A STUDY OF TWO HORTICULTURAL INSECT PESTS

PART I. A STUDY OF THE LIFE HISTORY, HABITS, AND CONTROL OF THE SIX-SPOTTED LEAFHOPPER Macrosteles fascifrons (Stal) (= divisus Uhl.) (HOMOPTERA: CICADELLIDAE). PART II. A STUDY OF THE LIFE HISTORY AND HABITS OF THE SPOTTED ASPARAGUS BEETLE Crioceris duodecimpunctata (L.) (COLEOPTERA: CHRYSOMELIDAE)

A Thesis

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by

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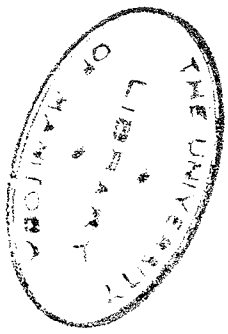

ABSTRACT

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PART I. A STUDY OF THE LIFE HISTORY, HABITS AND CONTROL OF THE SIX-SPOTTED LEAFHOPPER Macrosteles fascifrons (Stal) (= divisus Uhl.) (HOMOPTERA: CICADELLIDAE)

The purpose of this study was to learn something of the life history and habits of, and to find a chemical control for the six-spotted leafhopper Macrosteles fascifrons (Stal). The life history and other biological investigations were conducted in the laboratory, and chemical control studies were made on field plots of the Division of Plant Science, The University of Manitoba, Winnipeg, Manitoba.

Six-spotted leafhoppers were collected from grasses, stink weed, clovers and lettuce early in May 1954. Some of the specimens were mounted and sent to the Systematic Unit, Ottawa. They were identified by Dr. B.P. Beirne, as Macrosteles fascifrons (Stal).

The investigation of the six-spotted leafhopper showed that there were two complete generations of this insect in Winnipeg, Manitoba under field conditions while there were two and a half generations observed under laboratory conditions. Both the nymphs and the adults fed on commercial crops.

The following insecticides were used on the field plots, nine treatments replicated three times to make twenty-seven plots: malathion dust and emulsifiable concentrate; DDT dust, wettable powder and emulsifiable concentrate; toxaphene dust and emulsifiable concentrate; and methoxychlor wettable powder. The doubling of the rates of the insecticides did not show any appreciable decrease in the insect population.

The above insecticides, at the rates used did not control the six-spotted leafhoppers on lettuce, but the following insecticides gave a reasonably effective control on carrots: malathion dust and emulsifiable concentrate; DDT dust, wettable powder and emulsifiable concentrate; and methoxychlor wettable powder. DDT emulsifiable concentrate caused injury to lettuce and carrots. The foliage was stunted and the plants were dwarfed. The carrot roots were pock-marked, rough and deformed. Toxaphene dust or emulsifiable concentrate proved very ineffective in controlling the six-spotted leafhopper.

The result of the effect of insecticides on six-spotted leafhopper eggs in the laboratory, showed that malathion dust and emulsifiable concentrate have strong ovicidal effects, and methoxychlor wettable powder also to a slight extent.

PART II. A STUDY OF THE LIFE HISTORY AND HABITS OF THE SPOTTED ASPARAGUS BEETLE Crioceris duodecimpunctata (L.).

To ascertain the life history and habits of this insect, field and laboratory experiments and observations were con-

ducted. The time of emergence from hibernation, and the duration of time spent in egg, larval, and pupal stages, were ascertained in this study. The feeding and oviposition sites as well as pertinent observations on the life cycle and habits of this insect were also considered. The insect was observed to have one generation per year in Winnipeg, Manitoba. The adult insects were first observed on June 13 feeding on tender tips of asparagus plants. Mating was observed as soon as the insects emerged from hibernation on June 13. About a month later eggs were laid singly attached on their sides to asparagus branches. Eggs hatched July 14-24 and the resulting tiny larvae crawled to the berries, bored holes into the berries and entered, sealing the holes after them with darkish brown substances. The duration of the time spent in the pupal stage is about fourteen days. The newly emerged adult insects from the pupal cells began to feed immediately on the asparagus tips and leaves. This new adult generation went into hibernation between the end of September and October 22, 1954, in Winnipeg, Manitoba.

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CHAPTER I

INTRODUCTION

The six-spotted leafhopper, Macrosteles fascifrons (Stal) has been present in very large numbers in fields and in gardens in Manitoba in recent years. It is reported to be the vector in the transmission of aster yellows, a virous disease of many herbaceous plants. Aster yellows is particularly serious on carrots, lettuce and celery, on many ornamental flowers, and specialists in field crops believe that it is present in flax and sunflowers. There is also some evidence that purple top of potatoes may be a strain of this same disease. The problem is aggravated by the fact that so many plants, both wild and cultivated, are hosts to both leafhoppers and aster yellows, and that the insects keep migrating into plots which have been treated with insecticidal sprays or dusts, from untreated areas. If some method can be found to control the leafhopper, incidence of aster yellows in commercial crops should be lessened. A knowledge of the life history and habits of this insect is necessary for the proper use of chemical controls.

Problem

The purpose of this study was to learn the life history and habits, and to find a control for the six-spotted leafhopper, Macrosteles fascifrons.

Importance of the study

Although the aster yellows disease has only recently become a serious problem in Manitoba, various reports from United States have indicated heavy damage caused by this disease. Stephen (1948) in Manitoba reported that 50 per cent of the carrots planted were affected by the aster yellows disease in Brandon, Manitoba. The chief economic importance of the six-spotted leafhopper is that it is a vector of aster yellows virus of many commercial crops including lettuce, carrots, celery, potatoes and probably flax and sunflower. The value of the crops and the importance of the vector warrant such a study.

Location of the study

The major part of the work was conducted on field plots of the Division of Plant Science, The University of Manitoba, Winnipeg, Manitoba, while laboratory experiments were made in the Department of Entomology of The University of Manitoba.

CHAPTER II

REVIEW OF LITERATURE

Synonymy

The six-spotted leafhopper has been mentioned in the literature under many different scientific names. According to Beirne (1952) it was first described in 1858 as Thamnotettix fascifrons by Stal, redescribed by Fallen in 1806 as Cicadula sexnotata, and redescribed in 1877 by Uhler as Cicadula divisa. Other names it has had are Cicadula quadrilineata, C. pallida, C. scripta, Macrosteles slossoni and M. wilburi. Medler (1942) mentioned the name Jassus divisus. Osborn (1912,1916) used the name Cicadula sexnotata. In reviewing economic literature of recent years the name most commonly used is Macrosteles divisus. Beirne (1952) claims the correct name as M. fascifrons, qualified as M. fascifrons complex.

Distribution

According to Osborn (1912) the widely distributed six-spotted leafhopper Cicadula sexnotata was found in Europe more than a century ago. Uzel (1911) reported this species as injurious to sugar beet in Bohemia. Ellinger (1918) reported the same insect as injurious to wheat, oats, and barley in Sweden. Junger (1906) stated that the insect was well known throughout Germany as the cause of severe injury to grasses,

cereals and certain legumes. Kunkel (1926) stated that it occurs in Japan and probably throughout the orient.

Osborn found a specimen of Cicadula sexnotata in the Harris collection in the Boston Society of Natural History which according to Severin (1929) was probably collected between 1840 and 1850, but had no published record prior to 1884. This lack of published record of the occurrence of this insect suggested that it might be an introduced species. Yellows in lettuce was first described by Carpenter (1916) who stated that it was particularly severe in the Rio Grande Valley in Texas. Ogilvie (1927) reported an infestation of the six-spotted leafhopper in Bermuda. Severin (1929) reported the appearance of the insect on lettuce in California. He stated that Smith, who worked with aster yellows in Massachusetts noticed aster yellows at Boulder Creek, Santa Cruz County during 1925. Criddle (1931) reported a heavy and widespread infestation of the six-spotted leafhopper in Southern Manitoba, especially at Morden, Miami, and Treesbank. King and Arnason (1937) reported that the same insect was abundant at Saskatoon, Saskatchewan, infesting lawns, lettuce and other plants. Dorst (1937) reported the wide distribution of this insect in the United States and Canada. Handford (1937) reported the presence of this insect in the Aweme district, Manitoba. Arnason (1944) reported a heavy infestation on carrots at Moose Jaw, Saskatchewan, and he stated that 50 to

70 per cent of the crops were damaged. Stephen (1948) reported the spread of aster yellows in a large patch of carrots north of Brandon, Manitoba.

