EFFECTS OF SOME HERBICIDES AND PLANT GROWTH REGULATORS ON THE PEA APHID, *Acyrthosiphon pisum* (Harris), CAGED ON TREATED BROAD BEAN, *Vicia faba* L.

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ABSTRACT

by

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EFFECTS OF SOME HERBICIDES AND PLANT GROWTH REGULATORS ON THE PEA APHID, *Acyrthosiphon pisum* (Harris), CAGED ON TREATED BROAD BEAN, *Vicia faba* L.

The purpose of this investigation was to learn something of the effects of herbicides and plant growth regulators on the arthropod fauna of plants. The pea aphid, *Acyrthosiphon pisum* (Harris), was used as a test animal. The aphids were caged on treated or untreated broad bean plants, *Vicia faba* L. All experiments were conducted in a greenhouse or in a Plant Growth Cabinet.

Thirty chemicals were applied to plants in separate tests, both by root absorption and by leaf dipping. In every test pea aphids were caged for five days on treated and untreated plants and counts were made on adult or nymphal mortality and on number of progeny produced.

Twenty-seven of the chemicals showed no effects on the pea aphids, either beneficial or deleterious. Maleic hydrazide by root absorption caused a reduction in fecundity and some nymphal mortality. No reason could be demonstrated for this reduced reproduction other than inhibition or delay of parturition. Amitrole by root absorption caused a reduced fecundity and high nymphal mortality, apparently acting as a systemic insecticide against the nymphs. Zytron, both by root absorption and by leaf dipping, acted as a systemic insecticide against both nymphs and adults.

Several observations on pea aphid biology are reported, including a demonstration that weighing individual pea aphids before and after feeding is not a reliable method to measure amount of ingestion of plant sap by aphids. Weight gains during feeding can not be reliably calculated because of weight losses by excretion and reproduction.

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CHAPTER I

INTRODUCTION

The era since the Second Great War has seen the introduction of agricultural chemicals into our national economy in unprecedented numbers. Thousands of chemicals have been tested as insecticides, fungicides, herbicides, rodenticides and for other uses, and many of them have been accepted as valuable assets in our efforts to produce more and better agricultural products. In some instances they have unfortunately proved to be a mixed blessing. Some have been injurious to fish, birds and other wildlife. In other cases while one pest has been suppressed another has been encouraged to increase because the first pesticide perhaps upset the so-called "balance of nature" by destroying beneficial parasites and predators of the second pest. Many arthropods have become resistant to the chemicals which previously destroyed them. Some of the chemicals are dangerous to humans, either by original contact or subsequent consumption of contaminated food products. In other cases the chemicals have accumulated after repeated usage in soil or in plants. These and still other problems are being investigated by research workers so that the most efficient use may be made of these valuable agricultural chemicals with a minimum dislocation of a desirable environment.

The problem

The purpose of this study was to attempt to learn something of the effects of herbicides on the arthropod fauna. Obviously there are many pest arthropods, and many herbicides at present being used, and there must be a definite limit in such a study to the number of test animals, the number of herbicides tested and the number of plants to be treated. In this study thirty herbicides or plant growth regulators were applied both by leaf dipping and by root absorption to the broad bean, *Vicia faba* L. Pea aphids, *Acyrthosiphon pisum* (Harris), were caged on the treated plants so that mortality and fecundity could be measured. The thirty herbicides tested were chosen to include all those commonly in use at present in Western Canada. They also represent a wide range of biologically active chemicals.

Importance of the study

Not all herbicides are plant growth regulators and only a few plant growth regulators are regarded as herbicides. Both have many and varied uses in agriculture but herbicides are intended mainly to destroy undesirable plants in fields, pastures or gardens. The estimated total sale of herbicides in the United States in 1956 was thirty-five million dollars

(Fischer, 1956). Tonnage sales of 2,4-D alone were 34.1 million pounds for that year. In 1959 in the four provinces of Western Canada, 15,949,000 acres were treated with herbicides (Craig, 1959). What effects do all these herbicides have on the arthropod fauna? The herbicides may be beneficial or deleterious to arthropods, or there may be no measurable or noticeable effects. Very few observations have been made on the effects on arthropods of widespread spraying or dusting of herbicides. The present study was begun to supply some of this much needed information and aphids were chosen as the test animals because they are important pests on many of our commercial and ornamental plants.

Organization of the thesis

Common names for herbicides are used throughout the thesis because the correct chemical names are in many instances very long and cumbersome. These names are given immediately following this paragraph. Of the thirty chemicals tested only three, MH, amitrole and Zytron showed marked effects on the mortality or fecundity of the pea aphid. The first two are discussed first, followed by the others in no special order, except that where the herbicides are closely related chemically they are grouped together in close succession. The literature review covers not only the meager data available on the effects of herbicides on arthropods, but also attempts to discuss certain insect and host-plant relationships which are pertinent to this study. In certain cases it has been found more appropriate to discuss other research work along with specific observations made during the present study.

Names of chemicals used

The nomenclature is that accepted by the Terminology Committee of the Weed Society of America and published in Weeds, Vol. 8, No. 3, July 1960.

Common name		Chemical name
1.	MH	maleic hydrazide = 1,2-dihydropyridazine-3,6-dione
2.	amitrole	3-amino-1,2,4-triazole
3.	2,4-D	2,4-dichlorophenoxyacetic acid
4.	2,4,5-T	2,4,5-trichlorophenoxyacetic acid
5.	MCPA	2-methyl-4-chlorophenoxyacetic acid
6.	sesone	sodium 2,4-dichlorophenoxyethyl sulfate
7.	erbon	2-(2,4,5-trichlorophenoxy) ethyl 2,2-dichloropropionate
8.	silvex	2-(2,4,5-trichlorophenoxy)propionic acid
9.	4-(2,4-DB)	4-(2,4-dichlorophenoxy)butyric acid
10.	4-(MCPB)	4-(2-methyl-4-chlorophenoxy) butyric acid
11.	DNBP	4-6-dinitro ortho secondary butylphenol

12.	IPC	isopropyl N-phenylcarbamate
13.	CIPC	isopropyl N-(3-chlorophenyl) carbamate
14.	EPTC	ethyl N, N-di-n-propylthiolcarbamate
15.	barban	4-chloro-2-butynyl-N-(3-chlorophenyl) carbamate
16.	Avadex	2,3-dichloroallyl-diisopropylthiol-carbamate
17.	CDEC	2-chloroallyl diethyldithiocarbamate
18.	CDAA	2-chloro-N, N-diallylacetamide
19.	monuron	3-(p-chlorophenyl)-1, 1-dimethylurea
20.	TCA	trichloroacetic acid
21.	dalapon	2,2-dichloropropionic acid
22.	DMTT	3,5-dimethyltetrahydro-1,3-5,2H-thiadiazine-2-thione
23.	chlorazine	2-chloro-4,6-bis(diethylamino)-s-triazine
24.	simazine	2-chloro-4,6-bis (ethylamino)-s-triazine
25.	atrazine	2-chloro-4 ethylamino-6 isopropyl-amino-s-triazine
26.	2,3,6-TBA	2,3,6-trichlorobenzoic acid
27.	2,3,5,6-TBA	2,3,5,6-tetrachlorobenzoic acid
28.	NPA	N-1-naphthylphthalamic acid
29.	Zytron	O-(2,4-dichlorophenyl) o-methyl iso-propylphosphoroamidothioate
30.	gibberellic acid	potassium gibberellate

CHAPTER II

REVIEW OF THE LITERATURE

There are very few references in the literature to the effects of herbicides or plant growth regulators on arthropods. Ingram *et al* (1947) showed that the use of 2,4-D to control weeds in sugarcane fields in some way caused a material increase in infestations of the sugarcane borer, *Diatraea saccharalis* (F.). Fox (1948) drew attention to a relationship between the use of 2,4-D and damage to wheat caused by the wireworm *Ctenicera aeripennis destructor* Brown. Where 2,4-D was applied for weed control just prior to the seeding of wheat, the amount of damage the wireworms inflicted on the crop was increased. Putnam (1949) suggested that 2,4-D could be an environmental factor in the ecology of grasshoppers, because of possible influences on vegetation. Hofmaster and Danielson (1950) showed that spray applications of the herbicide dinitro ortho secondary amyl phenol to control weeds in strawberry plantings also greatly reduced populations of red spider mites. Beard (1951) treated corn plants with maleic hydrazide. In those plants designated Oh 26 in which growth was retarded, the whorl did not expand and no tassels nor ear shoots appeared. But on these plants a heavy infestation of corn leaf aphid built up within the whorl. This condition was similar only to a very susceptible

C31 *id* inbred line. Munger and Broadbent (1954) used 2,4-D to prolong the life of lemons in storage. This treatment did not interfere with the use of the fruit as hosts for cultures of California red scale, *Aonidiella aurantii* (Mask.). Watson and Leasure (1959) found that good control of ants was obtained in turf treated with Zytron for crabgrass control. Siakotos and Dewey (1959) included gibberellic acid in the diet of American cockroaches, *Periplaneta americana* L. There was no significant interaction between weights of insects and concentrations used and no significant differences occurred in egg production between the different concentrations of gibberellic acid fed. Maxwell and Harwood (1960) claimed that certain concentrations of 2,4-D on broad bean increased the reproductive rate of pea aphids feeding on the treated plants. They also found that longevity of aphid adults, and growth rate of grasshopper nymphs, *Melanoplus bivittatus* (Say), appeared unaffected. Adams (1960) found that sprays of 2,4-D caused an increase in length of development period of larvae of three species of coccinellid beetles.

An excellent review with lengthy bibliography on the effects of herbicides and fungicides on wildlife is that by Springer (1957). Some references are made to the effects of herbicides on arthropods or crustaceans in water. The author concludes that there is little hazard of poisoning wild birds or mammals from the present-day use of most herbicides and fungicides.

Shortly after the appearance of the first of the post-war herbicides and plant growth regulators Allen (1947) discussed the role of plant growth regulators in the expression of insect damage to plants, referring to insect galls and other tissue responses. He expressed the hope that further research might lead to the use of synthetic plant hormones to suppress insect damage. In 1950 an editorial in the Journal of Economic Entomology by Haseman suggested that more consideration be given to controlling insect pests through their nutritional requirements. Proof that entomologists have not been idle in their efforts to learn something of the relationships between insects and their plant food is evidenced by the excellent reviews by Friend (1958) and Thorsteinson (1960).

A brief mention will be made here to the literature on nutrition of aphids and especially the pea aphid. This search of the literature became necessary to find a possible explanation for the effects of MH and amitrole on the fecundity of the pea aphid. Most of the present-day research on aphids concerns one or more aspects of the following aphid-host plant relationships:

1. Size and weight of adult aphids, including a study of biotypes.
2. Fecundity and rate of reproduction.
3. Host selection by alate forms.
4. Concentrations of amino acids and sugars in host plants.

5. Mortality to nymphs or adults (one aspect of host plant resistance).
6. Rate and frequency of excretion of honeydew.
7. Artificial feeding techniques.

Bodenheimer and Swirski (1957) devote Chapter VI of their book to a discussion of the "ecology and physiology of nutrition" of aphids, with a good bibliography. Other useful recent general articles on aphid nutrition are those by Painter (1953), Kennedy (1953, 1958), Auclair (1958a), Kennedy and Stroyan (1959) and Shaposhnikov (1959). One of the current theories of the relationship between host plants and aphids is that by Kennedy, which resulted from the observation that growing and senescing leaves of certain plants were more susceptible to Myzus persicae (Sulzer) and Aphis fabae (Scopoli) than mature green leaves of the same plant. Kennedy referred to this as a "dual discrimination theory", to explain at least in part host alternation by many species.

Other papers which attempt to explain host plant selection and host alternation by aphids are by Evans (1938), Ibbotson and Kennedy (1950), Kennedy et al (1950), Kennedy and Booth (1954), Kennedy et al (1958), Mittler (1958), Müller (1958a, 1958b), Kennedy and Booth (1959), and Taylor (1959). Two very important reports are those by Bonnemaison (1951) and Markkula (1953). Further papers which deal more specifically with host plant resistance to aphids are by

Dahms and Painter (1940), Auclair and Maltais (1950), Jones *et al* (1950), Cartier and Painter (1956), Pathak and Painter (1958) and Painter (1958a, 1958b).

Critical studies on aphid nutrition have been hindered by lack of a suitable feeding technique. As early as 1930 Hamilton described attempts to induce aphids to feed through membranes of washed fish skin. Hamilton (1935) described a further artificial membrane consisting of the epidermis of cabbage leaves with some of the leaf tissue removed. Pletsch (1937) described an improved device for feeding aphids through a "fish-skin" or "gold-beaters' skin". However, natural animal or vegetable membranes are not bacteria-proof and they cannot be sterilized by steam heat or kept sterile by chemicals. Such membranes also tend to sag or break. Maltais (1952) attempted to improve on these devices by using a rubber membrane, with very limited success. Maltais (1959) described a method of feeding the pea aphid on plant cuttings in organic nutrient solutions. Recently Mittler (1957) has described how the willow aphid *Tuberolachnus salignus* feeds by inserting its stylets into a single sieve element. If the insect is severed from its proboscis whilst feeding, sap from the phloem sieve tube exudes from the cut end of the stylet canal and may continue for many hours. That botanists are using this information in a study of the physiology of the sieve tube is shown by the work of Weatherley *et al*

(1959). Studies on the feeding of aphids on radioactive plants are those by Day and Irzykiewicz (1953), Watson and Nixon (1953), and feeding and excretion by Banks and Nixon (1959).

