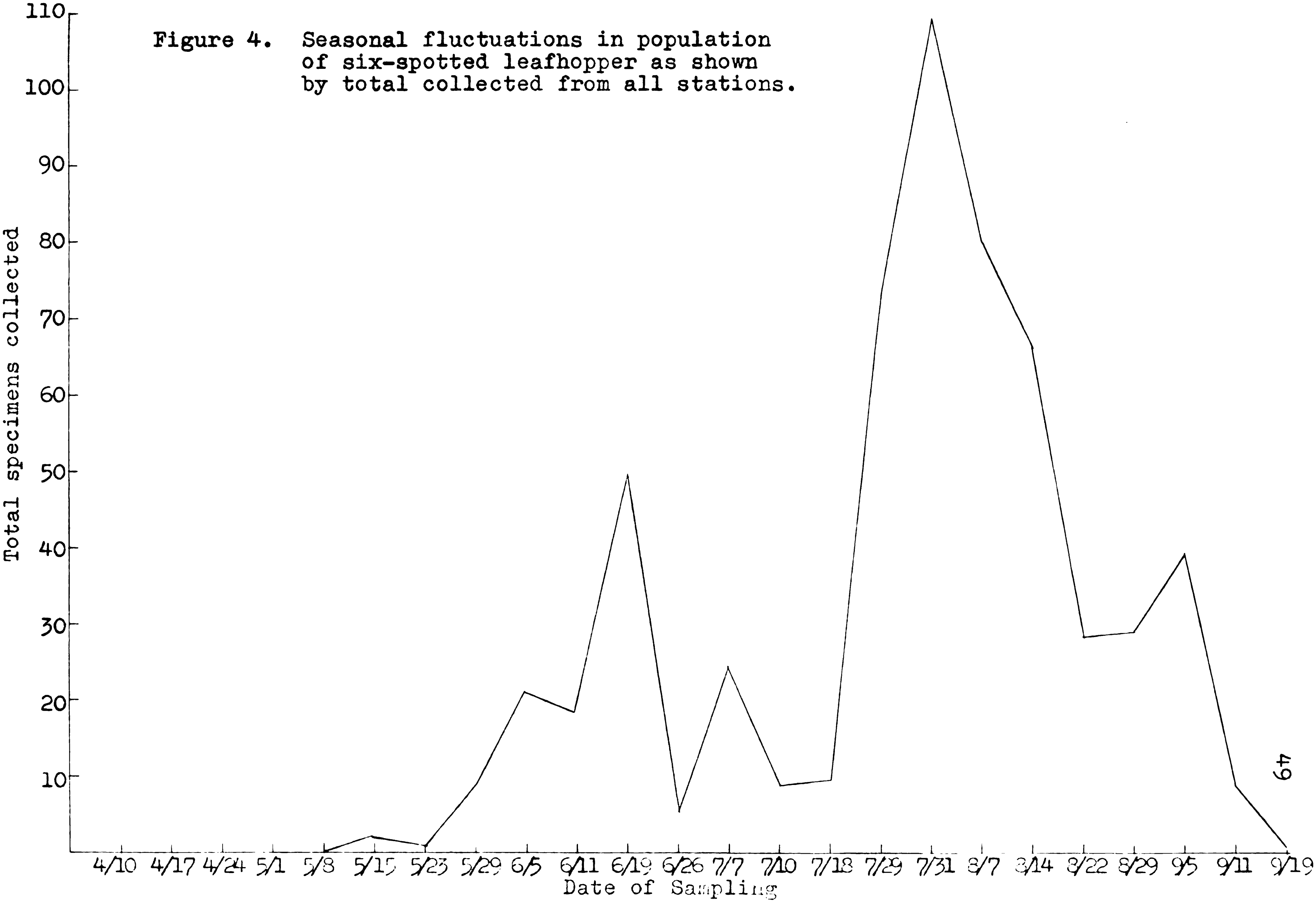


Figure 4. Seasonal fluctuations in population of six-spotted leafhopper as shown by total collected from all stations.