Life history

In the literature there is considerable disagreement with respect to the manner in which the insect vector overwinters. Osborn (1916) obtained a few individual adults in early spring but was uncertain of the method of overwintering. Kunkel (1926) believed that the six-spotted leafhopper overwinters in the egg stage in New York City but Severin (1924) said that it overwinters in the adult stage in California. Beckwith and Hutton (1929) stated that overwintering is done in the adult stage in New Jersey. Ashdown et al (1948) reported that Linn believed that the insect does not overwinter in the egg stage at Staten Island but that they may migrate from other localities to Staten Island. Stearns and MacCreary (1938) showed that the leafhopper can fly several miles over natural barriers when conditions are favourable. Beirne (1952) stated, "It is not clear whether the winter is passed in the adult or in the egg stage". Most previous life history studies have been mainly concerned with the relationship of this insect to aster yellows virus.

Relationship to aster yellows

Smith (1902) was the first to recognize the aster yellows

disease on flowers in Massachusetts. Kunkel (1926) pursued the study of the disease on several species of plants and vegetables. Kunkel's papers (1924,1926,1932) and those of Severin (1929,1932,1934) give the chief information about the disease and the relationship of the insect to its spread and development. In the opinion of Smith (1937), a rather strong point in favour of a specific relationship between leafhopper and virus lies in the fact that certain plant viruses can be transmitted by only one species. Heretofore it had been assumed that the aster yellows virus could be disseminated only by the aster leafhopper, Macrosteles divisus (Uhl.) = (Cicadula sexnotata) (Fall.) and by no other means except grafting and budding of the plant.

According to Kunkel (1926), the intimate and specific relation existing between the aster yellows virus and its insect vector is important evidence that the "causative entity is biological rather than chemical". Leach (1940) emphasized the biological, obligatory and highly specific transmission of virus by leafhoppers.

Aster yellows

Kunkel (1926,1931) reported that he experimentally transmitted the New York aster yellows virus by means of the aster leafhopper, Macrosteles divisus (= Cicadula sexnotata Fall.) to 184 species of plants in 151 genera belonging to 38 families. Severin (1929) reported the transmission of the

California aster yellows virus to celery, lettuce and other plants by short-winged aster leafhopper. Severin (1932) experimentally infected eleven varieties of carrots with aster yellows by infective leafhoppers. He also demonstrated that the virus of carrots, parsley, and parsnip yellows is identical with that of California aster and celery yellows. According to Leach (1940) the disease is rare or absent in Europe but there are a few reports of its occurrence in other countries such as in Bermuda. Leach believed that the disease is of American origin and can be found throughout North America. But Dorst (1931,1937) claimed that the vector Cicadula sexnotata (Fall.) was a European species and was not found in America. Later Kunkel (1926) concluded that the insect was introduced into America. The disease on lettuce has been named in different ways. Some of the terms referring to the same disease are "Rio Grande disease", "White heart", "Rabbits' ear", and "Aster yellows". The latter name is currently used in literature since it indicates the fact that the disease is caused by the aster yellows virus.

Severin (1929) described the symptoms on affected lettuce as follows: the outer leaves of the lettuce are yellow with a blanched appearance of the heart leaves, and a stunting of the plant. Dwarfism of the youngest leaves and reduction of the blades to a little petiole occur. In infected lettuce before heading the heart leaves curl outward instead of

inward and no heads are formed. If infected after heading the lettuce shows dwarfed blanched heart leaves which fail to form solid heads. Brown spots are visible along the margin of the heart leaves, and sometimes the tips of the central dwarfed leaves are entirely brown.

Severin (1929) described an infected carrot plant as a plant which shows a marked yellowing of the younger central leaves, and the older outer leaves are usually reddened or purple. A dense growth of adventitious chlorotic shoots occasionally develops at the center of the crown. The leaflets on the shortened petioles are sometimes reduced to short filaments which often become dry.

Control

Several attempts to control the six-spotted leafhopper have been made but no satisfactory economical method has been devised. Ashdown et al (1948) reported that Pepper and Haesler in New Jersey, obtained a successful control of the insect by using pyrethrum and rotenone dust containing sulphur, but Linn using the same materials failed to obtain a control on seeded lettuce crop in the Muckland area in New York. According to Ashdown et al (1948) Smith et al obtained good control by using DDT aerosols against six-spotted leafhoppers. Heald (1943) said that a number of different methods of exclusion of the leafhoppers by means of a wire screen fence were successfully obtained in New York though the same method was unsuccess-

ful in Wisconsin. Ashdown et al (1948) experimented by using 5 per cent DDT dust at 35 pounds per acre at five-day intervals from the time of emergence of seedlings until about three weeks before harvest. They obtained good control of the six-spotted leafhopper. Hervey et al (1948) using 4 pounds of 50 per cent DDT wettable powder and two quarts of a summer oil emulsion in 100 gallons of water applied three times at ten-day intervals were able to control the insects. Heald (1943) stated that disease is less severe in plots surrounded by cultivated fields than in those adjacent to pastures or waste lands, because of a smaller population of the vector. He also suggested that prevention or reduction of yellows disease can be obtained by the elimination of overwintering hosts from the vicinity of aster plantings and by the removal and destruction of aster plants as soon as symptoms of the disease are present.

CHAPTER III

BIOLOGY OF THE SIX-SPOTTED LEAFHOPPER

Life history

The description of the six-spotted leafhopper has been comprehensively discussed by Dorst (1937), Medler (1942), and Beirne (1952) but those authors give little life history of this insect. No life history studies have been made in Manitoba. The six-spotted leafhopper is ubiquitous. The insect is found on many different species of plants in Winnipeg, Manitoba. The commonest plants on which these insects were observed during the summer of 1954, were lettuce, carrot, ragweed, stink weed, clover, celery, flax and sunflower. Information as to natural occurrence on overwintering hosts is very incomplete.

According to Heald (1943) the aster yellows virus and leafhoppers overwinter in the same wild hosts, including wild carrots, sow thistles, fall dandelion, daisies, and chrysanthemums in the eastern United States. In different localities the insect has been indirectly proved to overwinter in different stages.

In Winnipeg, Manitoba, adult insects were collected on May 21, 1954, while the snow was still on the ground. The absence of nymphs at the time of collection and the abundance of the adults on stink weed, clovers and grasses indicate

that the insect probably overwinters in the adult stage in Winnipeg, Manitoba. About four weeks after their first appearance the adult female begins to deposit eggs on various species of plants such as ragweed, portulaca, carrot and lettuce. The eggs are deposited in the veins or under the epidermis of plants, in the leaf-sheath and in the base of fleshy petioles. The eggs are deposited in slanting close rows and sometimes scattered singly in the veins of the leaves. The egg hatches in about a week and the resulting nymph begins to feed on the sap of the leaves of host plants. The nymphs moult five times in sixteen to eighteen days under laboratory conditions. All the instars are active and can hop when disturbed. The complete life cycle of the six-spotted leafhopper in Winnipeg, Manitoba, from egg to adult, is approximately twenty-five days under laboratory conditions. There are two and a half generations per year in Winnipeg, Manitoba, under laboratory conditions, and under field conditions two generations per year. The second generation was completed in 1954 by the end of August under field conditions, and further development was prevented by the onset of cold weather.

Parasites and predators

No parasitism was observed of any of the life stages. The only predators noted were larvae of Chrysopidae, popularly known as aphid-lion larvae. Although the larvae were seen feeding on the adult leafhoppers, the extent of predatism is

probably very slight because the prey is so active that it can easily escape except when it is trapped as reported below.

On August 24, 1954 a sweep net was used to collect six-spotted leafhoppers from the lettuce in the field plots. An aphid-lion larva was caught in the net with the leafhoppers. When they were transferred to a bottle the aphid-lion larva was observed attacking the leafhoppers and later was observed feeding on a leafhopper. Four aphid-lion larvae were collected from the lettuce in the field and were caged with ten live leafhoppers. After twenty-four hours three of the leafhoppers were found dead. An attempt to feed aphid-lion larvae with six-spotted leafhopper eggs contained in lettuce leaves, was unsuccessful. The eggs were not attacked and after five days the aphid-lion larvae died.