Rate and frequency of excretion are frequently used to determine amounts of plant sap ingested by aphids. Mittler (1958) defines "frequency of excretion" as the number of honeydew droplets excreted per hour per aphid and "rate of excretion" as the total volume of honeydew excreted per hour per aphid. "Rate of feeding" is defined as the volume of sap ingested per hour per aphid. There is at present some controversy as to whether frequency of excretion is a reliable measure of rate of feeding. Smith (1937) used rate of deposition of honeydew by the mealy plum aphid to measure amount of intake of plant sap. Schaefer (1938) and Broadbent (1951) have pointed out that aphids may lose moisture through evaporation from the integument as well as in honeydew. Auclair (1958b) and Maxwell and Painter (1959) have presented suitable methods for measuring rate and frequency of deposition of honeydew. The physiology of excretion in insects in general has been reviewed by Craig (1960).

Some information is available on the effects on aphids of varying the nutrients fed to host plants. Barker and Tauber (1951a) recorded the effects of deficiencies of N, P, K, Ca or Mg on the green peach aphid on nasturtium and found no significant difference among treatments at the rates used. The same authors (1951b) found that Pisum sativum grown on soils severely deficient in either N, P, K, Ca or Mg would be injured worse by the pea aphid than would plants grown on soils of good fertility, not because the infestation would be more severe, but because the nutritionally weaker plants would be less tolerant of the feeding injury superimposed by the aphids. In 1954 Barker and Tauber reported on the fecundity of the pea aphid on garden pea under various combinations of light, moisture, and nutrients. Arant and Jones (1951) studied the influence of lime and nitrogenous fertilizers on the population of greenbugs infesting oats. Infestation counts showed that as the rates of nitrogen were increased the population of greenbugs per unit of leaf surface decreased. The addition of lime also decreased the population of greenbugs and the decrease was greatest where no nitrogen was used. Taylor et al (1952) reported that there were no significant differences in potato aphids on potato plants, or pea aphids on pea plants, on various fertility plots. Daniels and Porter (1956) found that increased greenbug populations were positively associated with high nitrogen levels in the soil and increased plant vigor. Daniels (1957) reported that reduced greenbug damage and less greenbugs per gram of wheat plant are positively associated with plant size and vigor (resulting from fertilizer application). Coon (1959) studied the effects on the apple grain aphid, *Rhopalosiphum fitchii* (Sand.) on oats grown in various nutrient solutions. The data indicated that there was a significantly greater population increase potential where nitrogen was available to the plants.

A research team at St. Jean, Quebec, has been investigating the relations between the pea aphid and amino acids present in various varieties of canning peas. One of the paper partition chromatography techniques is reported by Auclair and Maltais (1954). Auclair *et al* (1957) found that varieties of peas susceptible to pea aphids had higher concentrations of free and total amino acids and amides than resistant varieties.

A complicating factor in studies on pea aphids has been that of biological races, or biotypes. Harrington (1945) reported that he had tested thirty-one aphid lines from widely separated pea growing areas of the United States. On the basis of experiments involving comparative feeding injury, body size and rates of reproduction he found five separate biological races of the pea aphid. The research team previously mentioned from St. Jean, Quebec, now stipulate in their reports which biotype has been used. Cartier (1959) recognized three biotypes of the pea aphid from Southern Quebec. Cartier (1957) isolated two lines of the pea aphid and reared them for forty-four consecutive generations on the pea variety Perfection. The two lines differed in mean weights of the adults.

There are several fairly comprehensive works on the general biology or life history of the pea aphid. Recent studies in England are those by Kenten (1955) and Dunn and Wright (1955a, 1955b). The pea aphid has been studied in California by Davis (1926), in Kansas by Smith and Davis (1926), in Maine by Patch (1927), in Maryland by Ditman et al (1943) and in New York state by Evans and Gyrisco (1926), to mention only a few. Maltais (1948) discussed the pea aphid in Canada, and Dudley and Bronson (1956) the pea aphid in the United States.

Research on the use of herbicides to control weeds is reported in many agricultural journals, including the publication Weeds, and herbicides are widely discussed in various trade journals. A brief and useful guide to chemical control of weeds is the U.S.D.A. Special Report ARS 22-46 by Klingman et al (1958). Literature on plant growth regulators is widely scattered throughout various botanical and agricultural periodicals. A useful recent book on plant growth substances with an extensive bibliography is that by Audus (1959).

CHAPTER III

MATERIALS AND METHODS

Except for the few preliminary tests reported by Robinson (1959) all aphids were descendants from one apterous female isolated in December 1958. Under greenhouse conditions the summer form, the female summer *vivipara*, could be maintained in successive generations. The young nymphs were born parthenogenetically and viviparously, so there were no problems of males, mating, or waiting for eggs to hatch. Thus all aphids used after December 1958 could be regarded as a clone.

Cultures were maintained on *Vicia faba*, variety Windsor, in screened cages of various sizes, in the greenhouse. Temperatures fluctuated widely in the greenhouse over a yearly period, rarely falling below 60°F., but occasionally reaching 110°F. in the summer. Under certain conditions of crowding or plant deterioration there was a large percentage of alate adults, but normally most of the female adult aphids were wingless. Transfer of single aphids was accomplished with an aspirator which held them by suction against the end of a finely drawn out glass tubing.

For any one test the aphids were approximately the same age in all replicates, but between tests the ages at which the aphids were used varied according to availability in the stock cultures on a given date. This was arranged by placing apterous, bearing females on plants in screened cages for forty-eight hours and then removing the females. The resulting progeny remaining on the plants would be within forty-eight hours age of one another and could be used for tests at desired nymphal or adult ages.

All broad bean plants used in tests with herbicides or plant growth regulators were grown in soil to a height of two to four inches and then transplanted into vermiculite (Zonolite[1]) in individual three and one-half inch clay pots. Twenty plants were used in each treatment. The twenty pots were placed in galvanized metal trays twenty-three inches by eighteen inches, three inches deep. When the chemicals were applied by "root absorption" two gallons of the appropriate dilution with water were added to the trays and the pots were thus partly immersed. Because of the use of the inert vermiculite the plant roots could absorb only the chemical-and-water dilution as a nutrient. With the root absorption method the pots remained in the trays for forty-eight hours. When the chemicals were applied by "leaf-dipping" the lower double leaves of the plant were dipped for about five seconds in the appropriate chemical-in-water dilution to simulate field spraying. Two gallons of tap water were added to each tray and the pot partly immersed in the water for forty-eight

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[1]Insulation Industries Limited, Winnipeg.

hours. Trays were in all cases placed for the duration of the tests in a Coldstream Plant Growth Cabinet[2] at a temperature of $69^{o} \pm 2^{o}F$. and an average relative humidity of 70 per cent, with continuous lighting.

At the end of forty-eight hours the pots were removed and the metal trays were emptied. In tests where fecundity of female aphids was measured, one adult apterous summer vivipara was caged on one leaf of each plant for five days. In early tests one of the lower double leaves was removed to facilitate enclosing the remaining leaf in a cage of Visking dialyzing tubing (36 mm. diameter)[3]. In later tests the cage used was vastly superior, a clip cage similar to that reported by Noble (1958) (Figure 1). When chemicals were applied by root absorption the cages were clipped on one of the lower double leaves. When chemicals were applied by leaf-dipping the cages were placed on one of the next higher double leaves. During the five days of this test a nutrient solution of Plant Prod 20-20-20[4] was supplied in all trays, including the control tray (Figure 2). After five days the trays were removed from the Growth Cabinet and the number of young produced during

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[2]Fleming-Pedlar Limited, Winnipeg.

[3]Purchased as Cat. No. 29-070 from Canadian Laboratory Supplies.

[4]Plant Prod 20-20-20 purchased from Plant Products Company, Port Credit, Ontario.

that time by each female was recorded, as well as any mortality to nymphs or adults.

An example of the record sheet used and original data obtained is shown as Appendix A. This is reported in the text of the thesis as shown in Appendix B. In the statistical analysis of data on fecundity, because of possible zero counts, all means were transformed by using $\sqrt{x + 0.5}$ (Goulden, 1945). An example is shown as Appendix C.

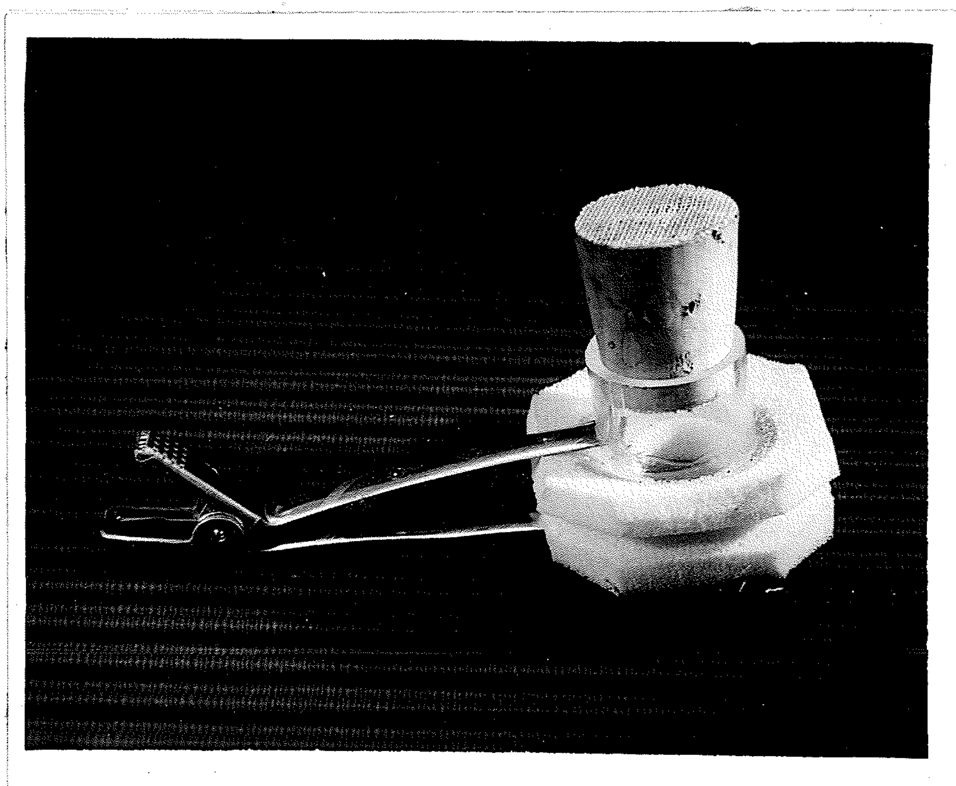

FIGURE 1

CLIP CAGE USED TO CONFINE PEA APHIDS ON LEAVES OF BROAD BEAN PLANTS

FIGURE 2

PEA APHIDS IN CLIP CAGES ON BROAD BEAN PLANTS IN METAL TRAY CONTAINING NUTRIENT SOLUTION

CHAPTER IV

SOME BIOLOGICAL NOTES ON THE PEA APHID

The pea aphid, Acyrthosiphon pisum (Harris), occurs in synonymy in the literature also under the scientific names of Aphis pisum, A. onobrychis, A. lathyri, A. pisi, Siphonophora pisum, Macrosiphum pisum, Nectarosiphon pisum and Illinoia pisi.

No detailed life history studies on the pea aphid have been made in Manitoba, but its life history is believed very similar to that in other parts of Canada and the northern part of the United States. Because it is regarded as one of the more important insect pests in North America it has been widely studied. It is also well-known in Europe as an insect of economic importance. It feeds on the sap of many species of the plant family Leguminosae. Under Canadian conditions the primary host plants include perennials and biennials such as the common clovers and alfalfa. The secondary host plants include most varieties of cultivated peas, vetches and sweet peas. Primary hosts are sometimes referred to as winter hosts, and secondary hosts as summer hosts.

The winter is passed as an egg on the primary host. Locally this is probably mostly alfalfa. When plant growth starts in the spring the egg hatches, and after passing through four nymphal stages becomes a wingless adult female known as the stem mother. The stem mother in turn produces parthenogenetically and viviparously a generation of wingless females. This type of reproduction continues until the secondary host plants, generally peas, are well established as growing plants. At that time a generation of both wingless and winged female aphids appears on the primary host. The winged individuals migrate to the secondary hosts, although some wingless generations may remain all summer on the primary host. In late summer winged adults return to the primary host. The last generation before winter consists of both males and females, which mate to produce the overwintering diploid eggs. In warmer climates, or under greenhouse or laboratory conditions, only the summer form is present, the wingless summer vivipara, although winged individuals often occur, for reasons which are not clearly understood.

At various times during the present study it was necessary for some particular reason to determine some aspect of the biology of the pea aphid or some aspect of aphid-host plant relationship. The results obtained are reported here under the general chapter heading of biological notes on the pea aphid.

Although only wingless adult females were used in all tests with herbicides or plant growth regulators, a study was made to compare the fecundity of winged and wingless pea aphids on broad bean. Aphids were nine to eleven days old. Results are shown in Table I. Winged aphids produced a smaller average number of nymphs than did the wingless, results being significantly different at the one per cent level.

Early in the study the questions arose as to whether the aphids should be caged on the upper or lower surfaces of the broad bean leaves, or whether it made any difference if one of the lower pairs of leaves was used, or one of the next higher of the double leaves. Table II shows the results from a test of fecundity of aphids caged on upper or lower surfaces. Aphids were put on as nymphs four to six days old, and kept in individual cages until they died. Because females died on varying dates, the criterion used to measure the average number of progeny was the total number of days females were alive in the cages. There was no significant difference in fecundity per day between upper and lower surfaces. In all tests which follow the aphids were confined to lower surfaces of the leaves, although the data in Table II show that they can successfully live on upper surfaces.