Figure 5. Comparison of populations of six-spotted leafhoppers outside, inside, and in the border spray area.

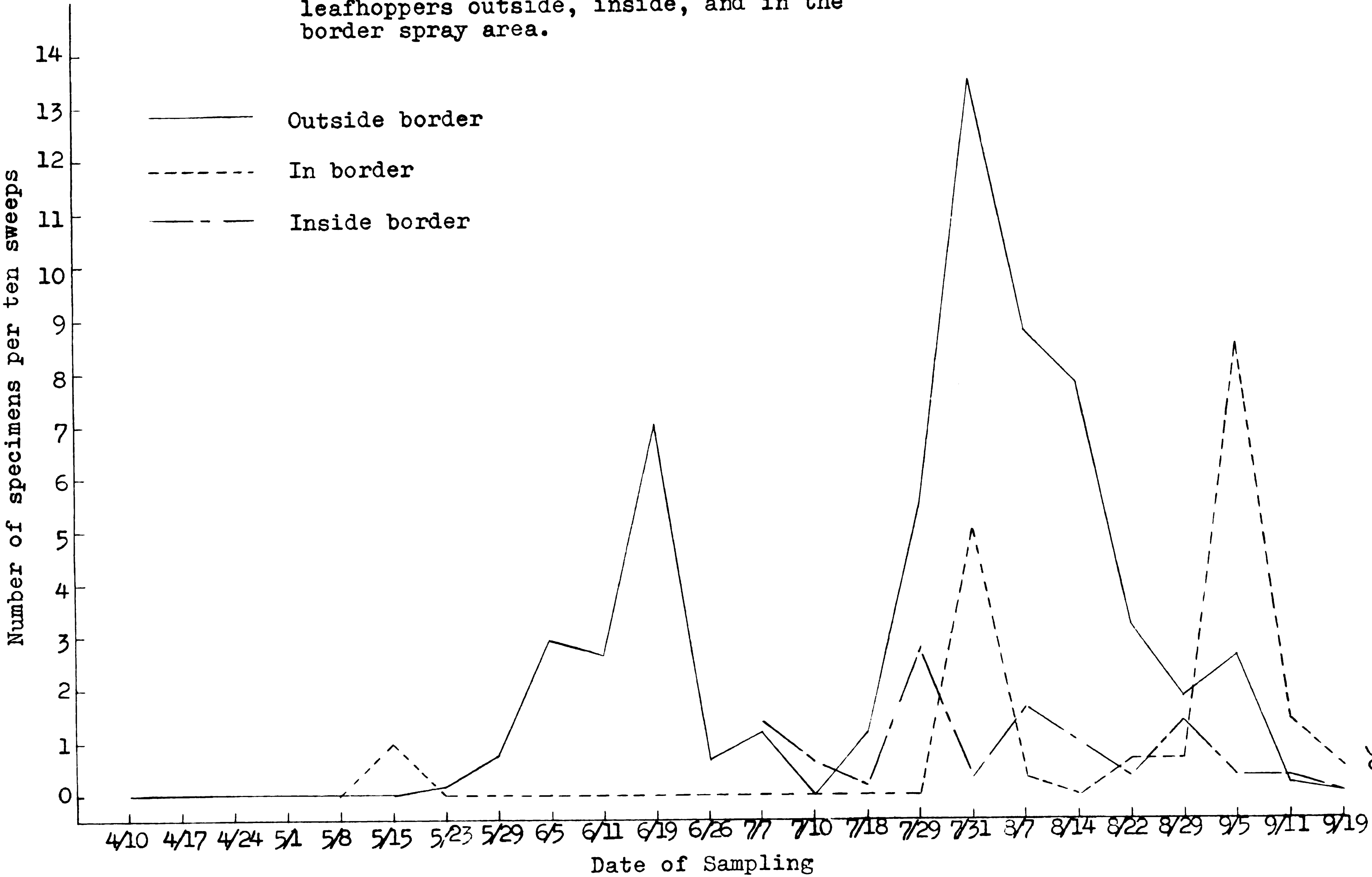
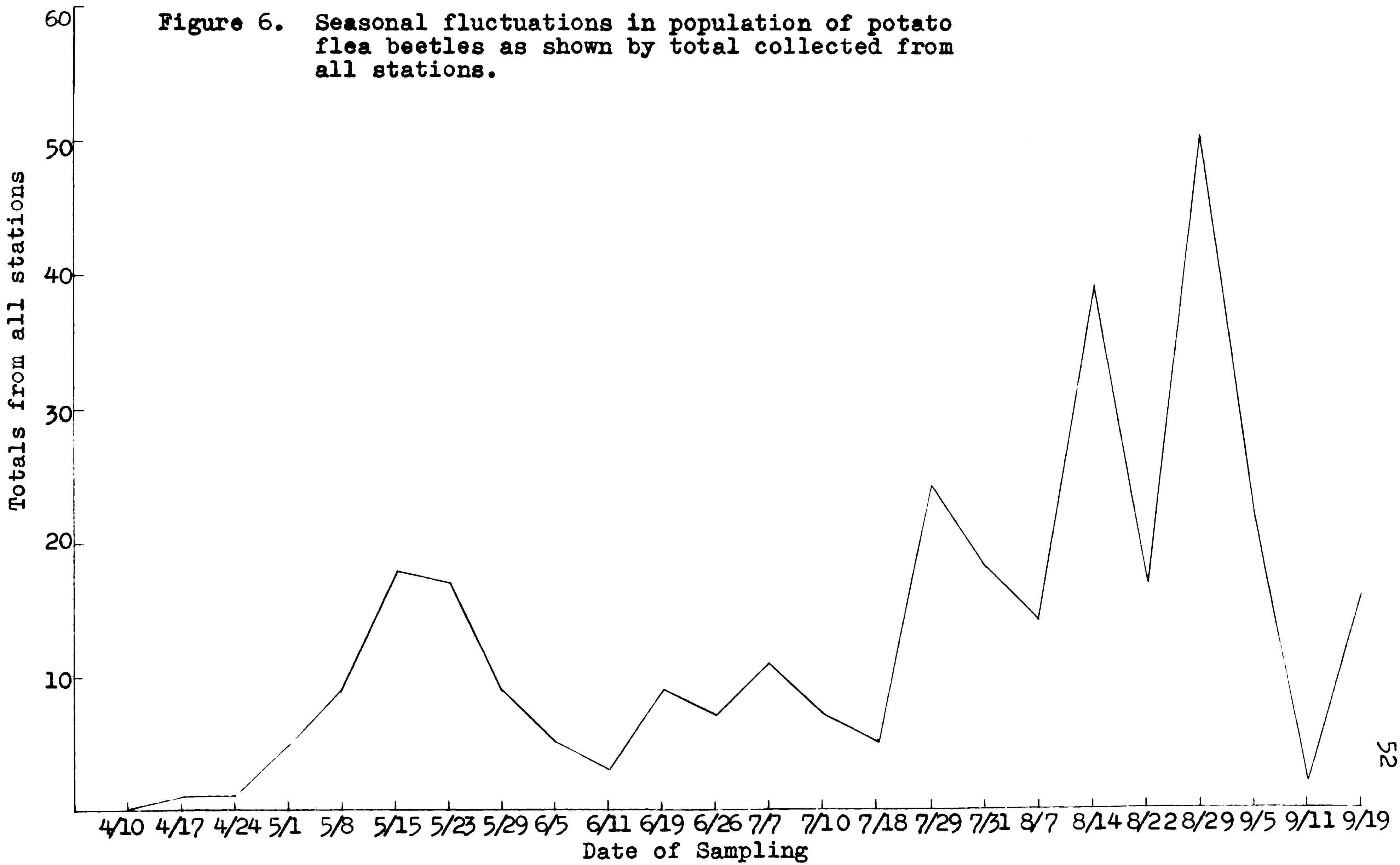


figure 6. An early peak in population was reached on 15 May. There was a gradual rise beginning on 24 April and continuing until the peak was reached. A decrease followed until 11 June. From this time there was a gradual increase until a second peak was reached 29 August. Following this peak there was a rapid decrease. Flea beetles overwinter as adults so this last decrease was probably caused by the beetles entering hibernation. The increase in population between 11 June and 29 August was probably an indication of a new generation of potato flea beetles.