Adult

The six-spotted leafhopper has presented so much resemblance to other species of the Macrosteles group that an identification was necessary. Eighty-one individuals were collected from various plants and they were mounted and sent to Ottawa for identification. Dr. B.P. Beirne, Systematic Unit, Entomology Division, Ottawa, identified them as Macrosteles fascifrons (Stal).

The description of the adult six-spotted leafhopper Macrosteles fascifrons (Stal) by Beirne (1952) fits the species found in Winnipeg, Manitoba. The full description of this

insect can also be found in Dorst's publication (1937), and Medler (1942). The leafhopper is greenish yellow, three to four millimeters in length. The insect has six dark spots on the vertex of the head. The head is broadly rounded with the front. The fore wing is brownish to darkish brown.

On May 21, 26, and June 1, 1954, an insect net was used to obtain adult six-spotted leafhoppers from stink weed, grasses, rhubarb, asparagus and clovers. There were no nymphs obtained in all the collections made. There was still some snow in sheltered localities at the time of the first collection.

The six-spotted leafhopper was found at the field plots of The Division of Plant Science, The University of Manitoba, on various species of plants including, grasses, portulaca, ragweed, beets, lettuce, carrot, and flax. Both the adults and nymphs feed chiefly upon the sap especially upon the veins of the leaves. Whenever the insect feeds upon the sap of the leaves a puncture is made, and whenever an egg is deposited in the veins or under the epidermis of plants such as lettuce and carrot, a definite brownish puncture is made. The nymphs and the adults are usually found on the under sides of the leaves. When approached they hop readily.

Studies of the number of generations of the six-spotted leafhopper were conducted in the laboratory. On June 7, Great Lake head lettuce and Chantenay carrots were seeded in four pots, two of each. On June 14, after the lettuce and

carrot shoots had appeared in the pots, live adult leafhoppers from the field were put in three of the four pots, three (on lettuce), six and twelve (on carrots) respectively. The fourth pot was seeded in order that fresh lettuce could be obtained when needed. The cage (Fig. 1) was a lantern glass covered on top with fine mesh cheese cloth held tightly in place with an elastic band. The flower pot containing three leafhoppers was set in a pot-saucer. Water was supplied regularly to the saucer. Observations were made daily on the insects. The other two pots containing six and twelve leafhoppers respectively were kept in case anything should happen to the first pot. On July 14, several nymphs were observed on the lettuce plants in the cage containing three adult leafhoppers. On July 16, the three original adults were transferred to another fresh pot of lettuce. Observations were made daily on the first generation nymphs. On July 20, thirty-two first generation nymphs were transferred by means of a fine camel-hair brush into a fresh pot of lettuce. On August 13, second generation nymphs were observed in this pot. All the first generation adults were transferred into another fresh pot of lettuce. The second generation nymphs were divided into three groups and distributed into fresh lettuce pots so that if something should occur to one pot another one could be used. On September 26, two third generation nymphs were seen in the pot. Some eggs were seen on the lettuce leaves in the cage.

FIGURE 1

REARING CAGE FOR Macrosteles fascifrons

On September 29, the adults and the nymphs were apparently thriving. On September 30, two adults and all the nymphs were found dead. All the adults and nymphs in the other cages were also dead the following day. This was probably due to the severe cold weather which occurred during the long week end. In the laboratory there are two and a partial third generations in Winnipeg, Manitoba. From the dates shown above there would be two complete generations in the field.

Oviposition and incubation

Studies of the preoviposition period of the six-spotted leafhopper were conducted in the laboratory. Twelve pots, six of lettuce and six of carrots, seeded on July 15, were placed on the window sills in the laboratory. On July 20, twelve adult six-spotted leafhoppers were collected from lettuce in the field and were put in one cage containing lettuce. These twelve leafhoppers which were enclosed in the cage on July 20, at 11:45 A.M. were carefully transferred on July 21, (at 11:45 A.M.) to another cage of fresh lettuce. The transfer was made by tilting the lantern a little and then using a tiny grass stem, about a foot long, to disturb the insects, taking care not to damage either the plants or the insects. The insect running for safety climbed the sides and the top of the lantern. By quickly removing the lantern and setting it over the new pot of lettuce which had been set close by, the insects

were transferred. The transfer was best done when the top of the lantern could be tilted towards the light. As soon as the transfer was made labels were affixed and the time of transfer was noted. The lettuce in the first pot from which the transfer was made was examined for eggs. Daily observations were made and the incubation period was calculated from the time the adults were placed on the plants to the time the nymphs emerged, (Table I). The incubation period was approximately eight days.

TABLE I

INCUBATION PERIOD OF EGGS OF Macrosteles fascifrons ON LETTUCE IN THE LABORATORY

Date and time adult enclosed	No. of adults enclosed	Date and time nymphs observed	Incubation period days
July 20.11.45 A.M.	12	July 28. 9.10 A.M.	8
21.11.45 A.M.	12	29. 11.05 A.M.	8
22.10.00 A.M.	20	31. 10.40 A.M.	9
23.11.00 A.M.	20	31. 11.00 A.M.	8
		Average	8.25 days

In order to find oviposition sites two Great Lake lettuce plants and two Chantenay carrot plants were removed from unsprayed field plots which were infested by six-spotted leafhoppers. The plants were taken to the laboratory and were examined under the binocular microscope for eggs. By means of

a graduated ruler a square inch of lettuce leaf was measured and cut. Five of these squares of lettuce leaf and five of lettuce leaf-stalk were cut and examined for eggs. In the same way five squares of carrot leaf and five of carrot stem were also examined. The number of eggs were counted in each of the squares, (Table II). Table II shows a total number of 104 eggs found in five squares of lettuce as opposed to no eggs in the five leaf-squares of carrot, and a total of 30 eggs in five stem-squares of lettuce to 7 eggs in the five stem-squares of carrot. Most of the eggs were found in the veins of the leaves especially on the under sides. On other occasions leafhopper eggs were found in the leaves of portulaca and ragweed.

Egg

The eggs are deposited in the leaf-sheath and in the base of the blade. In some cases the eggs are imbedded in the fleshy petioles. The eggs are inserted in the tissue at an angle, often eight to twelve in a row, but were also commonly found as scattered single eggs in the veins of the leaves. The egg is slightly curved at one end, cylindrical, elongate and is transluscent and greenish white. The incubation period during the summer in Winnipeg, Manitoba, under laboratory conditions, is eight to nine days. The eggs can be seen with a hand lens or under the binocular microscope.

TABLE II

COUNTS OF EGGS OF Macrosteles fascifrons ON ONE-SQUARE INCH SAMPLES OF LETTUCE LEAVES AND LEAF STALKS, AND CARROT LEAVES AND STEMS.

Lettuce		Carrot	
Leaf square	no. of eggs found	Leaf square	no. of eggs found
1	20	1	0
2	18	2	0
3	15	3	0
4	27	4	0
5	24	5	0
Total	104		0
Leaf stalk square		Stem square	
1	5	1	1
2	9	2	3
3	4	3	2
4	7	4	0
5	5	5	1
Total	30		7
Total lettuce	134	Total carrots	7

The eggs are usually more easily seen on the under side of the leaves than on the upper surface of the leaves. Over forty-five eggs were counted within the length of one inch of a leaf of lettuce.

A few portulaca and ragweed leaves were removed from the area surrounding the plots which were infested by six-spotted leafhopper. The portulaca leaves were kept in three clean butter plates. The ragweed leaves were placed in three other clean butter plates. All the plates were set on the window sill in the laboratory to incubate at room temperature. Examination of the leaves under the binocular microscope revealed several eggs. Daily observations were made to find out if the eggs observed were those of the six-spotted leafhopper. After several days of incubation several six-spotted leafhopper nymphs were observed in the plates. As soon as a nymph was observed it was transferred to a fresh lettuce pot.