Table III shows the results from an investigation to determine if results would differ if aphids were caged on one of the lower leaves of broad bean or on the next higher, on both treated (MH by root absorption) or untreated plants. Differences in fecundity between lowest and next higher leaves, for both treated and untreated, were very close to showing significant differences at the five per cent level,

TABLE I

COMPARISON OF FECUNDITY OF WINGED AND WINGLESS PEA APHIDS CAGED ON UNTREATED BROAD BEAN PLANTS FOR FIVE DAYS, MARCH 11, 1960

No. of adults	Form	Total no. of live nymphs	Total no. of dead nymphs	Average no. of live nymphs	Transformed average
39	Winged	784	6	20.1	4.40**
40	Wingless	1222	28	30.5	5.44

** Significant at the 1% level

TABLE II

FECUNDITY OF THE PEA APHID CAGED ON UPPER OR LOWER SURFACES OF LEAVES OF TWENTY UNTREATED BROAD BEAN PLANTS AUGUST 17, 1959

Leaf surface	No. of adults	Total days lived by all females	Total progeny	Average fecundity per day	Transformed average
Upper	20	138	659	4.8	5.46
Lower	20	169	839	4.9	6.27

TABLE III

FECUNDITY OF THE PEA APHID CAGED ON LOWEST OR NEXT HIGHER LEAVES OF TWENTY BROAD BEAN PLANTS TREATED WITH MH (3,000 P.P.M. OF ACTIVE INGREDIENT) BY ROOT ABSORPTION, AND TWENTY PLANTS UNTREATED, AUGUST 12, 1959

Treatment	Leaf position	No. of adults	Total days lived by all females	Total progeny	Average fecundity per day	Transformed average
MH	Lowest	20	178	566	3.2	4.34
	Next higher	20	183	772	4.2	5.42
Water only	Lowest	20	201	1053	5.2	6.66
	Next higher	20	245	1465	5.9	8.35

but in neither case could significant differences be clearly demonstrated. Apparently the choice of leaf position on the plant between the lower double leaves or next highest is not an important factor in tests with caged aphids on young broad bean plants.

During the various investigations, with caged aphids at constant temperatures and continuous light, certain interesting observations on life history were made. The longest life of any one individual female in a cage, including nymphal instars, was thirty days. Most females began producing young on the eighth day of life, although a few produced young on the seventh day. The peak of production of young was usually the thirteenth to fourteenth day of life. This is illustrated in Figure 3 on Page 43. The greatest number of young born to any one female in a twenty-four hour period was twenty-one but the average number was ten to fifteen. One female produced one hundred and twenty-three young during its reproductive period and several gave birth to more than one hundred.

An attempt was made during these investigations to find some method to determine the amount of plant sap ingested by aphids. It was hoped that if such a method existed it might be used to explain certain reductions in fecundity of aphids feeding on plants treated with maleic hydrazide and amitrole which will be reported later. A search of the literature revealed two published reports on a method whereby aphids were starved, weighed, fed and again weighed. Hamilton (1935) measured the volume of liquid ingested from leaves by the green peach aphid, Myzus persicae (Sulz.). One hundred aphids were weighed collectively, starved for fourteen hours, and showed a collective gain in weight after six hours of feeding. Watson and Nixon (1953) commented on the disadvantages of this method of measuring feeding rates. Pathak and Painter (1958 b) found that corn leaf aphids, Rhopalosiphum maidis (Fitch), responded more consistently in the amount of plant liquid intake when they were kept without food for a period of fourteen to sixteen hours and then allowed to feed for three hours. They measured differential amounts of material taken up by four biotypes of corn leaf aphids from resistant and susceptible sorghums.

Several tests were made, using either a Cahn Electro-balance (0-50 mg.) or a Roller-Smith Microtorsion Balance (0.05-100 mg.). The tests were all unsuccessful, so the results from only two of the tests will be reported here to illustrate what happened. Because the aphids fell off or walked off the small delicate balance pans during weighing, an effort was made to immobilize them first. Aphids were subjected to a few seconds of below zero temperatures, in the hope that they would be temporarily immobilized. However, it was found that subsequent exposure to the warm humid air of the room resulted in an increase in body weight due to condensation on the cold aphid integument. Attempts to use carbon dioxide anaesthesia occasionally produced detrimental after effects. One accurate method, which proved to be a very time-consuming one, was to place each aphid in an individual gelatin capsule, size No. 5 (Eli Lilly and Company). Eventually with increased proficiency it became possible to simply place the aphids free on the pan and quickly weigh them.

Adults of the pea aphid, apterous summer viviparae not yet in parturition, were starved for fourteen, sixteen or eighteen hours and then placed in clip cages on broad bean plants to feed for periods of three or six hours. Results are shown in Table IV. This test and several previous tests with both microbalances showed that the average per cent loss in weight for the pea aphid varies between fifteen and twenty-five per cent for any periods of starvation between fourteen and eighteen hours. This compares favorably with the data of Schaefer (1938) of pea aphids from pea seedlings where there was an average per cent loss of 14.4 per cent in twelve hours of starving, and 21.9 per cent in twenty-four hours, with rapid loss in weight by evaporation of body moisture during the first few hours of starving, followed by a levelling-off as the remaining body

TABLE IV

GAIN OR LOSS IN WEIGHT OF PEA APHIDS FEEDING ON BROAD BEAN PLANTS AFTER STARVING, TEN APHIDS EACH TEST, WEIGHED INDIVIDUALLY, MAY 11, 1960.

Hours of starving	Average per cent loss in weight after starving	Hours of feeding	Average per cent gain or loss in weight after feeding
14	- 25.5	3	- 5.5
14	- 20.9	6	+ 3.2
16	- 21.5	3	- 6.4
16	- 21.9	6	- 1.3
18	- 23.5	3	- 6.9
18	- 23.3	6	+ 3.5

contents "concentrated". Of the three groups in Table IV none showed an average per cent gain after only three hours of post-starvation feeding. Of twenty-nine individuals only nine showed a gain in weight in the three hours. Of those feeding six hours after starving two groups out of three and twelve individuals out of twenty-seven showed a small gain in weight. In none of the fifty-six aphids was there a gain during feeding of the weight lost during starving.

A further test is reported in Table V. Adults nine days old which had begun reproducing were starved fourteen hours and then allowed to feed for periods of six, twelve or twenty-four hours. The data show that even twelve and twenty-four hours of feeding after a period of fourteen hours of starving may not be sufficient for an intake of plant sap that can be reliably measured as an increase in weight of the pea aphid. This is probably because of two reasons: the aphids begin producing young as soon as they resume feeding, and they also begin excreting honeydew. Also, Auclair (1958 b) has shown that the pea aphid increases in weight from 3.810 mg. to 4.086 mg. from "new adult" to "bearing-adult". The aphids used in the test shown in Table IV may therefore have made slight gains during the feeding period due to this natural increase in weight. When a test extends over several hours of feeding a number of young are produced, as shown in Table V. Newly born nymphs of the pea aphid

TABLE V

GAIN OR LOSS IN WEIGHT OF PEA APHIDS FEEDING ON BROAD BEAN AFTER STARVING FOURTEEN HOURS, TEN APHIDS EACH TEST, WEIGHED INDIVIDUALLY, MAY 16, 1960

Average per cent loss in weight after 14 hours starving	Average per cent gain or loss after feeding	Average per cent further loss, no feeding	Average per cent gain or loss, continuous feeding	Ave. no. of nymphs produced during feed-ing
- 16.8	6 hours -14.7			3.9
- 21.8	12 hrs. - 2.7			4.1
- 20.9	24 hrs. - 1.4			6.8
- 17.7		6 hrs.-13.1		
- 19.4		12 hrs.-21.1		
- 21.8		24 hrs.-22.7*		
			20 hrs.-11.5	6.7
			26 hrs.+10.7	4.9
			38 hrs.+15.4	9.4

* 7 aphids out of 10 died before end of 38 hours.

weigh slightly less than 0.2 mg. If several of these are born during a period between weight measurements, how are these losses to be corrected for? Honeydew excretion almost ceases during starving, and resumes when feeding begins. Auclair (1958 b) stated that the pea aphid excreted its own weight in honeydew in eighteen to thirty-two hours. If rate of honeydew excretion is approximately equal to intake of plant sap, one might even argue that the aphids could never regain their original "pre-starving" weight!

Mean weights of pea aphids after several days of development on plants, as used by Cartier (1959) and Maltais (1959) should show with reasonable accuracy gains or losses due to nutrition. But the data shown in Tables IV and V indicate that weighing either young adult pea aphids or those which have already begun reproducing, after starving, is not a reliable method of measuring ingestion of plant sap during immediate subsequent hours of feeding.

CHAPTER V

TESTS WITH MALEIC HYDRAZIDE

Maleic hydrazide, or MH, has the chemical name of 1,2-dihydro-pyridazine-3,6-dione. It is a synthetic plant growth inhibitor. It has a limited commercial use to suppress suckering, to delay flowering, to suppress apical dominance and bolting in vegetables, to induce dormancy in root crops such as onions and potatoes, and to retard grass growth on lawns. No reports were found in the literature of possible effects on arthropods.

In early tests MH was used as a forty per cent soluble powder, and in later tests only the MH thirty per cent amine was available. Broad bean plants treated with MH by root absorption at the rates used were very much inhibited in growth. At rates over 4,000 p.p.m. the plants were killed. Table VI gives results of adult and nymphal survival and fecundity of the pea aphid after five days caged on broad bean plants treated with MH at rates of 4,000, 3,000 and 2,000 p.p.m. (active ingredient) by root absorption, ten aphids per treatment. Table VII shows the results of a further test with twenty aphids per treatment. In both cases the average number of live progeny of surviving adults after five days on the treated plants differed significantly at the one per cent level from that on the untreated check sample. Nymphal

TABLE VI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH40 (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
July 5, 1958	4,000 p.p.m.	9	1	101	46	6.1	2.24**	0-15
	3,000 p.p.m.	9	1	70	12	6.4	2.34**	0-22
	2,000 p.p.m.	10	0	119	30	8.9	2.90**	1-17
	Water only	8	2	161	2	16.4	4.05	10-30

** Significant at the 1% level

TABLE VII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH_{40} (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
August 7, 1958	4,000 p.p.m.	8	12	71	66	0.6	0.98**	0-3
	3,000 p.p.m.	17	3	173	125	2.5	1.45**	0-16
	2,000 p.p.m.	16	4	171	119	3.2	1.74**	0-12
	Water only	20	0	336	0	16.8	4.04	5-37

** Significant at the 1% level

mortality was high. Many of the nymphs appeared to have been born dead, because legs and antennae still closely adhered to the body.

When MH was applied by root absorption at rates of 1,500 and 1,000 p.p.m. plant growth was inhibited, but there was no significant decrease in fecundity.

Table VIII shows results obtained using winged adults of the pea aphid instead of wingless, at 3,000 p.p.m. of MH30 amine. Aphids used in this test were of the same age, but past their reproductive peak, as indicated in Table VIII by the low average of 12.1 nymphs on the untreated sample. However, the average number of live progeny of surviving adults on the treated plants differed significantly at the one per cent level from that on the check, showing a reduction in fecundity.

The next test was to determine if the reduction in fecundity of wingless adult females on plants treated with MH30 at 4,000, 3,000 and 2,000 p.p.m. would continue if the same females were caged for a further five days on untreated plants. Table IX shows the beginning of this test, and Table X shows the results obtained after they were transferred for a further five days. Results shown in Table IX demonstrate the usual reductions in fecundity, and the nymphal mortality, significant at the one per cent level. Table X shows clearly that the injurious effect on the reproductive

TABLE VIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE ALATE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH_{30} (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
July 19, 1960	3,000p.p.m.	11	9	54	17	3.3	1.74**	0-11
	Water only	16	4	214	0	12.1	3.51	4-20

** Significant at the 1% level

TABLE IX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH_{30} (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 25, 1959	4,000p.p.m.	16	4	421	346	4.7	1.74**	0-36
	3,000p.p.m.	19	1	498	312	9.8	2.36**	0-43
	2,000p.p.m.	18	2	508	438	3.7	1.44**	0-27
	Water only	14	6	627	109	33.1	5.74	16-47

** Significant at the 1% level

TABLE X

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF PEA APHIDS FROM PLANTS TREATED WITH MALEIC HYDRAZIDE, CAGED FOR A FURTHER FIVE DAYS ON UNTREATED BROAD BEANS

Source plants	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Trans-formed average	Range of fecundity
4,000 p.p.m.	11	5	0	0	0	0.7 **	0-0
3,000 p.p.m.	12	7	59	5	4.5	1.45**	0-36
2,000 p.p.m.	8	10	42	11	3.9	1.46**	0-28
Water only	7	6	272	46	32.3	5.63	22-41

** Significant at the 1% level

metabolism of the female aphids persists after they are removed from treated plants and placed on untreated plants for a further five days.

In a further test nymphs were allowed to remain until they became adults on plants treated with MH at 4,000 p.p.m. by root absorption and then were transferred to untreated plants for the remainder of their lives. This was done to ascertain any deleterious effects on nymphs born and reared on treated plants, and whether such effects might continue after they became adults, even though no longer on treated plants. Results are shown in Table XI. They show that the harmful effects of the MH on the nymphs are expressed as a decrease in fecundity of the adult females, differences from the check being significant at the one per cent level.