Tables 4 through 12 show the results of sampling from the collecting stations outside the border and in the border spray area. Tables 6 and 9 show the results of collections from stations C and F respectively. These two stations were in the border spray area. Previous to the first spray application one six-spotted leafhopper was collected from station C and four from station F. No potato leafhoppers were collected from either station prior to spraying. After spraying, the potato leafhopper population remained low at both stations. Station F yielded nine M. fascifrons on 31 July. There was no border spray application between 18 July and 31 July. The sample from this station was taken before the spray application of this date. When spraying was resumed on a regular basis, this population dropped and remained low until

Figure 6. Seasonal fluctuations in population of potato flea beetles as shown by total collected from all stations.



spraying was ceased. On 29 August, the six-spotted leafhopper population at station F began to increase. This last buildup can be at least partially explained. This station was between sections C and E of the Muck Experimental Farm (fig. 1). There were three potato fields north and three south of this station. One plot to the south was separated from station F by only a narrow road. Two plots to the north were separated from this station by a sugar beet field fifty feet wide. Although none of these plots were included in the regularly sampled plots inside the border, occasional sweepings were taken on them. All showed substantial populations of M. fascifrons. In late August and early September, these potato vines began to die. As the plants became unavailable, or undesirable, as food plants, the leafhoppers moved. As a result of this late migration, some of these insects arrived at station F. Again, frost was probably responsible for the reduction of this population.

The effectiveness of the border spray program can be seen in figures 3 and 5. These figures are based on an average number of leafhoppers per ten sweeps. It was evident that the border spray program was not effective in preventing the movement of E. fabae from the bordering fields to the crop areas. During the early part of the study the population in the bordering fields was higher.

From late July to the end of the sampling period, however, the population inside the border was higher than that outside the border spray area.

The border spray control program did appear to be effective in controlling the migration of M. fascifrons from the bordering fields to the crop areas. The population outside the border was consistently higher than inside the border. From 29 August to the end of this study the population in the border area was higher than both inside and outside the border. This observation has been discussed previously.

Chemical Control

Table 14 shows the results of sampling from the spray plots inside the border. These plots are grouped by the crop grown. Thiodan at one quart of 25 percent emulsion per acre and Sevin at two pounds of 50 percent wettable powder per acre were applied to two plots each. Table 14 shows an average for the two plots. All materials gave satisfactory control of both E. fabae and M. fascifrons. Significant differences were observed between the materials for control of aphids. The aphids involved were the green peach aphid, Myzus persicae (Sulzer). The DDT - parathion mixture gave good control of these aphids as did Thiodan at two quarts. Thiodan at one quart gave some

TABLE 14

TOTAL NUMBERS OF INSECTS COLLECTED FROM SPRAY PLOTS INSIDE BORDER

Crop Material Rate/acre	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Green Peach Aphids	Tarnished Plant Bug	Flea Beetles
Potatoes						
Thiodan 1 Qt. 25% Emul.	21	9	13	132	19	8
Thiodan 2 Qt. 25% Emul.	16	11	35	45	6	5
Sevin 2# 50% WP	16	8	66	349	18	25
DDT 1 Qt. 25% Emul. Parathion 1 pt. 25% Emul.	6	8	36	31	46	9
Beans						
Sevin 2# 50% WP	6	5	6	21	-	-
Thiodan 1 Qt. 25% Emul.	3	2	5	5	-	-

Table 14. Continued.