Nymph

Four butter plates were set in the laboratory, two of which contained fresh lettuce leaves and the other two contained ragweed leaves and portulaca leaves respectively. Ten nymphs which had hatched from portulaca leaves mentioned above were transferred into the new plate of fresh portulaca leaves. Another set of ten nymphs from portulaca were transferred into a fresh lettuce plate. Similarly ten nymphs from ragweed leaves were transferred into a fresh plate containing ragweed

leaves while ten nymphs from the ragweed also were transferred into a fresh plate of lettuce leaves. Observations were made daily to find out if the insects would thrive on these different hosts. It was observed that after a few weeks, (July 22-29), all the nymphs in both the plates of ragweed and portulaca leaves were dead whereas all the nymphs transferred to lettuce leaves were alive and active (Table III). This indicates that under laboratory conditions nymphal survival is better on lettuce than on portulaca or ragweed.

TABLE III

SURVIVAL OF NYMPHS OF Macrosteles fascifrons TRANSFERRED ON JULY 22, 1954 FROM PORTULACA AND RAGWEED TO LEAVES OF LETTUCE, PORTULACA AND RAGWEED IN THE LABORATORY. (10 NYMPHS PER BUTTER PLATE)

Host	Number of nymphs surviving		
	July 25	July 28	July 29
Lettuce	10	10	10
Lettuce	10	10	10
Portulaca	4	0	0
Ragweed	6	1	0

Lettuce leaves containing six-spotted leafhopper eggs were kept in five butter plates and were incubated at room temperature. Observations were made daily to find out the day the eggs would hatch so that the duration of the instars

could be determined. This was done by observing the plates daily and transferring the nymphs after each moult into another fresh lettuce plate. The transfer was made by using a fine camel-hair brush. It was observed (Table IV) that the nymphs moulted five times in sixteen to eighteen days. The duration of each instar was approximately the same. Under field conditions the time spent in the nymphal instars is probably longer than that determined under laboratory conditions.

TABLE IV

DURATION OF INSTARS OF *Macrosteles fascifrons* REARED IN THE LABORATORY

Date eggs hatched	Nymphs per cage	Maximum duration in days, calculated from the moult of the latest nymph in each cage					
		First instar	second instar	third instar	fourth instar	fifth instar	total
July 28	4	4	3	3	4	3	17
29	10	5	3	3	3	4	18
Aug. 3	15	3	3	4	4	4	18
5	9	3	3	3	3	6	18
6	10	3	3	3	4	3	16
Average		3.6	3	3.2	3.6	4	17.4

The first instar is dusky, darkish brown. The second instar is pale white with dull red eyes. The third instar has

slightly visible wing pads and hops more readily than the first and second instars. The fourth and fifth instars show distinct wing formation.

CHAPTER IV

METHODS AND MATERIALS IN CHEMICAL CONTROL

Description of plots

There were three main blocks (Fig.2). The three main blocks were each divided into nine plots. Each block was replicated three times, making a total of twenty-seven plots. Each block was 143 feet long. Each plot was fifteen feet long with a two foot space between every plot. The plots were surrounded by different varieties of apple trees. On June 16, the plots were raked and prepared for seeding. Each plot was given a letter as shown in Figure 2 except the last plot which had a double letter, so that the letters ran from A to Z, and last plot ZZ. Each plot consisted of two rows of carrots and one row of lettuce. Because of the heavy seeding, the lettuce and carrots were thinned. The plots were tilled as often as possible but the surrounding area contained different species of weeds such as stink weed, ragweed and portulaca which were not mowed until they were quite tall.

Seeding of plots

On June 16, furrows were made with a hoe along string stretched along the plots. By hand, Chantenay carrot seeds were first sprinkled into the furrows and were firmly covered with soil. Similarly Great Lake head lettuce was seeded and

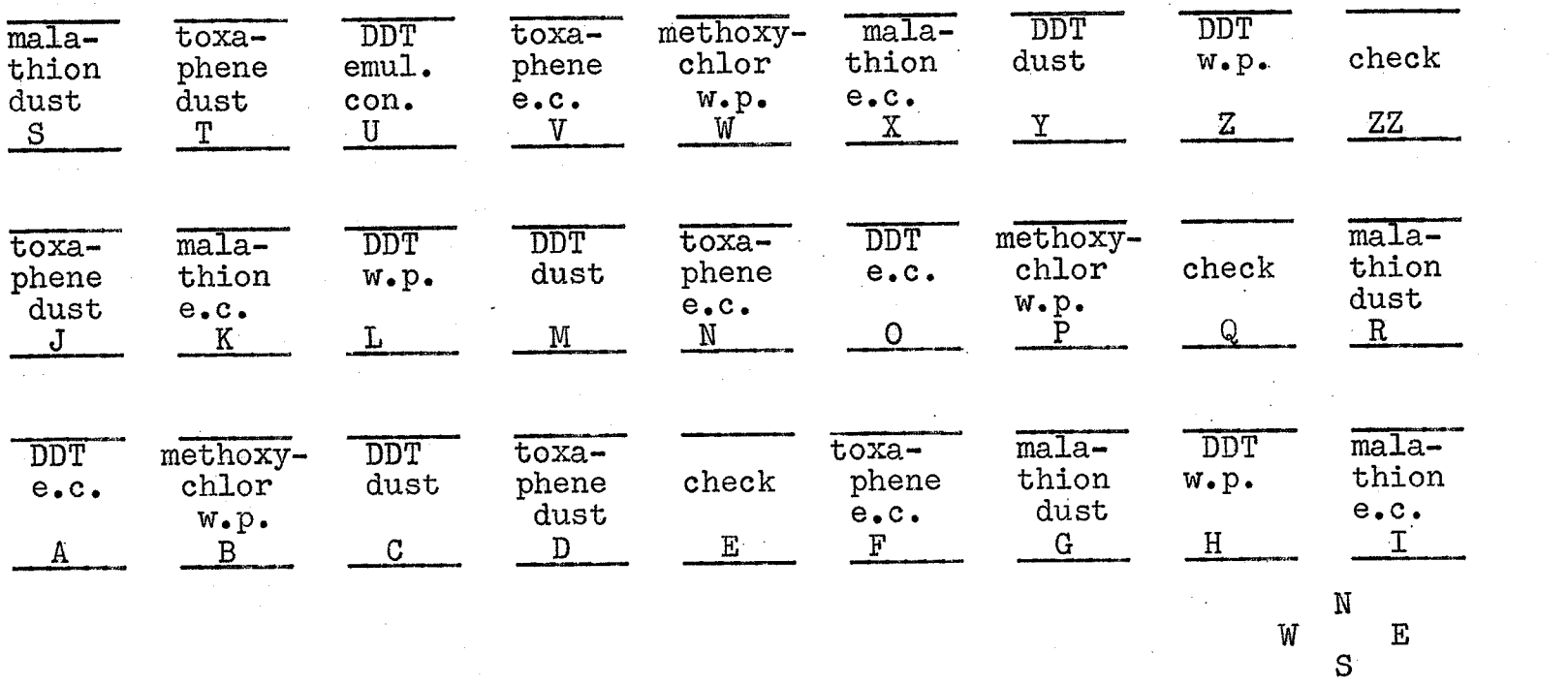


FIGURE 2

PLAN OF PLOTS USED IN CHEMICAL CONTROL OF
Macrosteles fascifrons

covered with soil. The seeding was all done by hand and thinning was done twice after the emergence of the seedlings. All the weeds were hoed except in cases where the weeds were close to the plants and had to be removed by hand.

Insecticides tested

The following insecticides were used in 1954 in field plot-trials to find a control for the six-spotted leafhopper:

1. Toxaphene, 60 % emulsifiable concentrate, at 1.5 lb. of actual material per acre.
2. Toxaphene, 10% dust, applied at 1.5 lb. of actual material per acre.
3. Malathion, 50% emulsifiable concentrate, at 1.5 lb. of actual material per acre.
4. Malathion, 4% dust, at 35 lb. per acre.
5. DDT, 25% emulsifiable concentrate, at 2 lb. of actual material per acre.
6. DDT, 50% wettable powder, at 2 lb. of actual material per acre.
7. DDT, 3% dust, at 2 lb. of actual material per acre.
8. Methoxychlor, 50% wettable powder, at 1.5 lb. of actual material per acre.
9. Check (unsprayed).

Application of insecticides

Insecticides were applied once a week, for seven con-

sective weeks, beginning when the plants were newly emerged seedlings, at which time the rows of lettuce and carrots were barely distinct. Application of the dusts and sprays was made every Friday morning on the following dates: July 2,9, 16,23,30, August 6, and 13. The sprays were applied by means of a Dobbins Bighead 2½ gallon compressed-air sprayer and the dusting was done with a small Hudson hand-duster. Because of the interference of little showers of rain during the first three applications, and because of the heavy increase in population of the insects, the insecticides were applied at a double rate for the last four weeks of the seven consecutive weeks of application.