In another test twenty plants were treated with MH_{30} at 4,000 p.p.m. by root absorption and twenty plants with water only. At the end of forty-eight hours late instar nymphs were placed singly in clip cages on the plants in nutrient solution. As soon as they became adults and began reproducing counts were made daily on the number of young produced during the remainder of their lives. Results from this test are illustrated in Figure 3, which shows the peak of reproduction in both cases on July 28, the thirteenth day of life, and also the greatly decreased fecundity of the aphids on the plants which had been treated with MH for

TABLE XI

FECUNDITY OF PEA APHIDS BORN AND REARED ON BROAD BEAN PLANTS TREATED WITH MALEIC HYDRAZIDE AT 4,000 P.P.M., AND FROM UNTREATED PLANTS; TRANSFERRED TO UNTREATED PLANTS ON BECOMING ADULTS, JULY 29, 1959

Source	No. of adults	Total days lived by all females	Total progeny	Average fecundity per day	Transformed average
From plants treated with MH	11	143	326	2.3	4.50 **
From plants treated with water only	29	357	2,025	5.7	8.19

** Significant at the 1% level

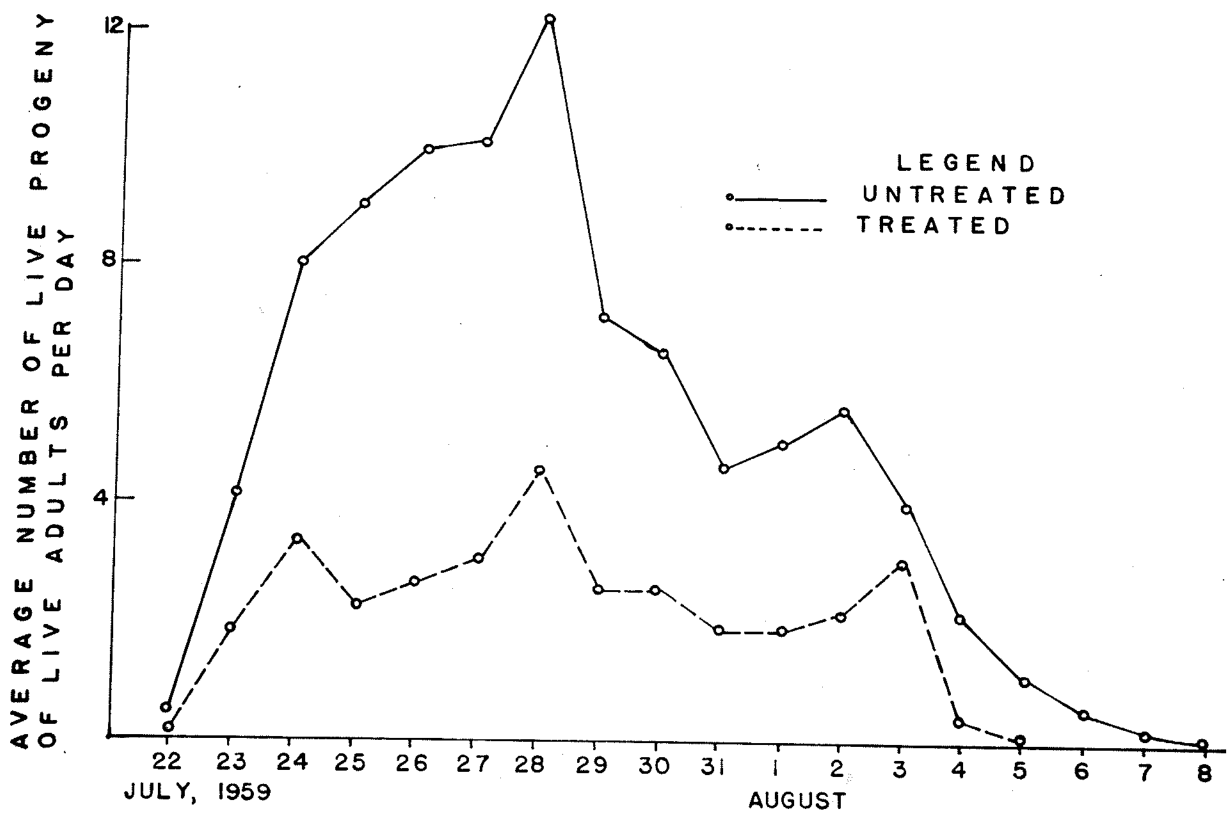

FIGURE 3

COMPARISON BETWEEN AVERAGE NUMBER OF PROGENY PRODUCED PER DAY BY TWENTY PEA APHIDS CAGED SINGLY ON TWENTY BROAD BEAN PLANTS TREATED WITH MH AT 4,000 P.P.M. AND BY TWENTY APHIDS CAGED ON TWENTY UNTREATED PLANTS forty-eight hours. The treated plants were inhibited in growth for several days, but began to grow again before the experiment concluded.

To determine if maleic hydrazide is insecticidal as a direct contact spray at 4,000 p.p.m. of active ingredient on the adult female aphids two tests were conducted. Sprays were applied with a DeVilbiss No. 33 Pocket Atomizer, soaking the aphids almost to the point of drowning in the Petri plates in which they were held. Check aphids were sprayed with water. After the sprays had been applied the aphids were placed immediately in clip cages on untreated broad bean plants and counts on mortality and fecundity were recorded after five days. Results are shown in Table XII. In both tests there was no significance between number of progeny from aphids sprayed with MH and those sprayed with water only, and no direct toxicity to adult aphids was demonstrated.

Crafts _et al_ (1958) stated that maleic hydrazide is effective as a growth inhibitor of plants when absorbed through either leaves or roots. The present study showed that broad bean growth is inhibited by dipping the lower leaves for five seconds in solutions of MH, although much higher concentrations (usually as high as 20,000 p.p.m.) are required than for root absorption. To avoid possible residues on dipped leaves, and also because the dipped leaves at high concentrations often were severely damaged, aphids in

TABLE XII

FECUNDITY OF PEA APHIDS SPRAYED WITH MH AT 4,000 P.P.M. OR WITH WATER AND CAGED FOR FIVE SUBSEQUENT DAYS ON UNTREATED BROAD BEAN PLANTS

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
July 10, 1959	MH 4,000 p.p.m.	16	4	448	75	20.7	4.29	1-39
	Water only	20	0	553	9	27.2	5.09	0-45
July 22, 1959	MH 4,000 p.p.m.	19	1	490	25	24.8	4.93	3-37
	Water only	18	2	535	42	26.5	5.14	6-41

the following tests were caged for the five day periods on one of the next higher double leaves.

Table XIII shows results obtained when concentrations of MH were 4,000, 3,000 and 2,000 p.p.m. of active ingredient, Table XIV results at 10,000, 8,000 and 6,000 p.p.m., Table XV results at 16,000, 14,000 and 12,000 p.p.m., Table XVI the data at concentrations of 24,000, 22,000 and 20,000 p.p.m. and Table XVII the data at 40,000, 30,000 and 20,000 p.p.m. At none of these concentrations by leaf-dipping was there any reduction in fecundity or adult mortality demonstrated among aphids on treated plants and those on the check plants. The aphids used for the test reported in Table XVII were past their reproductive peak as shown by the low average number of progeny in all treatments. During this series of tests the water soluble powder was replaced by the thirty per cent amine because a supply of the former was no longer available.

The results of all these tests with maleic hydrazide have been reported by Robinson (1959, 1960). They indicate that MH by root absorption at certain concentrations definitely causes a decrease in fecundity, and high nymphal mortality. The question arises whether these deleterious effects are caused by changes within the treated plant, or by some direct toxic effect on the reproductive metabolism of the female aphid, or perhaps some change in feeding habits.

TABLE XIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH40 (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
March 5 1959	4,000 p.p.m.	13	7	282	36	17.5	4.18	4-29
	3,000 p.p.m.	15	5	293	15	16.7	4.07	3-25
	2,000 p.p.m.	14	6	330	4	21.2	4.59	10-38
	Water only	13	7	314	20	20.5	4.57	16-28

TABLE XIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH40 (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
March 26 1959	10,000 p.p.m.	16	4	332	5	19.3	4.39	7-30
	8,000 p.p.m.	19	1	349	0	18.4	4.28	7-32
	6,000 p.p.m.	19	1	384	0	20.2	4.51	11-30
	Water only	15	5	360	4	20.5	4.54	9-30

TABLE XV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH_{40} (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
April 29, 1959	16,000 p.p.m.	20	0	460	0	23.0	4.70	3-39
	14,000 p.p.m.	17	3	344	0	20.2	4.52	12-32
	12,000 p.p.m.	20	0	506	0	25.3	4.91	0-41
	Water only	17	3	479	6	26.8	5.19	14-38

TABLE XVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH_{30} (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 2, 1959	24,000 p.p.m.	19	1	223	4	11.5	3.16	0-31
	22,000 p.p.m.	19	1	204	8	10.3	3.15	0-20
	20,000 p.p.m.	14	6	157	2	9.9	2.83	0-25
	Water only	19	1	312	1	16.4	3.78	0-35

TABLE XVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MH_{30} (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 20 1959	40,000 p.p.m.	15	5	149	0	9.9	2.66	0-34
	30,000 p.p.m.	15	5	109	15	5.1	2.03	0-16
	20,000 p.p.m.	18	2	133	0	7.4	2.39	0-30
	Water only	18	2	92	0	5.1	2.05	0-27

Fults and Payne (1956) reported on the effects of maleic hydrazide on the tops of potatoes, sugar beets and pinto beans. When relative total free amino acids from plants treated with foliar sprays were compared, MH produced a significant increase in both sugar beets and potatoes, but the effect on pinto beans was not significant. However, there was a large decrease in relative total proteins and a change in character of the proteins. Crafts _et al_ (1958) reviewed the herbicidal properties of maleic hydrazide and reported on further studies made on bean, barley and Bermudagrass. Using C^{14} - labelled MH they found this chemical translocated freely to all parts of the plant. Their studies showed MH to be primarily a dormancy - inducing agent. Audus (1959) has reviewed the evidence that maleic hydrazide is an auxin inhibitor. He concluded that there is not yet sufficient evidence that MH inhibits plant growth primarily by upsetting the auxin balance. Other observations are reviewed on the possibility that carbohydrate metabolism is seriously disturbed. Zukel (1957) has made a literature summary on maleic hydrazide for the years 1949-1957.

There is general agreement on the non-toxicity of maleic hydrazide for mammalian tissues. Barnes _et al_ (1957) concluded after extensive tests with rats and mice that MH had no effect on the growth and general health of rats or mice, and no carcinogenic properties. When MH was introduced into mice both orally and by skin injection there was no evidence of any effect on mitosis or cell division. Klingman *et al* (1958) state that the LD_{50} for rats is 5,800 mg./kg. In this connection it is interesting to note the findings of Fischnich *et al* (1958). Potato tubers were treated with MH to prolong tuber dormancy. Long-term feeding trials showed that if rats were maintained on a diet including tubers from plants sprayed with MH fertility was reduced. No such effect was noted where the diet included tubers treated with MH after lifting. This report on reduced fertility from MH was one of two found in the literature, on any animal. Zukel (1957, p. 115) reported that C. J. Nusbaum found that foliar applications of MH inhibited the development of galls on tobacco plants and the reproduction of the nematode *Meloidogyne incognita*. The significance of these two reports is their similarity to the present findings with the pea aphid.

Little is known of the effects on insects of natural inhibitors present in plants. Lipke and Fraenkel (1954) reviewed this subject briefly and commented on the inability of certain pests of stored grains to develop normally on soybean products. From tests with *Tribolium confusum* where extracts of raw soybean were toxic to all the larvae at the 2.5 per cent level and inhibited the digestion of protein in vitro by 50 per cent, they concluded that the relative freedom of soybeans from insect damage may be due to the presence of a hitherto undescribed toxin.

As mentioned above, research reports on the metabolic disturbances caused in plants by MH are contradictory. During the present study one attempt was made to determine possible plant changes, following the method of Porter et al (1957). Visual comparisons of chromatograms from extracts of broad bean treated with MH at 4,000 p.p.m. and untreated plants failed to show qualitative differences in amino acids.

McLeish (1953) has shown that maleic hydrazide suppresses mitosis in all actively growing plant tissues of *Vicia*. It breaks chromosomes, however, only in plants with visible heterochromatin. Breakage can occur in up to fourteen distinguishable segments, eight of which are known to be heterochromatic. Breakage frequency is proportional to the visible size of the several heterochromatic segments. As mentioned above, Barnes et al (1957) found no evidence of any effect from MH on mitosis or cell division in mice. Similar negative findings on the effect of MH on dogs, rabbits, guinea pigs, rats, mice, frogs, toads and salamanders are reported in the literature summary by Zukel (1957). This can be concisely stated by the following excerpt from page 7 of the above summary: "There is a fundamental difference in response of plant and animal tissue to MH. Cell division in plants is inhibited at low dilution whereas cultures of mammalian tissue are unaffected at high concentrations. Similarly, growth of tumors in plants is inhibited whereas animal tumors are not affected".

Because none of the above literature summary contained information on the effects of MH on arthropods, and the present study had offered no suitable hypothesis to account for the reduction in fecundity of the pea aphids, an attempt was made beginning in July, 1960, to find some embryological or histological explanation.

One sample of pea aphids was allowed to feed for five days on plants treated with MH by root absorption at 4,000 p.p.m., and another sample was caged for five days on untreated plants. Aphids were then killed and fixed in Zenker's Fluid, hardened and dehydrated in succession through 50 and 70 per cent ethyl alcohol, 80 per cent alcohol with iodine, 96 per cent and absolute ethyl alcohol, and further treated with xylol and cedarwood oil. Embedding was done in paraffin wax. Serial sections were stained with Mallory's Triple Stain.

Figures 4 and 5 are photographs of longitudinal sections, cut at 8 microns, of aphids from untreated plants. Figure 6 is a photograph of a transverse section, cut at 8 microns, of an aphid from an untreated plant.

Figures 7 and 8 are photographs of longitudinal sections, cut at 10 microns, of aphids from plants treated with maleic hydrazide. Figure 9 is a photograph of a transverse section, cut at 8 microns, of an aphid from a plant treated with maleic hydrazide.

The six figures were chosen from many serial sections on several dozens of slides, to illustrate typical sections showing embryos in all stages of development inside the mother aphid. All the slides were examined at a magnification of 120 X. During examination reference was made to the text and very fine drawings of aphid embryos found in Uichanco (1924).