Crop Material Rate/acre	Potato Leafhopper	Six-spotted Leafhopper	Spittlebug Adults	Green Peach Aphids	Tarnished Plant Bug	Flea Beetles
Celery						
Sevin 2# 50% WP	14	7	16	25	6	-
DDT 1 Qt. 25% Emul.	9	14	14	11	9	-
Carrots						
Sevin 2# 50% WP	6	6	143	10	33	-
DDT 1 Qt. 25% Emul. Parathion 1 pt. 25% Emul.	1	37	175	6	26	-

control but could not be called satisfactory. Sevin gave very little control of aphids on potatoes. The green peach aphid populations on plots sprayed with Sevin were considerably higher than those on the plots sprayed with the other materials. Spittlebugs and flea beetles were more numerous in the plots sprayed with Sevin.

Both Sevin and Thiodan at one quart gave satisfactory control of leafhoppers on beans. There was an indication that Thiodan gave better control of aphids although both populations were low as shown by table 13. These aphids were also the green peach aphid.

Observations on celery indicated that Sevin gave better results in controlling six-spotted leafhoppers than did the DDT - parathion mixture. Both materials gave satisfactory control of all other insects.

The results of samples taken on carrots also indicated Sevin gave better control of M. fascifrons than the DDT - parathion mixture. Spittlebug populations were high in both the Sevin and DDT - parathion plots. Both materials gave satisfactory control of all other insects.

SUMMARY

The primary purpose of this study was to determine the effectiveness of a border spray control program in preventing the movement of the potato leafhopper, *Empoasca fabae* Harris, and the six-spotted leafhopper, *Macrosteles fascifrons* (Stål), from bordering areas to cultivated crops. The arrival dates and seasonal fluctuations in populations of these leafhoppers were also determined.

A second objective of this program was the evaluation of insecticidal spray materials for control of insect pests on potatoes, beans, carrots, and celery. Thiodan and Sevin were compared with the standard DDT - parathion recommendation.

The Michigan State University Muck Experimental Farm, Clinton County, Michigan, was chosen as the location for this study. Nine sampling stations were established. Six of these were in the bordering fields, two were in the border spray area, and one was a plot inside the border which was planted to grass and was not sprayed. Beginning 10 April, 1958, and lasting for a period of twenty-three weeks, sweep-net samples were taken weekly from each of these locations. To determine the effectiveness of the border spray control program, twelve plots were chosen inside the border on which insecticide trials were being

conducted. The insecticides tried were Thiodan, Sevin, and DDT - parathion mixture. The insecticide trial plots included six plots of potatoes on which all three materials were being applied on one or more plots, two plots of celery on which DDT - parathion and Sevin were used, two carrot plots on which these same two materials were used, and two plots of beans on which Thiodan and Sevin were applied.

The results were as follows:

1. The first potato leafhopper was collected on 8 May, 1958. One specimen was taken on this date.
2. The first six-spotted leafhopper appeared in the sample taken 15 May, 1958, when two specimens were collected.
3. The border spray program proved effective in slowing the movement of M. fascifrons from the border fields to the cultivated areas. A total of 458 were taken outside the border and 120 inside the border.
4. The border spray control program did not prove successful in preventing movement of E. fabae from the border fields to the crop area. A total of 89 potato leafhoppers were collected outside the border and 133 inside.

5. The DDT - parathion mixture was found to be the most satisfactory material against all of the plant pests involved in this study. There were, however, indications that this mixture was not effective against adult spittlebugs on carrots.
6. Sevin was effective against leafhoppers, particularly M. fascifrons. Sevin gave no control of the green peach aphid. There were indications that this material was less effective against flea beetles than the other materials.
7. Leafhopper populations were abnormally low during the entire 1958 season.
8. Thiodan at two quarts of 25 percent emulsion was effective against all insects. Thiodan at one quart of 25 percent emulsion did not prove effective against the green peach aphid. There were indications that this material was not as effective against E. fabae as Sevin and the DDT-parathion mixture.

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