Counts were made of adult leafhoppers present 24 hours and 72 hours after each application (Tables V and VI). This was done by waving the hand to and fro twice along a linear foot of row and counting quickly the numbers of adults disturbed in this manner, which flew up from the leaves. The counts were made on the following dates: July 3, 10, 17, 24, 31, August 7, 14 and July 5, 12, 19, 26, August 2, 9, 16, 24-hour count and 72-hour count respectively.

A count was made of nymphs present on each plot at the end of the seven weeks (Table VII). The count was made on August 17, by counting the number of nymphs on twelve lettuce plants and twelve carrot plants on each plot.

TABLE V

COUNTS OF ADULTS OF Macrosteles fascifrons
PRESENT 24 HOURS AND 72 HOURS AFTER APPLICATION
OF INSECTICIDES, FIRST THREE WEEKS OF EXPERIMENT

Insecticides, formulation and strength actual per acre	Total of three replicates 24-hour count				Total of three replicates 72-hour count			
	July 3	July 10	July 17	Total	July 5	July 12	July 19	Total
DDT 25% e.c. at 2 lb.	8	2	11	21	2	12	29	43
DDT 50% w.p. at 2 lb.	9	13	28	50	15	11	41	67
DDT 3% dust at 2 lb.	13	16	18	47	10	24	32	66
Methoxychlor 50% w.p. at 1.5 lb.	8	8	18	34	6	20	38	64
Toxaphene 60% e.c. at 1.5 lb.	29	22	45	96	39	31	84	154
Toxaphene 10% dust at 1.5 lb.	38	29	46	111	30	29	69	128
Malathion 4% dust at 1.4 lb.	10	2	12	24	19	20	39	78
Malathion 50% e.c. at 1.5 lb.	3	2	6	11	15	19	28	62
Check	42	33	124	199	34	44	198	276
Total	160	125	308	593	170	210	558	938

TABLE VI

COUNTS OF ADULTS OF Macrosteles fascifrons
PRESENT 24 HOURS AND 72 HOURS AFTER APPLICATION
OF INSECTICIDES, LAST FOUR WEEKS OF EXPERIMENT

Insecticides, formulation and strength actual per acre	Total of three replicates 24-hour count					Total of three replicates 72-hour count				
	July 24	July 31	Aug. 7	Aug. 14	Total	July 26	Aug. 2	Aug. 9	Aug. 16	Total
DDT 25% e.c. at 4 lb.	10	1	10	1	22	15	17	9	0	41
DDT 50% w.p. at 4 lb,	21	1	11	5	38	24	13	16	0	53
DDT 3% dust at 4 lb.	1	0	5	1	7	10	10	23	0	43
Methoxychlor 50% w.p. at 3 lb.	11	2	9	2	24	13	19	6	0	38
Toxaphene 60% e.c. at 3 lb.	53	13	38	14	118	63	47	19	11	140
Toxaphene 10% dust at 3 lb.	45	11	32	15	103	50	45	47	14	156
Malathion 4% dust at 2.8 lb.	8	11	8	0	27	6	37	33	0	76
Malathion 50% e.c. at 2.8 lb.	8	1	4	2	15	5	17	15	1	38
Check	200	86	209	200	695	335	173	203	140	851
Total	357	126	326	240	1049	521	378	371	166	1436

TABLE VII

COUNTS OF NYMPHS OF Macrosteles fascifrons
MADE AFTER FINAL INSECTICIDE APPLICATION
ON SEPTEMBER 14, 1954

Plots	No. of nymphs per block on carrot	No. of nymphs per block on lettuce	Total
DDT emulsifiable concentrate	0	0	
	0	0	0
	0	0	
Methoxychlor wettable powder	0	0	
	0	0	0
	0	0	
DDT dust	0	0	
	0	0	0
	0	0	
DDT wettable powder	0	0	
	0	0	0
	0	0	
Malathion dust	0	0	
	0	0	0
	0	0	
Malathion emulsifiable concentrate	0	0	
	0	0	0
	0	0	
Toxaphene dust	0	4	
	3	12	24
	2	3	
Toxaphene emulsifiable concentrate	5	13	
	3	22	72
	1	28	
Checks	13	49	
	6	59	192
	5	60	
Total	38	250	288

Estimation of results

Four weeks after the application of the insecticides was stopped, (September 14), the carrots were harvested and findings were recorded. The carrots were dug out carefully by means of a garden fork and they were arranged on the sides of the rows. Final results were obtained by counting all the carrots in each plot, noting the number infested with aster yellows disease. Table VIII shows the number and the percentage of carrots infested with aster yellows for each treatment.

Testing of insecticides on eggs

Several lettuce leaves were removed from an unsprayed plot which was infested by six-spotted leafhoppers. The leaves were examined for leafhopper eggs under the binocular microscope. The eggs were counted. Lettuce leaves containing over twenty-five eggs were sprayed with insecticides and placed in butter plates on the table in the laboratory. All the insecticides used were at the same rates as in the original field plot experiments. Five sets of lettuce leaves containing eggs were sprayed with methoxychlor 50 per cent wettable powder. Another set of plates containing lettuce leaves was set on the table as a control. Similarly five other plates were sprayed with malathion 50 per cent emulsifiable concentrate. A control was also used. Another set of

TABLE VIII

PERCENTAGE OF ASTER YELLOWS INFECTION
ON CARROTS AT TIME OF HARVESTING

Plots	Total no. of carrots	No. infected	Percentage infected
A	342	38	11.1
B	319	20	6.3
C	317	14	4.4
D	374	130	34.8
E	375	137	36.5
F	289	71	24.6
G	301	24	8.0
H	270	20	7.4
I	335	28	8.4
J	314	96	30.6
K	290	29	10.0
L	329	15	4.6
M	322	32	9.9
N	332	126	38.0
O	322	24	7.5
P	323	26	8.1
Q	426	102	23.9
R	375	37	9.9
S	292	47	16.1
T	297	99	33.3
U	262	30	11.5
V	266	108	40.6
W	231	26	11.2
X	263	17	6.5
Y	297	22	7.4
Z	294	28	9.5
ZZ	351	83	23.7

plates was dusted with malathion 4 per cent dust and a control was used. All the plates were incubated at room temperature. Daily observations were made and each time a nymph emerged it was removed and placed in a new plate of fresh lettuce marked with the same number as on the plate from which the nymph had been transferred. After a period of five days the total number of nymphs which had developed from the eggs in various plates was checked and the findings were recorded. Table IX shows the count of nymphs that had developed from the plates. Malathion emulsifiable concentrate and dust showed strong ovicidal effect and methoxychlor to a slightly less extent. All the nymphs died that were transferred from the plates on which insecticides had been applied, which is evidence of contact poisoning to the nymphs after walking over the treated leaves. All the nymphs from the control plates survived after being transferred.

TABLE IX

EFFECT OF INSECTICIDES ON EGGS OF
Macrosteles fascifrons

Insecticide	Total eggs in 5 plates	Total nymphs emerging from 5 plates	Percent mortality to eggs
Methoxychlor 50% wettable powder	125	23	81.6
Control	125	105	16.0
Malathion 50% emulsifiable concentrate	125	0	100.0
Control	125	113	9.6
Malathion 4% dust	125	1	99.2
Control	125	118	5.6

CHAPTER V

RESULTS AND DISCUSSIONS

In the spring and summer of 1954 an experiment was conducted on field plots of the Division of Plant Science, The University of Manitoba, to try to find a chemical control for the six-spotted leafhopper on carrots and lettuce.

Effect of insecticides on eggs

Malathion emulsifiable concentrate and malathion dust showed strong ovicidal effect. In all the plates on which malathion emulsifiable concentrate was applied, no nymphs were observed. The plate on which malathion dust was applied had one nymph and another which only partially emerged. A few nymphs were observed in each of the plates treated with methoxychlor. Table IX shows the percent mortalities for each insecticide tested.