No histological differences could be found in tissues of female aphids or their embryos between those from untreated plants (Figures 4, 5 and 6) and from plants treated with maleic hydrazide (Figures 7, 8 and 9). Embryological development apparently proceeded normally in aphids from plants treated with MH. However, the data illustrated in Figure 3 show that a reduced fecundity occurs for the life time of the aphid. One can only assume that rate of embryological development is retarded and that parturition is inhibited or suppressed.

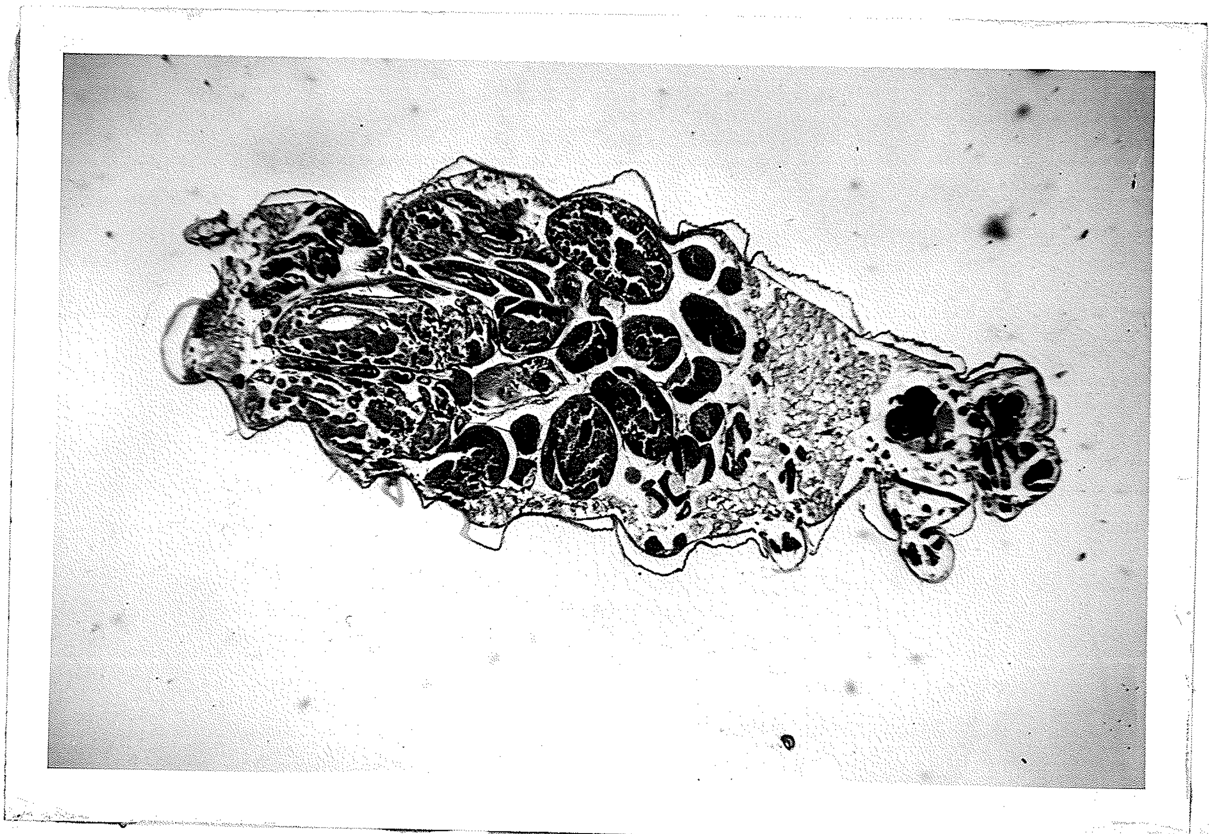

FIGURE 4

PHOTOGRAPH OF LONGITUDINAL SECTION OF ADULT
PEA APHID FROM UNTREATED BROAD BEAN
PLANT, 8 MICRONS, ENLARGED 42 X

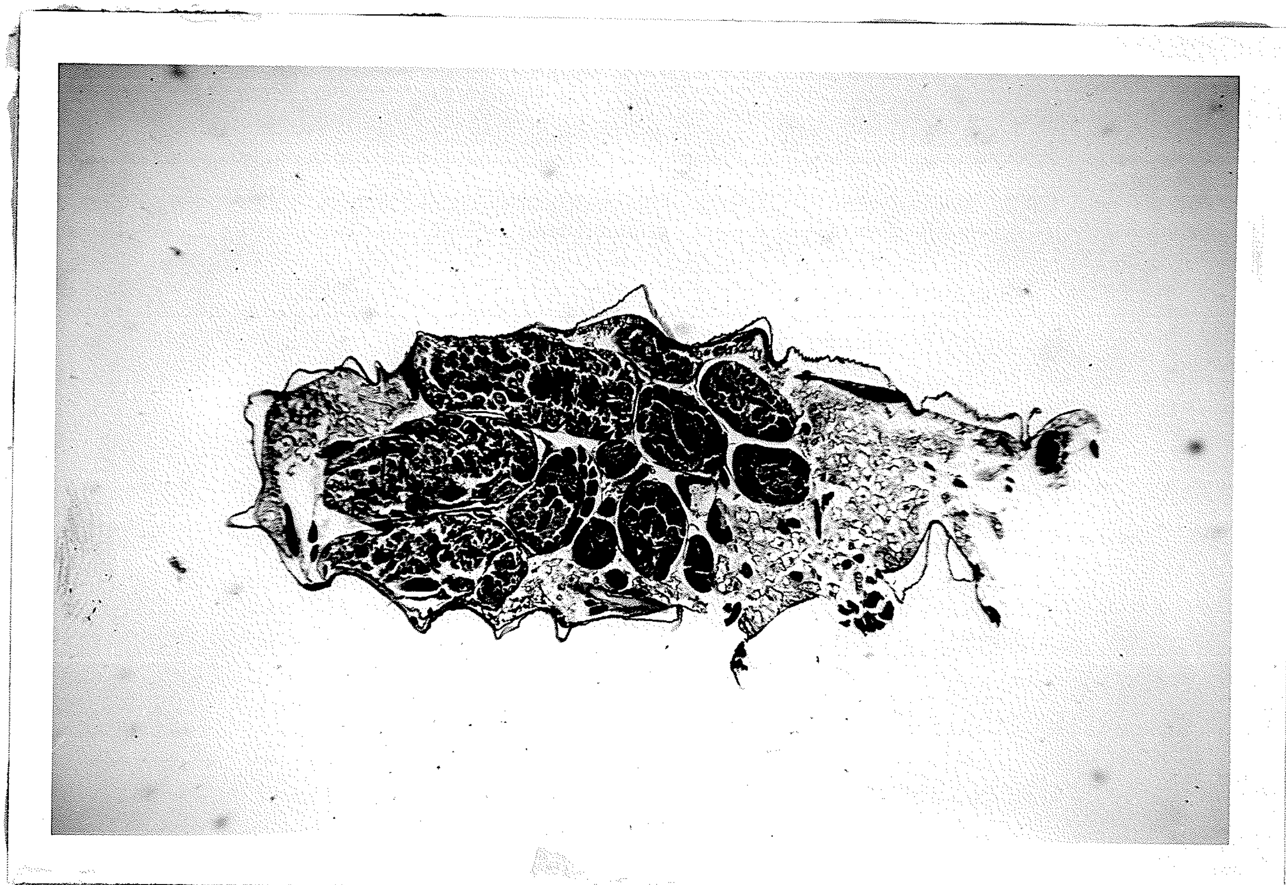

FIGURE 5

PHOTOGRAPH OF LONGITUDINAL SECTION OF ADULT PEA APHID FROM UNTREATED BROAD BEAN PLANT, 8 MICRONS, ENLARGED 42 X

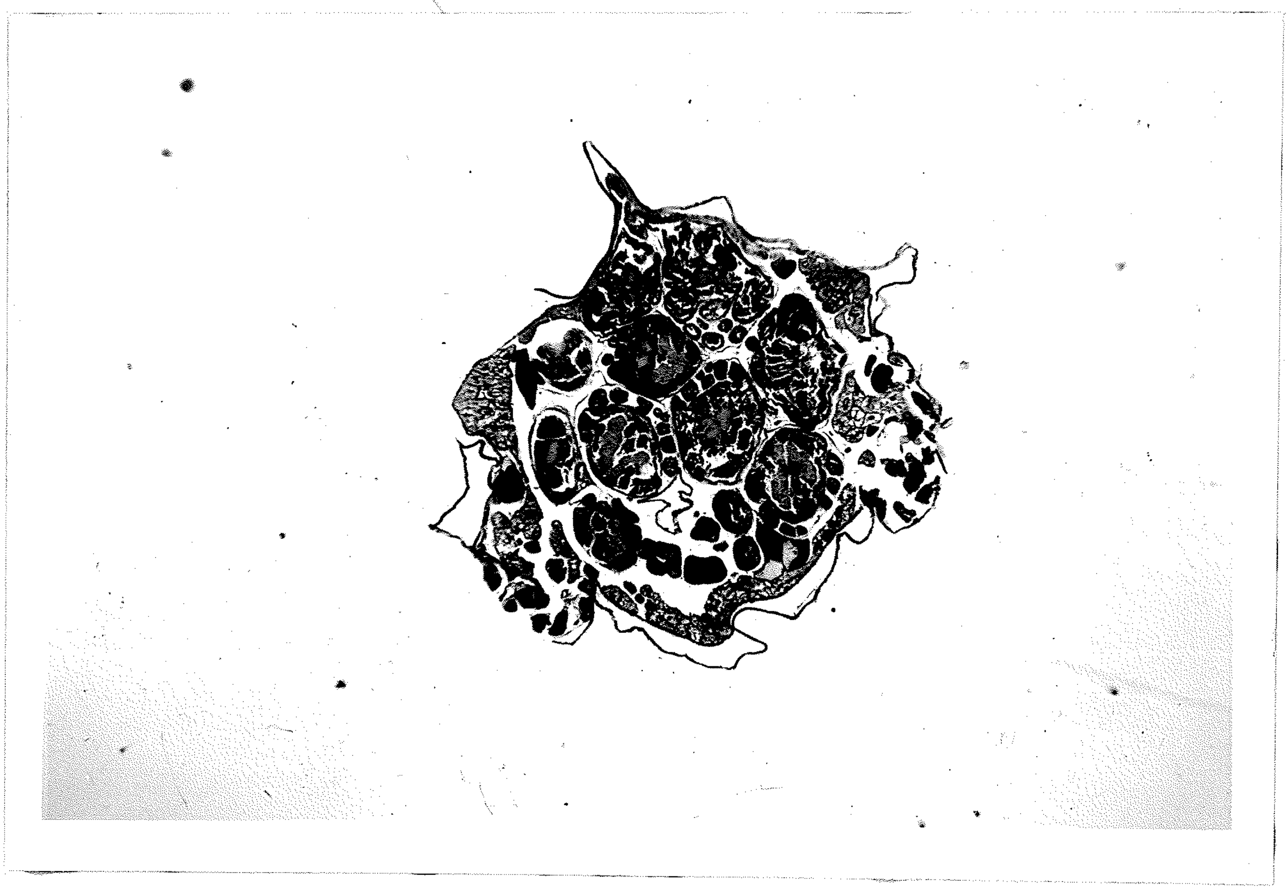

FIGURE 6

PHOTOGRAPH OF TRANSVERSE SECTION OF ADULT PEA APHID FROM UNTREATED BROAD BEAN PLANT, 8 MICRONS, ENLARGED 56 X

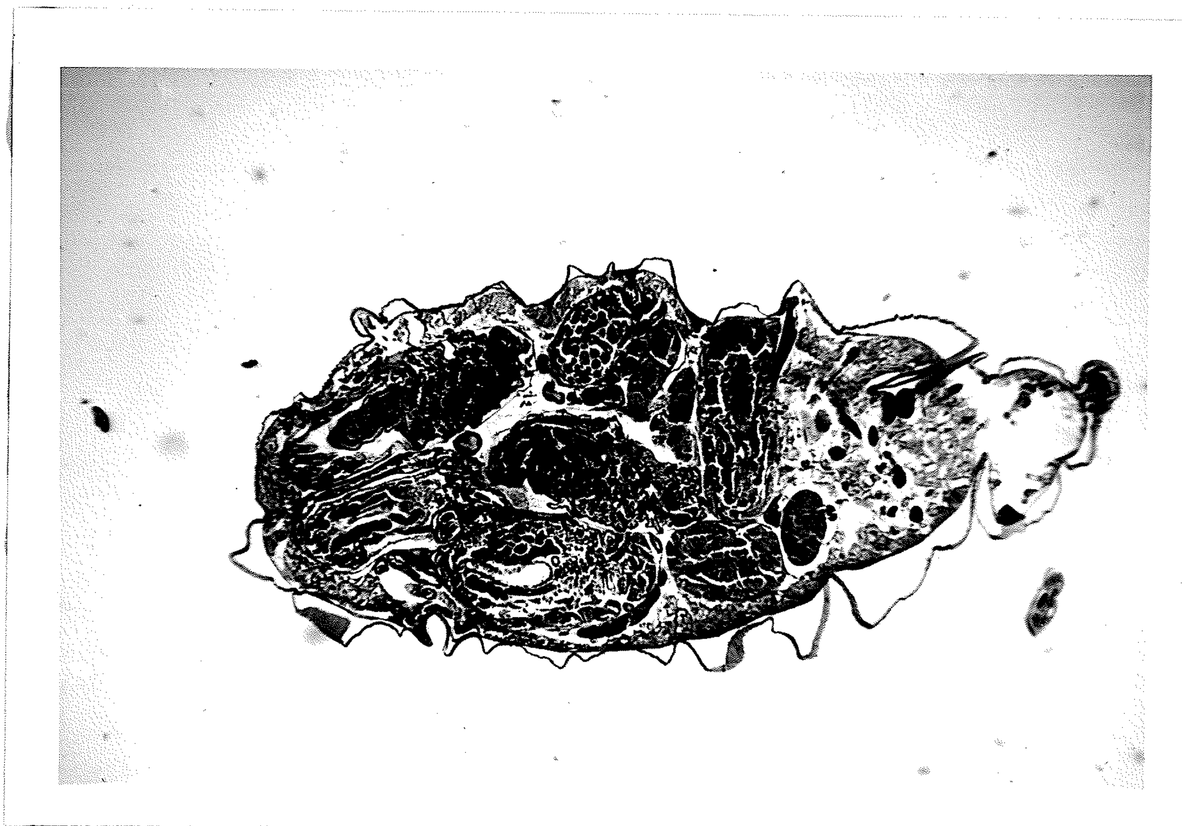

FIGURE 7

PHOTOGRAPH OF LONGITUDINAL SECTION OF ADULT PEA APHID FROM BROAD BEAN PLANT TREATED WITH MH, 10 MICRONS, ENLARGED 42 X

FIGURE 8

PHOTOGRAPH OF LONGITUDINAL SECTION OF ADULT PEA APHID FROM BROAD BEAN PLANT TREATED WITH MH, 10 MICRONS, ENLARGED 42 X

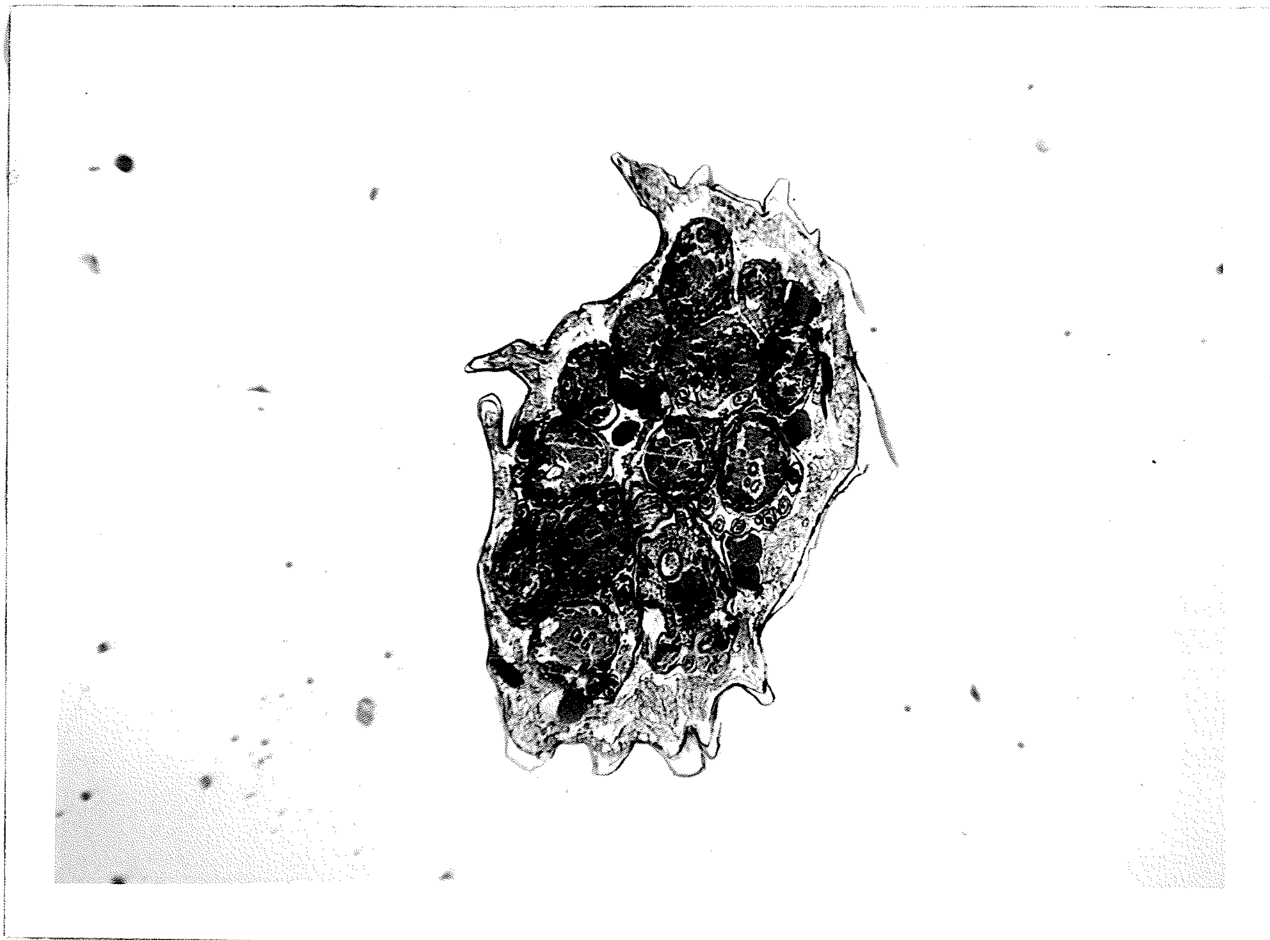

FIGURE 9

PHOTOGRAPH OF TRANSVERSE SECTION OF ADULT PEA APHID FROM BROAD BEAN PLANT TREATED WITH MH, 8 MICRONS, ENLARGED 56 X

CHAPTER VI

TESTS WITH AMITROLE

The chemical name of amitrole, also sometimes referred to as aminotriazole or ATA, is 3-amino-1, 2, 4-triazole. It has shown promise for control of Canada thistle, leafy spurge, Russian knapweed, quackgrass, Bermudagrass, sedges, horsetail rush, cattails, and tules, and several woody plants such as poison ivy, poison oak, white ash and prickly ash. Amitrole is translocated throughout the plant and affects the growing points, producing chlorosis and inhibition. It is low in oral toxicity (LD_{50} = 15,000 mg./kg. for mice).

When amitrole was applied to broad bean, both by root absorption and by leaf dipping, plants were quite severely damaged by the end of one week at rates of 300 and 200 p.p.m. of active ingredient. At both rates and also at 100 p.p.m. terminal leaves were highly chlorotic. Over 300 p.p.m. plant injury was so severe that the plants died. A twenty-five per cent liquid formulation was used in all tests.

Table XVIII shows the results obtained when wingless pea aphids were caged for five days on broad bean plants treated with amitrole by root absorption at rates of 100, 10 and 1 p.p.m. There was a reduction in average number of live progeny of surviving adults significant at the one per cent level of aphids on the plants treated at 100 p.p.m., but not

TABLE XVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AMITROLE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Nov. 21, 1959	100 p.p.m.	19	1	296	267	1.5	1.21**	0-8
	10 p.p.m.	20	0	603	0	30.1	5.52	20-41
	1 p.p.m.	19	1	535	0	28.2	5.33	20-42
	Water only	19	1	652	0	34.3	5.87	18-48

** Significant at the 1% level

on those treated at 10 and 1 p.p.m. Table XIX shows the results obtained when rates by root absorption were increased to 300, 200 and 100 p.p.m. There was no significant adult mortality, but high nymphal mortality. It was observed that nymphs crawled off the leaves on to the sides of the clip cages to die. Average numbers of live progeny of surviving adults were reduced significantly at the one per cent level from the check at all three rates. Total fecundity was reduced. Table XX shows results obtained when winged adults were caged on plants treated at 100 p.p.m. Total number of progeny was greatly reduced and nymphal mortality was high. There was a reduction in average number of live progeny of surviving adults significant at the one per cent level from the check.

Twenty adult wingless female aphids were sprayed with amitrole as a contact spray, similar to the test reported in the previous chapter with MH, and twenty were sprayed with water. They were caged immediately for five days on untreated broad bean plants. Results are shown in Table XXI. Adult mortality appeared to be fairly high (thirteen died out of twenty) but those that lived produced almost the same number of progeny as those sprayed with water.

A further test was conducted to determine if this disturbance of reproductive metabolism and high nymphal mortality would continue if wingless adult females were caged

TABLE XIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AMITROLE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Dec. 9, 1959	300 p.p.m.	17	3	320	320	0	0.71**	0-0
	200 p.p.m.	19	1	473	473	0	0.71**	0-0
	100 p.p.m.	19	1	497	459	2.0	1.39**	0-9
	Water only	20	0	662	0	33.1	5.74	13-50

** Significant at the 1% level

TABLE XX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE ALATE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AMITROLE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
July 19, 1960	100 p.p.m.	13	7	123	105	1.4	1.17**	0-9
	Water only	19	1	422	0	22.1	4.72	9-28

** Significant at the 1% level

TABLE XXI

FECUNDITY OF PEA APHIDS SPRAYED WITH AMITROLE AT 100 P.P.M., OR WITH WATER, AND CAGED FOR FIVE SUBSEQUENT DAYS ON UNTREATED BROAD BEAN PLANTS

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 9, 1960	AMITROLE 100 p.p.m.	7	13	222	0	25.7	5.08	14-33
	Water only	16	4	445	0	27.6	5.14	0-42

for five days on plants treated at 100 p.p.m., and then transferred for a further five days to untreated plants. Table XXII shows the beginning of this test, with the high nymphal mortality. Table XXIII shows the results obtained when the aphids were caged for a further five days on untreated plants. Average number of live progeny of surviving adults from the plants treated with amitrole at 100 p.p.m. differed significantly at the one per cent level from the check, but nymphal mortality was relatively low. This indicates that the nymphal mortality on treated plants must be due at least in part to toxic plant sap ingested by the first instar nymphs.

In another experiment the lower double leaves of broad bean plants were dipped in concentrations of amitrole of 300, 200 and 100 p.p.m. At the end of forty-eight hours wingless adult females were caged on one of the next higher leaves for five days. Results are shown in Table XXIV. Despite the fact that terminal leaves were highly chlorotic, there was no adult or nymphal mortality and no reductions in fecundity. There is no ready explanation why amitrole by root absorption causes significant toxicity to the nymphs, but not by leaf dipping.

A hypothesis was advanced that reductions in fecundity of aphids caged on broad bean plants treated with either MH or amitrole might be due to a decrease in plant sap ingested. In order to make a comparison, aphids were starved for twenty-

TABLE XXII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AMITROLE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Aug. 30, 1960	100 p.p.m.	13	7	99	88	0.8	0.98**	0-6
	Water only	14	6	301	0	21.2	4.51	3-37

** Significant at the 1% level

TABLE XXIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF PEA APHIDS FROM PLANTS TREATED WITH AMITROLE, CAGED FOR A FURTHER FIVE DAYS ON UNTREATED BROAD BEANS

Source plants	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Amitrole 100 p.p.m.	11	2	164	25	12.6	3.27**	0-27
Water only	13	1	330	8	24.7	4.95	13-35

** Significant at the 1% level

TABLE XXIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AMITROLE (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Apr. 25, 1960	300 p.p.m.	20	0	636	0	31.8	5.65	20-48
	200 p.p.m.	20	0	635	0	31.7	5.57	3-50
	100 p.p.m.	20	0	617	0	30.8	5.56	16-43
	Water only	19	1	565	0	29.7	5.47	16-41

four hours to determine if starvation for a short period would decrease fecundity. The data shown in Table V indicated that starvation periods of thirty-eight hours caused the death of seven out of ten aphids. Aphids starved for twenty-four hours were caged for five subsequent days on untreated broad bean plants, and compared with others from plants treated with MH at 4,000 p.p.m., amitrole at 100 p.p.m. and water only. Results are shown in Table XXV. There was no significant reduction in fecundity of the aphids starved for twenty-four hours. These data and those in Table V indicate that if aphids are starved for short periods normal reproduction commences on resumption of feeding. The reductions in fecundity of aphids caged on broad bean plants treated with either MH or amitrole at the rates indicated in Table XXV are not due to non-feeding by the adult aphids.

An attempt was made to determine if nymphs born and reared on broad bean plants treated with amitrole at 100 p.p.m. would show a reduction in fecundity when caged as adults for the remainder of their lives on untreated plants. Results are shown in Table XXVI. For some unknown reason, of the twenty aphids from plants treated with water only, fifteen were winged after becoming adult. Of eleven nymphs which were transferred from the plants treated with amitrole, only three survived, and these were all winged as adults. The data show that there was no significant difference in

TABLE XXV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF PEA APHIDS STARVED FOR TWENTY-FOUR HOURS, COMPARED WITH OTHERS FROM BROAD BEAN PLANTS TREATED WITH MH AND AMITROLE

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 19 1960	MH 4,000 p.p.m.	19	1	249	62	9.8	2.69**	0-37
	Amitrole 100 p.p.m.	14	6	205	199	0.4	0.86**	0-5
	Starved 24 hours	20	0	692	0	34.6	5.84	3-45
	Water only	20	0	750	0	37.5	6.14	21-47

** Significant at the 1% level

TABLE XXVI

COMPARISON OF FECUNDITY OF WINGED PEA APHIDS BORN ON BROAD BEAN PLANTS TREATED WITH AMITROLE AT 100 P.P.M., OR WITH WATER, TRANSFERRED TO UNTREATED PLANTS FOR THE REMAINDER OF THEIR LIVES

Source	No. of adults	Total days lived by all females	Total progeny	Average fecundity per day	Trans-formed average
From plants treated with amitrole	3	72	187	2.6	7.88
From plants treated with water only	15	358	780	2.2	7.19

average fecundity per day between aphids from the plants treated with amitrole and those treated with water only. This indicates that the reproductive capacity of the three survivors was not impaired.

Table I shows an average number of live progeny of winged females for a five day period near the peak of production, of 20.1 (or 4.02 per day). The average fecundity of winged females shown in Table XXVI is based on their total life span as adults, including in most individuals a fairly long post-oviposition period, which reduces average fecundity per day to 2.6 or 2.2 nymphs.