Nymphal count

Table VII shows the nymphal count that was made after the application of insecticides had ceased. Only unsprayed plots and those of toxaphene dust and emulsifiable concentrate had nymphs. There were more nymphs found on the lettuce plants than on the carrot plants. Sixty-three nymphs were counted on twelve lettuce plants as compared with nine nymphs counted on twelve carrot plants on the toxaphene emulsifiable concentrate

plot. There were 168 nymphs counted on the check plot per twelve lettuce plants as compared with 24 nymphs per twelve carrot plants. The absence of nymphs on all the other plots except those of check and toxaphene emulsifiable concentrate suggests a contact poisoning to the nymphs after walking on the sprayed or dusted plants.

24-hour and 72-hour counts

Counts were made of adult leafhoppers present 24 hours and 72 hours after each application of the insecticides. Tables V and VI show the following: the number of adult leafhoppers counted before and after the rates of the insecticides were doubled; the total number of adult leafhoppers counted per three replicates and the increase in population of leafhoppers after every 24-hour count as indicated by the 72-hour count.

Doubling the rate of the insecticides did not/appreciably decrease the number of adults on the 24-hour and 72-hour counts.

Assessment of harvested carrots

The final results obtained by counting all the carrots in each plot, and noting the number infected with aster yellows are shown in Table VIII. The infected carrot roots produced numerous bunched adventitious rootlets arising from the elevations on the carrot root (Fig.3). Uninfected carrot root is large, robust, and lacks bunched rootlets (Fig.4).

FIGURE 3

CARROT INFECTED WITH ASTER YELLOWS

FIGURE 4

HEALTHY, UNINFECTED CARROT ROOT

DDT 25 per cent emulsifiable concentrate, at the rate used, caused a noticeable dwarfing of the foliage of carrot and scars on the carrot roots. The foliage of the carrot plants was yellowish, and reduced while the roots were rough and pock-marked (Fig. 5). Figure 5 shows the scars on the carrots. The carrot leaves were burnt, and the plants were about an inch shorter than the rest of the plants on other treated plots.

Toxaphene dust or emulsifiable concentrate proved very ineffective in controlling the six-spotted leafhoppers although the insecticide did not injure the plants. Figure 4 shows one of the robust uninfected carrot roots which were harvested from the plots on which malathion, methoxychlor, DDT wettable powder, and toxaphene had been applied. The least infected plots were those on which DDT dust, wettable powder, or emulsifiable concentrate, malathion emulsifiable concentrate or dust, and methoxychlor wettable powder were applied. The most infected plots were those of toxaphene dust or emulsifiable concentrate, and the checks. The symptoms of the aster yellows disease were easily recognized on the carrots.

Assessment of unharvested lettuce

All the lettuce plants died in all the plots. This was possibly due to aster yellows disease, but the symptoms on lettuce were somewhat obscure, and could not be determined. The contributing factors may have included root-rots, excessive

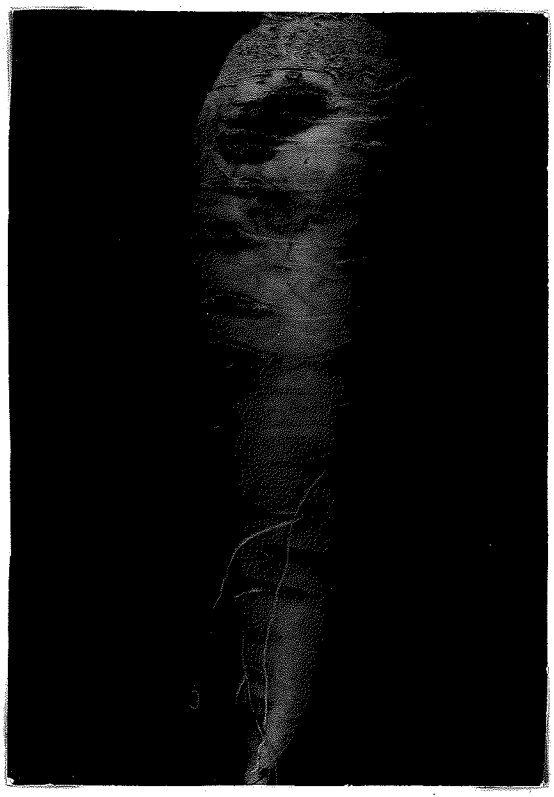


FIGURE 5

EFFECT OF DDT 25 PER CENT EMULSIFIABLE CONCENTRATE ON CARROT ROOT

rainfall or 2,4-D drift.

Discussion

Table X shows the average percentage of infected carrots for each treatment, derived from Table VIII. Results of this experiment indicate that a fair measure of control of leafhoppers on carrots can be obtained by a weekly application of DDT dust or wettable powder, malathion dust or emulsifiable concentrate, or methoxychlor wettable powder. Continued application is necessary in order to obtain a complete control of the leafhoppers because they migrate in from other areas. Protection must be maintained from the time the seedlings emerge. Doubling the rate of insecticides does not decrease the number of adults found on the 24-hour and 72-hour counts.

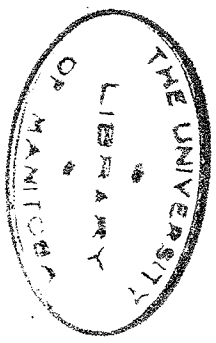
DDT 25 per cent emulsifiable concentrate gave a reasonable control but at the rate used it was noticeably injurious to lettuce and carrot plants. The carrot roots were heavily scarred and pock-marked (Fig. 5). A comparison can be made by looking at photographs 3,4, and 5. The carrot and lettuce plants on all the plots on which this insecticide had been applied showed dwarfing of the foliage, yellowing, and burnt leaves. This result suggests that DDT 25 per cent emulsifiable concentrate is not favourable for use on lettuce and carrot at the rates used.

Toxaphene dust or emulsifiable concentrate was not

TABLE X

PERCENT INFECTION OF ASTER YELLOWS ON CARROTS FOR EACH TREATMENT

Insecticide	Total percentage of infected carrots per three plots	Average percentage of infected carrots
DDT wettable powder	21.5	7.2
DDT dust	21.7	7.2
Malathion emulsifiable concentrate	24.9	8.3
Methoxychlor wettable powder	25.6	8.5
DDT emulsifiable concentrate	30.1	10.0
Malathion dust	34.0	11.3
Check	84.1	28.0
Toxaphene dust	98.7	32.9
Toxaphene emulsifiable concentrate	103.2	34.4



harmful to the plants but proved very ineffective in controlling the six-spotted leafhoppers. Table X shows average percentage of 28 infected carrots on the check as compared with 34.4 on toxaphene emulsifiable concentrate and 32.9 on toxaphene dust plots.

All the counts of eggs (Table II), nymphs (Table VII), and adult leafhoppers (Table XI) on lettuce exceeded the counts made on carrots. Perhaps the insect is more attracted to lettuce for oviposition than to carrot. Although the results of this experiment show that a fair measure of control of leafhoppers on carrots can be obtained by weekly application of DDT dust or wettable powder, malathion dust or emulsifiable concentrate, or with methoxychlor wettable powder, cost and availability of insecticide must be considered in any recommendation. It would be expedient to compare the cost of protection with the cash value of the crop to be protected before the control measures are taken.