CHAPTER VII

TESTS WITH OTHER HERBICIDES OR PLANT GROWTH REGULATORS

2,4-D

2,4-D has the chemical name 2,4-dichlorophenoxyacetic acid. It is widely used as a post-emergence selective herbicide to control broadleaved weeds in corn, small grains, sorghum, rice, flax, lawns, and to control brush and weeds in pastures, along roadsides and in drainage and irrigation ditches. In the present series of tests 2,4-D was used at several different rates on broad bean plants, because of the recent report by Maxwell and Harwood (1960) which will be discussed later. In all tests the fifty per cent amine of 2,4-D was used. When rates over 2 p.p.m. were applied by root absorption to broad bean plants the plants were killed. Rates as low as 0.01 p.p.m. caused noticeable epinasty of the plants.

Table XXVII shows results obtained when 2,4-D was applied by root absorption for forty-eight hours at rates of 1, 0.1, and 0.01 p.p.m. and adult wingless female aphids were caged for five days on one of the lower double leaves. Table XXVIII reports results obtained at rates of 2, 1 and 0.5 p.p.m. The data show that there were no significant increases or decreases in average number of live progeny of surviving adults at any of the rates used.

TABLE XXVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4-D (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 29 1958	1.0 p.p.m.	9	1	173	11	17.6	3.95	1-33
	0.1 p.p.m.	8	2	164	3	16.8	4.01	2-30
	0.01 p.p.m.	8	2	242	3	27.4	5.02	12-69
	Water only	7	3	174	0	24.9	4.96	13-41

TABLE XXVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4-D (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Aug. 18 1958	2 p.p.m.	18	2	229	0	12.3	3.46	0-23
	1 p.p.m.	17	3	160	3	9.1	3.12	1-22
	0.5 p.p.m.	17	3	157	0	9.0	2.87	0-28
	Water only	18	2	203	6	9.5	3.09	3-19

In the next series of tests 2,4-D was applied by dipping lower leaves of broad bean, and caging adult wingless females for five days on one of the next higher leaves. Table XXIX shows results obtained at rates of 1, 0.1 and 0.01 p.p.m., and Table XXX at rates of 1000, 100 and 10 p.p.m. The data show that there were no significant increases or decreases in average number of live progeny of surviving adults at any of the rates used.

These results are contrary to the findings of Maxwell and Harwood (1960). These authors claim to have demonstrated an increased reproduction of pea aphids on broad beans treated with 2,4-D. However, their experiments were not conducted under controlled temperatures or photoperiod and this probably accounts at least in part for the very erratic results shown in their Table 1. Percentage increases over ten days varied from a low of 4.8 per cent at a concentration of 41.0 p.p.m. in August to a high of 450 per cent at a rate of 4.1 p.p.m. in July. No mention was made of the number of replicates used, and the data were not analyzed statistically. Table 2 of Maxwell and Harwood (1960) gives the production of nymphs (presumably both live and dead) in five days in four tests, four aphids each test, on broad bean plants treated at 4.1 p.p.m. of 2,4-D. An overall increase of eight per cent is claimed, although the data were not subjected to statistical analysis. It is worthy of note that in four out of the

TABLE XXIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4-D (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Jan. 29 1959	1 p.p.m.	8	12	243	27	21.3	4.65	16-28
	0.1 p.p.m.	13	7	277	34	18.0	4.26	10-31
	0.01 p.p.m.	15	5	278	12	16.5	3.96	0-25
	Water only	15	5	340	4	21.3	4.65	12-30

TABLE XXX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4-D (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Feb. 12 1959	1000 p.p.m.	12	8	220	21	14.8	3.73	0-25
	100 p.p.m.	16	4	295	3	16.0	3.99	3-26
	10 p.p.m.	15	5	241	19	13.9	3.62	1-26
	Water only	15	5	274	21	15.2	3.87	5-28

sixteen tests there was an actual decrease in fecundity. The results reported by Maxwell and Harwood (1960) are not sufficiently convincing to demonstrate their claim that reproduction of pea aphids is increased on broad beans treated with 2,4-D.

2,4,5-T

The chemical name for 2,4,5-T is 2,4,5-trichlorophenoxyacetic acid. It is used as a post-emergence selective herbicide to control broadleaved weeds. Its main use is as a "brush-killer", either alone or in combination with 2,4-D.

A 42.5 per cent liquid formulation was available for testing possible effects on pea aphids caged on treated broad beans. Table XXXI shows results obtained when concentrations of 2,4,5-T at 0.01, 0.001 and 0.0001 p.p.m. were applied by root absorption. Results in Table XXXII were obtained at rates of 0.1, 0.01 and 0.001 p.p.m. Severe epinasty occurred at the higher concentrations and at 1 p.p.m. plants were killed. When 2,4,5-T was applied by dipping the lower leaves of broad bean epinasty was severe at 0.1 p.p.m., and less noticeable at 0.01 and 0.001 p.p.m. Results of the leaf dipping experiment are shown in Table XXXIII. At none of the rates used of 2,4,5-T, either by root absorption or by leaf dipping, was there any significant increase or decrease in fecundity of pea aphids caged on the treated plants, nor evidence of adult or nymphal mortality when compared with the check.

TABLE XXXI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4,5-T (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 3 1958	0.01 p.p.m.	9	1	191	4	20.8	4.51	8-31
	0.001 p.p.m.	9	1	130	8	13.4	3.23	0-25
	0.0001 p.p.m.	10	0	205	1	20.4	4.53	11-29
	Water only	10	0	158	5	15.3	3.73	4-28

TABLE XXXII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4,5-T (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 15 1958	0.1 p.p.m.	9	11	244	43	18.0	3.94	0-38
	0.01 p.p.m.	7	13	271	53	13.9	3.32	0-38
	0.001 p.p.m.	10	10	364	48	24.1	4.87	6-34
	Water only	12	8	251	6	18.8	4.25	1-28

TABLE XXXIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,4,5-T (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Feb. 25 1959	0.1 p.p.m.	17	3	424	14	22.1	4.67	5-37
	0.01 p.p.m.	16	4	386	15	22.0	4.72	14-31
	0.001 p.p.m.	13	7	363	34	22.2	4.70	7-31
	Water only	11	9	371	36	23.9	4.91	17-34

MCPA

The chemical name of MCPA is 2-methyl, 4-chlorophenoxyacetic acid. It is used as a post-emergence selective herbicide. In Manitoba it is recommended for control of weeds in oats, because oats are more sensitive to 2,4-D than are wheat or barley. The formulation used in the following tests was a fifty per cent amine. When MCPA was used at 10 p.p.m. by root absorption most of the plants were killed. Table XXXIV shows results obtained when pea aphids were caged on plants treated at 8, 4 and 2 p.p.m. by root absorption. Table XXXV gives the results from rates of 10, 1, and 0.1 p.p.m. by dipping the lower leaves. At none of the rates used, either by root absorption or by leaf dipping was there any significant increase or decrease in fecundity of pea aphids caged on treated plants, nor evidence of adult or nymphal mortality when compared with the check.

Sesone

Sesone, also known as 2,4-DES, has the chemical name of 2,4-dichlorophenoxyethyl sulfate. It is formulated as the sodium salt, a white crystalline powder that is soluble in water. When applied to moist soils sesone is converted into a herbicide with properties similar to 2,4-D. It is effective as a pre-emergence herbicide for weed control in a number of crops.

TABLE XXXIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MCPA (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 2 1958	8 p.p.m.	12	8	368	15	22.3	4.63	5-41
	4 p.p.m.	14	6	343	8	21.6	4.41	0-36
	2 p.p.m.	17	3	399	6	22.6	4.67	3-36
	Water only	16	4	442	2	26.2	5.09	9-40

TABLE XXXV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MCPA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
April 9 1959	10 p.p.m.	12	8	259	23	16.9	4.15	11-27
	1 p.p.m.	14	6	267	37	14.9	3.13	6-24
	0.1 p.p.m.	13	7	236	26	14.0	3.72	6-31
	Water only	11	9	220	25	13.5	3.58	1-23

Results proved to be erratic using a soluble powder and several tests were discarded before those reported in Table XXXVI where sesone was applied by root absorption at rates of 1000, 100 and 10 p.p.m. In some tests a rate of 100 p.p.m. would kill some of the plants and in other tests many of the plants would survive at a rate of 1000 p.p.m. by root absorption. Table XXXVII reports results obtained when sesone was applied to lower leaves of broad bean at concentrations of 8,000, 4,000 and 2,000 p.p.m. At none of these rates, either by root absorption or by leaf dipping, was there any increase or decrease in fecundity, or evidence of adult or nymphal mortality of the pea aphids caged on the treated broad beans.

<u>Erbon</u>

The chemical name of erbon is 2-(2,4,5-trichlorophenoxy) ethyl 2,2-dichloropropionate. It is classed as a systemic herbicide, toxic to both grasses and broad-leaved plants. It is persistent in soil and useful for non-selective weed control. A 41.3 per cent liquid formulation was used during the present tests. Table XXXVIII gives the results obtained when erbon was applied by root absorption to broad bean plants at rates of 1,000, 100 and 10 p.p.m. and Table XXXIX when erbon was applied by leaf dipping at 10,000, 1000 and 100 p.p.m. In all treatments when pea aphids were caged on treated plants for five days there were no significant

TABLE XXXVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH SESONE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Oct. 7 1959	1,000 p.p.m.	16	4	354	0	21.6	4.71	4-42
	100 p.p.m.	20	0	404	0	20.2	4.45	8-39
	10 p.p.m.	19	1	541	0	28.2	5.31	14-43
	Water only	18	2	409	0	21.9	4.68	8-37

TABLE XXXVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH SESONE (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 9 1959	8,000 p.p.m.	17	3	176	21	8.8	2.95	1-16
	4,000 p.p.m.	18	2	194	48	7.9	2.80	0-12
	2,000 p.p.m.	17	3	226	26	10.6	3.29	4-19
	Water only	18	2	195	15	10.0	3.10	0-18

TABLE XXXVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH ERBON (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Oct. 12 1959	1,000 p.p.m.	20	0	582	0	29.1	5.38	10-41
	100 p.p.m.	20	0	606	0	30.3	5.51	18-41
	10 p.p.m.	20	0	637	0	31.8	5.66	20-41
	Water only	19	1	630	0	33.2	5.72	14-48

TABLE XXXIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH ERBON (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 30 1959	10,000 p.p.m.	18	2	599	10	30.9	5.45	1-49
	1,000 p.p.m.	19	1	711	2	36.1	5.88	0-52
	100 p.p.m.	20	0	611	3	30.4	5.31	0-54
	Water only	19	1	622	0	31.9	5.54	5-49

mortality to nymphs or adults, compared with those on untreated plants.

Silvex

Silvex has also been designated as 2-(2,4,5-TP), and trade names are Kuramine and Kuron. Its chemical name is 2-(2,4,5-trichlorophenoxy) propionic acid. It is recommended as a post-emergence selective herbicide to control broadleaved weeds. A 42.5 per cent liquid ester formulation was used in tests on broad beans by root absorption at 100, 10 and 1 p.p.m. (Table XL) and by leaf dipping at 100, 10 and 1 p.p.m. (Table XLI). Epinasty was severe at all rates for both methods of application. Results in Tables XL and XLI show that there were no significant increases or decreases in fecundity of aphids caged on treated plants and no significant adult or nymphal mortality.

4-(2,4-DB)

The chemical name for 4-(2,4-DB) is 4-(2,4-dichlorophenoxy) butyric acid. It has shown promise for post-emergence control of broadleaved weeds, particularly in relatively tolerant legumes such as white clover, alsike, red clover, alfalfa and birdsfoot trefoil. A forty per cent liquid amine salt was used in the following tests. When 4-(2,4-DB) was applied by root absorption at 1000, 100 and 10 p.p.m. epinasty was so severe at 1000 p.p.m. that only

TABLE XI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH SILVEX (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 29, 1960	100 p.p.m.	17	3	721	22	39.4	6.23	8-53
	10 p.p.m.	20	0	687	0	34.3	5.79	1-45
	1 p.p.m.	18	2	750	0	38.6	6.18	17-56
	Water only	20	0	723	0	36.1	6.02	19-46

TABLE XLI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH SILVEX (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
April 25 1960	100 p.p.m.	16	4	452	16	27.0	5.21	15-37
	10 p.p.m.	18	2	423	9	22.1	4.65	9-38
	1 p.p.m.	20	0	515	0	25.7	5.09	17-38
	Water only	18	2	415	5	22.0	4.67	6-36

one plant of twenty survived, as shown in Table XLII. Table XLIII shows results obtained by dipping lower leaves at rates of 100, 10 and 1 p.p.m. There was no significant increase or decrease in fecundity of pea aphids caged on treated broad beans, nor any significant adult or nymphal mortality compared with the checks shown in Tables XLII and XLIII.

4-(MCPB)

The chemical name of 4-(MCPB) is 4-(2-methyl-4-chlorophenoxy) butyric acid. It has shown promise in experimental trials for post-emergence control of broad-leaved weeds. In the present series of tests it was used as a liquid forty per cent amine salt at rates of 100, 10 and 1 p.p.m. by root absorption as shown in Table XLIV, and at 1,000, 100 and 10 p.p.m. by leaf dipping as shown in Table XLV. When 4-(MCPB) was applied by root absorption at 1,000 p.p.m. all the broad bean plants were killed. There was no significant increase or decrease in fecundity of pea aphids caged on treated broad beans, nor any significant adult or nymphal mortality compared with the checks shown in Table XLIV and XLV.