TABLE XI

COMPARISON BETWEEN ADULT COUNTS OF *Macrosteles fascifrons* ON LETTUCE AND ON CARROTS, ALL PLOTS

Date of application	Carrot		Carrot		Lettuce	
	24-hr.	72-hr.	24-hr.	72-hr.	24-hr.	72-hr.
July 2	42	55	31	41	87	74
9	39	43	41	37	45	130
16	79	101	76	105	153	352
23	70	149	86	171	201	201
30	23	106	39	121	64	151
Aug. 6	80	84	104	133	142	154
13	63	28	65	55	112	83
Total	396	566	442	663	804	1145

CHAPTER VI

SUMMARY

The six-spotted leafhopper, Macrosteles fascifrons (Stal), has been present in very large numbers in fields and gardens in Manitoba in recent years. It is the most outstanding vector in the transmission of aster yellows, a virus disease of many herbaceous plants. The abundant appearance of the adult six-spotted leafhoppers early in May on a variety of plants including lettuce, carrots, stink weed, clovers, and grasses, and the absence of nymphal stage at the time of collection in May, indicate that the six-spotted leafhopper in Winnipeg, Manitoba, probably passes the winter in the adult stage. The insects were captured early in spring while snow was still on the ground. They were observed in large numbers on grasses and stink weed, suggesting that these plants may also be important overwintering hosts. There was no evidence to indicate that the insect overwinters in the nymphal stage in this latitude. The six-spotted leafhopper feeds on carrots and lettuce as soon as the shoots are out of the ground. The insect feeds and breeds on commercial crops and also in garden crops moving in from surrounding vegetation. The eggs are deposited in the veins of leaves or at the bases of petioles in rows of 8 or 12. The eggs are found in a slanting arrange-

ment in close rows and in scattered single eggs in the veins of the leaves. The incubation period during the summer in Winnipeg, Manitoba is eight to nine days. The eye spots become visible on the fourth day after the egg is deposited. Nymphs moult five times in sixteen to eighteen days. Under laboratory condition there are two and a half generations per year, and about two complete generations in the field. It takes between 24 to 25 days for the six-spotted leafhopper to develop from the day that the egg is laid to the day of the last instar. It was shown that the six-spotted leafhopper breeds on portulaca and ragweed, in all probability it may thrive also on these hosts although the insects did not live on them long in the laboratory. Transferred nymphs which had hatched from eggs deposited in the veins of ragweed and portulaca leaves thrived and developed to adults on lettuce plants.

The count of leafhopper eggs on a square inch of lettuce leaf was more than the count of eggs on a square inch of carrot leaf. The total count of adult leafhoppers on three replicates of carrots compared with the total count of adult leafhoppers on three replicates of lettuce showed that each count on each row of lettuce was more than each count on each row of carrot (Table XI). The consistency of the larger number of eggs, nymphs, and adults counted on lettuce as compared with the number of the same stages counted on carrots, probably suggests that the lettuce is more attractive to the

insect than the carrot. In all probability they oviposit more on the lettuce plants than on the carrot plants.

No parasitism was observed of any of the life stages of the six-spotted leafhopper. The only predators noted were aphid-lions. The aphid-lion larvae were seen in the field feeding on adult leafhoppers, but the extent of predation is probably very slight, because the prey is so active that it can escape. Out of ten live leafhoppers caged with four aphid-lion larvae, only three were killed.

The following insecticides gave practical control of six-spotted leafhopper when applied at seven-day intervals for seven consecutive weeks: DDT wettable powder, DDT dust, malathion emulsifiable concentrate or dust, methoxychlor wettable powder and DDT emulsifiable concentrate. DDT emulsifiable concentrate, at the rate used caused a noticeable dwarfing and yellowing of the foliage of carrot and lettuce plants and scarred the carrot roots. Toxaphene dust or emulsifiable concentrate was ineffective. All the lettuce plants died in all the plots. This was possibly due to aster yellows disease, but the symptoms on lettuce were somewhat obscure, and contributing factors may have included root-rots, excessive rainfall or 2,4-D drift.

CHAPTER VII

PART II

INTRODUCTION

The two major insect pests of asparagus in Canada are the asparagus beetle, Crioceris asparagi (L.), and the spotted asparagus beetle, Crioceris duodecimpunctata (L.). The latter was reported by Armand (1951) as an important pest in Quebec, Ontario, and British Columbia, and it is said to be present wherever asparagus is grown. The numbers of this pest may fluctuate from year to year, and extensive damage may be caused by a serious outbreak. Asparagus is the only crop that is known to be attacked. The main damage inflicted by this beetle results from the feeding of the overwintered adults on the tender tips in early spring. The constant gnawing of the beetle on the shoots causes the shoots to be scarred, tough and woody. The larvae confine their attack to the berries. A knowledge of the life history and habits of this pest is necessary for a proper timing of control measures.

Problem

The purpose of this study was to learn the life history and habits of the spotted asparagus beetle, C. duodecimpunctata (L.), in Manitoba, and to review the literature and recommended methods of control.

Importance of the study

A study of a chart of the nutritive value of cooked asparagus based on edible portions of 100 grams indicates that asparagus is a source of food energy, protein, fat, carbohydrates, calcium, iron, phosphorous, vitamin A, and ascorbic acid. According to the report in The Marketing of Fresh Fruits and Vegetables in Greater Winnipeg (1946), the value of Manitoba asparagus purchased by twenty-two wholesalers, two department stores, and one chain store in Winnipeg is estimated to be $15,264.00. In the report of The Dominion Bureau of Statistics (1954), which gives estimates of acreage and production of asparagus in Canada, and the provinces for 1953, with revised estimates for 1952, Manitoba has a total production of 231,000 pounds out of the total production of 6,694,000 pounds in Canada. No serious infestation or damage by this insect has been reported in Manitoba. No study of the life history and habits of this species has been made in Manitoba. According to Drake and Harris (1932) asparagus plants attacked by these beetles in Iowa, United States, are usually weakened and unable to store up food in their roots to any great extent, causing the next year's yield to be small. In addition to the low yields, the asparagus becomes tough and woody. In order to find a satisfactory method of control, the life history and habits of the pest should be known in advance in the event of future outbreaks.

Location of the study

The main part of the study was conducted at the field plots of the Division of Plant Science, The University of Manitoba, Winnipeg, Manitoba. Some rearing and experimental observations were carried out in the laboratory of the Department of Entomology, The University of Manitoba.

CHAPTER VIII

REVIEW OF LITERATURE

Distribution

According to Drake and Harris (1932), asparagus was brought to North America from Europe by the early settlers, and it was grown as a cultivated crop in the United States for more than two centruies before it became troubled with insect pests of major importance. The two main enemies of asparagus are the asparagus beetles introduced into America from Europe. These pests, and a native fly whose larva is called the asparagus miner, comprise the major insects affecting the growing of asparagus. Chittenden (1907) reported the appearance of the spotted asparagus beetle, C. duodecimpunctata (L.) in the United States in 1896. Drake and Harris (1932) stated that this pest was first found in America in the vicinity of Baltimore, Maryland, in 1881. Then it spread throughout much of the area east of the Mississippi river and today occurs almost everywhere that asparagus is grown. Drake and Harris (1932) discovered this species for the first time in Iowa, at Pleasant Valley on July 29, 1931. Chittenden (1907) pointed out that Smith had observed this species in New Jersey and Delaware in 1898. He also reported that Felt had observed this pest in various places in New York, such as Albany, Batavia, Leroy, Riverdale, Oswego,

Glendale, and also in the Niagara district in Canada as far north as Hamilton, Ontario, in 1899. Chittenden believed that the two species of asparagus beetles appeared to have arrived in the Niagara Peninsula simultaneously, though the spotted asparagus beetle was by far the more common one. In later years different observers noted its further spread in Canada. Professor A.V. Mitchener of the Department of Entomology, The University of Manitoba, records that this insect was first taken in Manitoba in 1948 by W.J. Turnock in a home garden in Winnipeg.

Life history

A comprehensive description of the spotted asparagus beetle can be found in the publications of the following authors: Chittenden (1907), Caesar (1931), Drake and Harris (1932), and Armand (1951). Chittenden described the insect, and gave an illustration of the egg and its manner of deposition. He stated that the insect develops and feeds almost exclusively on the berry, but the adult attacks young asparagus shoots before the berries appear. He described the young, freshly hatched larva as having a round head, nearly twice as wide as long seen from above. The thoracic plates are distinctly separated at the middle, with the intervening areas yellow. The length is 1 mm. and width, 0.35 mm. Caesar described the adult insect as similar in size and shape to the

common asparagus beetle, Crioceris asparagi (L.), but differs from it by its red colour and the twelve black spots on its wing covers. He also described the egg as elongate, dark green, and attached by its side to the branches of the plant. The larva is similar to that of the asparagus beetle but is yellowish white to brownish yellow or orange instead of grey. Drake and Harris also described the stages of the spotted asparagus beetle but stated that each larva devours two or three berries before it achieves full growth and falls from the plant, and enters the soil for pupation. Armand described the spotted asparagus beetle as a slightly larger species than the asparagus beetle. He stated that the eggs hatch in one to two weeks, and the yellow or orange larvae mature in three to four weeks, feeding entirely on the berries. The larvae pupate for two weeks, and the adults emerge. There are two generations per year in Chatham, Ontario. The second generation of adults emerge in September and go into hibernation quarters before winter. All the above authors contend that the larvae of the spotted asparagus beetle confine their feeding entirely to the berries. The only report of a serious injury to young asparagus tips by the larvae was that of Petch (1937).

Control

The asparagus beetle has not been a difficult pest to control because ordinarily it may be kept at low population

levels by simple practices and without much cost to the grower. Dustan et al (1946) experimentally showed that DDT, and benzene hexachloride were effective in killing the spotted asparagus beetles. Caesar (1931) said that cultivation and fertilization of the asparagus plots allow the plants to grow rapidly, and cutting frequently prevents the beetles from injuring the shoots. Caesar stated that poultry can be used on the plots to eat the beetles, but in cases where the plants are heavily attacked he recommended spray with two pounds of arsenate of lead to forty gallons of water to which has been added one-third pound of calcium caseinate mixed spreader. Armand (1951) stated that effective control can be obtained during the cutting season by destroying all the volunteer plants, cutting of the crop every two or three days, and putting pulverized cyanamid along the rows at the rate of 300 pounds per acre to repel the insect, or by spraying or dusting with rotenone. Drake and Harris (1932) recommended sprays or dusts containing rotenone every three or four days while beetles are present. The dust should be used at twenty to thirty pounds per acre of one percent rotenone, while the spray should be satisfactory at one and one-half pounds of derris (5 per cent rotenone) in forty gallons of water. Arsenical applications should never be used on the shoots during the cutting season, but may be used after the cutting season is over.

CHAPTER IX

LIFE HISTORY STUDY

Adult

The spotted asparagus beetle has been described fully by Chittenden (1907), Caesar (1931), Drake and Harris (1932), and Armand (1951). The description of the spotted asparagus beetle by the above authors fits the species found in Winnipeg, Manitoba. In the spring of 1954 several adults were dug out of the soil under different shelters including dandelion, stink weed, rhubarb, ragweed, and asparagus plants. Thirty-five percent of the beetles dug out of the ground in May and early in June, before their normal emergence, were found dead (Table XII). The adult beetle was observed to hibernate in the soil at different depths and under various species of plants. The first emerging adults were seen on June 13, 1954, on the asparagus plot of the Division of Plant Science, The University of Manitoba. The adults upon emerging fed on the newly emerged tender tips and leaves of the asparagus plants. Mating was observed as soon as they emerged, and continued throughout the summer.

Egg

The females began to lay eggs approximately four weeks after emergence from hibernation. The first eggs were observed

TABLE XII

RESULTS OF SEARCH FOR ADULTS OF *Crioceris duodecimpunctata* (L.) IN THE SPRING OF 1954 BEFORE NORMAL EMERGENCE TIME

Date	Where found	No. of beetles dead	No. of beetles alive	Depth of soil in inches
May 13	In soil 6 ft. from asparagus bed	3	4	4-5
May 14	In soil 3 ft. from asparagus bed	3	0	4-5
May 17	In soil 3 ft. from asparagus bed	0	1	4-5
May 18	Base of dandelion	3	6	4-5
May 20	Base of stink weed	0	1	4-5
May 31	In asparagus bed	0	3	4-5
June 1	Base of rhubarb	0	3	2-3
June 7	Base of ragweed	2	4	2-3
June 9	Under dry leaves	9	15	1-0
	Total	20	37	

Apparent overwintering mortality is 35.1

in the field on July 14, 1954. The eggs are elongate, oval in form, and pale green but become dark green after a few days. The eggs are laid singly on the leaves of the asparagus and are attached to the leaves on their side instead of on one end as is the case in the other asparagus beetle eggs. Several asparagus branches were examined daily in the field and as soon as eggs were found the branches were marked. Daily observations were made in the field and in the laboratory. The observations showed that eggs hatched in about nine days under laboratory conditions (Table XIII), and ten days in the field (Table XIV).

When ten asparagus plants were checked for eggs at random in the field 439 eggs were counted - an average of 43.9 eggs per plant (Table XV).

Larva

The newly hatched larva is very tiny, but it crawls immediately along the branch in search of a berry. A two-day old larva measures about one-eighth of an inch in length. A fully grown larva measures about three-eighths of an inch. The head is round and dark, but the general colour is nearly creamy white to pale yellow, and the body surface is much wrinkled. About the time the larva is ready to pupate, the colour becomes bright creamy yellow. The larva bores holes into berries, and the holes are sealed with yellowish or

TABLE XIII

INCUBATION PERIOD FOR EGGS OF *Crioceris duodecimpunctata* (L.) IN THE LABORATORY

Date eggs deposited	Date eggs hatched	Incubation period, days	No. of eggs deposited	No. of eggs hatched
July 14	July 23-24	9	15	15
17	26-27	9	25	25
19	28-29	9	9	9

TABLE XIV

INCUBATION PERIOD FOR EGGS OF *Crioceris duodecimpunctata* (L.) IN THE FIELD

Date eggs deposited	Date eggs hatched	Incubation period, days	No. of eggs deposited	No. of eggs hatched
July 16	July 26	10	4	4
19	28-30	9	11	11
27	Aug. 7-8	11	7	7

TABLE XV

COUNT OF EGGS OF Crioceris duodecimpunctata (L.)
MADE ON 10 ASPARAGUS PLANTS ON AUG. 3, 1954

Plant No.		No. of eggs
1		75
2		48
3		84
4		13
5		19
6		24
7		47
8		43
9		41
10		28
	Total	439 eggs
	Average	43.9 eggs

blackish substances. When the larva is fully grown (8 to 10 days) it drops to the ground. It produces white substances which are mixed with the earth to form a cocoon in which pupation takes place for two weeks. The average length of time spent in the larval stage was estimated to be 6.6 days (Table XVI). This was calculated from the day the eggs were hatched to the day the larvae pupated.

Pupa

Four ice-cream cartons $4\frac{1}{2}$ inches high and $3\frac{1}{4}$ inches in diameter, were set on the table in the laboratory. The lids were fitted with 12-inch mesh wire screen. Some soil was put in each of the cartons. Several larvae in berries were put on top of the soil, Daily observation was made to determine the day the larvae pupated. The period of pupation was determined as soon as adults appeared. The average length of time spent in the pupal stage was fourteen days (Table XVII).

A half-gallon carton was filled with soil and buried in the plot in the field containing infested asparagus plants. Forty berries, each containing an asparagus beetle larva, were put on the soil in this cage. The carton was covered with 12-inch mesh wire screen. Observations were made to find out if the pupal period differs under field and laboratory conditions, and also to find out how many would emerge. The average length of time spent in the pupal stage was fourteen days and the

TABLE XVI

LENGTH OF LARVAL PERIOD OF
Crioceris duodecimpunctata (L.)
IN THE LABORATORY

No. of larvae	Date hatched	Date pupated	Larval period days
15	July 23	July 29	6
25	26	Aug. 2	7
9	28	4	7

TABLE XVII

LENGTH OF PUPAL PERIOD OF
Crioceris duodecimpunctata (L.)
IN THE LABORATORY

No. of pupae	Date pupated	Date adults emerged	Pupal period days
15	July 29	Aug. 12	14
25	Aug. 2	16	14
9	4	18	14

forty caged larvae emerged as adults. The first generation adults began to emerge on July 29, 1954, and continued to emerge for several weeks. They went into hibernation between the end of September and October 22.

CHAPTER X

SUMMARY

The data presented in this thesis prove that there is one generation per year of the spotted asparagus beetle in Winnipeg, Manitoba. The adults emerged from hibernation around June 13, 1954, and became abundant during July. The adults fed upon tips and leaves of asparagus. The adult is active and readily takes to flight when approached. It makes a squeaking noise when caught, but the method by which this noise is produced is not known. The female adult lays eggs singly on the leaves and the eggs are attached on their sides. They are laid a month after emergence from hibernation, mating being started as soon as they emerged and continuing throughout the summer. The eggs hatched within nine to twelve days. The larvae, immediately upon hatching from the eggs, fed on the berries. After a few days of feeding they fell on the ground and pupated. The pupal stage has a duration of at least fourteen days. The first generation adults upon emerging fed on leaves and berries of asparagus but there is no evidence that they feed or breed on the surrounding vegetation. It was observed that the adults go into hibernation between the end of September and October 22, depending upon the weather. The insect overwinters in the adult stage in sheltered quarters. The larvae were not observed feeding on the stem or foliage before entering the fruit.

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