DNBP

DNBP is a dinitro compound, 4,6-dinitro ortho secondary butylphenol. It is recommended for pre-emergence

TABLE XLII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 4-(2,4-DB) (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Jan. 14 1960	1,000 p.p.m.	Plants	killed	---	---	---	---	---
	100 p.p.m.	20	0	773	0	38.7	6.24	28-53
	10 p.p.m.	20	0	810	0	40.5	6.38	21-51
	Water only	20	0	774	0	38.7	6.24	24-51

TABLE XLIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 4-(2,4-DB) (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 9, 1960	100 p.p.m.	18	2	609	19	31.8	5.62	15-48
	10 p.p.m.	19	1	654	0	34.4	5.87	22-48
	1 p.p.m.	16	4	656	14	37.2	6.07	13-52
	Water only	16	4	528	22	30.8	5.38	6-48

TABLE XLIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 4-(MCPB) (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Trans-formed average	Range of fecundity
Feb. 1, 1960	100 p.p.m.	19	1	769	0	40.3	6.35	18-55
	10 p.p.m.	20	0	808	0	40.4	6.33	8-51
	1 p.p.m.	20	0	701	0	35.5	5.92	21-46
	Water only	18	2	752	3	40.7	6.36	15-54

TABLE XLV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 4-(MCPB) (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 9, 1960	1,000 p.p.m.	17	3	526	0	29.6	5.43	13-42
	100 p.p.m.	19	1	624	10	31.9	5.61	4-41
	10 p.p.m.	18	2	596	11	32.0	5.68	25-39
	Water only	20	0	677	0	33.8	5.84	19-42

and nonselective post-emergence weed control. The material used for the present tests was a fifty-three per cent amine salt, which when sold as a commercial formulation is called Dow Premerge. When DNBP was applied by root absorption to broad bean plants at 300 p.p.m. all plants were killed. At 200 and 100 p.p.m. some plants were killed, which accounted for the large number of dead adults shown in the data of Table XLVI. Results are shown in Table XLVII for DNBP applied by leaf dipping at rates of 1,000, 100 and 10 p.p.m. There were no significant increases or decreases in fecundity of aphids caged for five days on the treated broad beans and no significant adult or nymphal mortality except on dead plants.

IPC

IPC is a carbamate known chemically as isopropyl N-phenylcarbamate. It is a selective herbicide to certain grass-type plants. In Manitoba it is recommended for wild oat control in peas, sugar beets, sunflowers, soybeans and rapeseed, as a pre-planting treatment. In the present tests it was used as a twenty-five per cent liquid formulation. It was applied by root absorption at rates of 1,000, 100 and 10 p.p.m. Only three plants survived the treatment of 1,000 p.p.m., which explains the seventeen dead adults at that rate in Table XLVIII. IPC was applied by leaf dipping at rates of 1,000, 100 and 10 p.p.m. and the results from this test

TABLE XLVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH DNBP (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Feb. 3, 1960	300 p.p.m.	Plants	killed	---	---	---	---	---
	200 p.p.m.	10	10	435	40	37.0	6.02	13-51
	100 p.p.m.	13	7	537	11	37.9	6.13	14-53
	Water only	19	1	843	0	44.0	6.66	33-55

TABLE XLVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH DNBP (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 11, 1960	1,000p.p.m.	18	2	632	0	35.1	5.93	14-44
	100p.p.m.	19	1	606	21	30.5	5.49	11-48
	10 p.p.m.	20	0	637	14	31.1	5.55	9-42
	Water only	20	0	722	0	36.1	6.02	25-48

TABLE XLVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH IPC (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Oct. 14, 1959	1,000 p.p.m.	3	17	88	0	29.3	5.45	25-35
	100 p.p.m.	12	8	417	0	34.7	5.85	12-54
	10 p.p.m.	20	0	540	0	27.0	5.09	5-44
	Water only	20	0	595	0	29.7	5.47	17-39

are shown in Table XLIX. There were no significant increases or decreases in fecundity of aphids caged on any of the treated plants, nor any significant adult or nymphal mortality.

CIPC

The chemical name of CIPC, also sometimes called chloro IPC, is isopropyl N-(3-chlorophenyl) carbamate. It has properties similar to those of IPC. It has a somewhat longer residual action and controls wild oats and green foxtail and a variety of broad-leaved weeds. For the present tests a forty-eight per cent liquid formulation was used. CIPC was applied by root absorption to broad bean plants at rates of 3,000, 2,000, and 1,000 p.p.m., (Table L) and by leaf dipping at rates of 10,000, 1,000 and 100 p.p.m. (Table LI). There were no significant differences in fecundity of aphids caged on the treated plants and no significant adult or nymphal mortality compared with the checks.

EPTC

EPTC, also known as Eptam, is a thiocarbamate, with the chemical name ethyl N, N-di-n-propylthiolcarbamate. It has been used experimentally as a pre-emergence herbicide to control various grasses and broadleaved weeds. A liquid seventy-eight per cent formulation was applied to broad beans by root absorption at rates of 100, 10 and 1 p.p.m. Results

TABLE XLIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH IPC (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 17, 1960	1,000 p.p.m.	18	2	711	5	38.3	6.17	10-49
	100 p.p.m.	16	4	638	42	36.7	6.07	27-47
	10 p.p.m.	17	3	649	40	34.1	5.82	16-50
	Water only	18	2	665	16	35.2	5.85	7-50

TABLE L

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CIPC (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Nov. 11, 1959	3,000 p.p.m.	19	1	677	0	35.6	5.99	19-44
	2,000 p.p.m.	18	2	609	0	33.8	5.83	19-46
	1,000 p.p.m.	20	0	638	0	31.9	5.65	17-40
	Water only	19	1	681	0	35.8	6.01	25-48

TABLE LI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CIPC (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 14 1960	10,000 p.p.m.	19	1	539	0	27.6	5.23	8-40
	1,000 p.p.m.	20	0	620	0	31.0	5.51	6-48
	100 p.p.m.	20	0	590	0	29.5	5.27	0-47
	Water only	19	1	646	0	34.1	5.84	19-46

are shown in Table LII. At each of the three rates some of the plants were somewhat injured, in that the leaves were dry like paper. Both adults and nymphs of the pea aphid caged on such leaves died, because of lack of plant sap. However, other plants were uninjured at the same rates and large populations of aphids were found. EPTC was applied by leaf dipping at rates of 1,000, 100 and 10 p.p.m. (Table LIII). In all tests there were no significant differences among aphids caged on treated broad beans compared with the check as to fecundity or adult or nymphal mortality.

Barban

Barban, also known as Carbyne, is showing great promise in extensive tests against wild oats in Western Canada. Its chemical name is 4-chloro-2-butynyl N-(3-chlorophenyl) carbamate. When barban was applied by root absorption to broad bean plants at 10,000 p.p.m. there was severe epinasty. At rates of 1,000 and 100 p.p.m. the plants appeared to be etiolated and spindly. However, this did not appear to have any effect on the aphids, as shown in Table LIV, when concentrations of 12.5 per cent barban liquid formulation were applied at rates of 3,000, 2,000, and 1,000 p.p.m. of active ingredient by root absorption. Table LV shows results obtained when barban was applied by leaf dipping at rates of 8,000, 4,000 and 2,000 p.p.m. At none of the rates used was there any significant difference in fecundity

TABLE LII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH EPTC (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Dec. 28 1959	100 p.p.m.	14	6	702	55	41.9	6.49	32-54
	10 p.p.m.	15	5	642	60	42.8	6.53	24-55
	1 p.p.m.	14	6	616	94	38.1	6.16	17-52
	Water only	18	2	771	0	42.8	6.58	33-54

TABLE LIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH EPTC (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 17 1960	1,000 p.p.m.	18	2	627	31	32.8	5.69	13-46
	100 p.p.m.	17	3	561	17	30.8	5.39	5-49
	10 p.p.m.	17	3	629	85	31.8	5.54	4-47
	Water only	19	1	692	11	34.3	5.85	10-48

TABLE LIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH BARBAN (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 21 1959	3,000 p.p.m.	14	6	531	0	34.8	5.92	22-46
	2,000 p.p.m.	15	5	535	0	32.8	5.71	10-40
	1,000 p.p.m.	12	8	462	0	33.2	5.72	11-48
	Water only	20	0	693	0	34.7	5.91	21-45

TABLE LV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH BARBAN (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 16 1959	8,000 p.p.m.	17	3	126	4	7.0	2.43	0-23
	4,000 p.p.m.	20	0	270	3	13.3	3.50	0-27
	2,000 p.p.m.	15	5	186	0	12.5	3.27	0-29
	Water only	18	2	195	0	10.8	3.09	0-32

of pea aphids caged on the treated broad beans, and no significant adult or nymphal mortality.

Avadex

Avadex has the chemical name of 2,3-dichloroallyldiisopropyl dithiocarbamate. It has shown great promise in control of wild oats in extensive trials in Western Canada. It was available for the present tests against aphids as a fifty per cent liquid formulation. It was applied to broad bean plants at rates of 4,000, 3,000 and 2,000 p.p.m. both by root absorption (Table LVI) and by leaf dipping (Table LVII). In neither of the experiments were there any significant differences among counts of live progeny of surviving adults, nor was there any significant adult or nymphal mortality.

CDEC

The chemical name of CDEC is 2-chloroallyl diethyldithiocarbamate. It has shown promise for the pre-emergence control of certain weeds in several vegetable crops. It is more effective on weedy grasses than on broadleaved weeds. A 46.4 per cent liquid formulation was used in the following tests. Table LVIII shows results obtained when CDEC was applied by root absorption at rates of 100, 10 and 1 p.p.m. to broad bean plants on which pea aphids were caged for five days. Table LIX shows the results obtained by leaf dipping at rates of 1,000, 100 and 10 p.p.m. There were no significant differences in fecundity among any of the treatments and no significant adult or nymphal mortality.

TABLE LVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AVADEX (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 21 1960	4,000 p.p.m.	18	2	589	12	31.1	5.45	0-48
	3,000 p.p.m.	15	5	484	21	30.4	5.47	8-45
	2,000 p.p.m.	20	0	634	0	31.7	5.57	3-44
	Water only	20	0	698	0	34.9	5.93	22-43

TABLE LVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH AVADEX (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 21 1960	4,000 p.p.m.	18	2	674	0	37.4	6.13	21-51
	3,000 p.p.m.	19	1	825	6	42.6	6.55	35-50
	2,000 p.p.m.	20	0	752	0	37.6	6.14	15-50
	Water only	20	0	782	0	39.1	6.27	27-48

TABLE LVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CDEC (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
March 7 1960	100 p.p.m.	18	2	657	11	35.9	5.97	15-53
	10 p.p.m.	18	2	725	34	38.3	6.20	27-51
	1 p.p.m.	18	2	697	12	37.9	6.16	20-53
	Water only	20	0	676	53	31.2	5.52	8-48

TABLE LIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CDEC (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 24 1960	1,000 p.p.m.	20	0	669	0	33.4	5.76	15-52
	100 p.p.m.	18	2	605	0	33.3	5.72	8-48
	10 p.p.m.	19	1	653	24	33.1	5.71	10-48
	Water only	20	0	667	11	32.4	5.66	9-47

CDAA

The chemical name of CDAA is 2-chloro-N, N-diallylacetamide. It is commonly sold under the trade name of Randox. It has shown promise in tests in Manitoba as a pre-emergence control of weeds in corn and soybeans, but inconsistent results in tests against wild oats. A forty-seven per cent liquid formulation was available for tests on broad bean plants. CDAA was applied by root absorption at rates of 100, 10 and 1 p.p.m. and by leaf dipping at 1,000, 100 and 10 p.p.m. Results for the root absorption tests are shown in Table LX and for the leaf dipping tests in Table LXI. There were no significant differences among live progeny of surviving adults caged on treated plants and no significant adult or nymphal mortality.

Monuron

Monuron is a "substituted urea", formerly called CMU. It has the chemical name 3-(p-chlorophenyl)-1, 1-dimethylurea. The formulation used for the following tests was an eighty per cent wettable powder called Karmex W. It is a soil sterilant which will usually keep the soil free of vegetation for several years when used at rates of 2 to 3 oz. per 100 sq. ft. When applied by root absorption to broad bean plants at 10 p.p.m. all plants were killed. Table LXII shows results obtained when applied by root absorption at rates of 1, 0.1 and 0.01 p.p.m. Only four plants survived

TABLE LX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CDAA (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Feb. 8 1960	100 p.p.m.	18	2	689	36	36.0	5.86	0-53
	10 p.p.m.	17	3	611	10	34.5	5.89	24-44
	1 p.p.m.	16	4	572	9	33.9	5.80	16-44
	Water only	17	3	538	17	28.6	5.29	3-43

TABLE LXI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CDAA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 24, 1960	1,000 p.p.m.	17	3	614	12	35.2	5.84	6-53
	100 p.p.m.	17	3	580	10	33.1	5.66	11-53
	10 p.p.m.	18	2	597	9	32.7	5.71	16-46
	Water only	20	0	768	0	38.4	6.14	13-52

TABLE LXII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MONURON (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
April 3 1960	1 p.p.m.	4	16	235	84	28.5	5.28	12-38
	0.1 p.p.m.	5	15	291	121	26.8	5.20	21-36
	0.01 p.p.m.	18	2	538	0	28.9	5.29	6-48
	Water only	19	1	676	8	35.4	5.96	23-55

the 1 p.p.m. treatment, but the four aphids caged on them produced a normal number of progeny. Similarly, only five plants survived the treatment of 0.1 p.p.m. Table LXIII shows results obtained when monuron was applied by leaf dipping at rates of 1,000, 100 and 10 p.p.m. In none of the tests were there any significant differences among number of live progeny produced by surviving adults, nor was there any significant adult or nymphal mortality on plants that survived the treatments.

TCA

TCA is trichloroacetic acid. In Manitoba it has been used to control green foxtail (wild millet) in flax, peas and sugar beets, and to eradicate patches of quack grass. A sodium salt with seventy-nine per cent acid equivalent was used in the following tests. Table LXIV shows results obtained when TCA was applied by root absorption to broad bean plants at rates of 4,000, 3,000 and 2,000 p.p.m., and Table LXV results when it was applied by leaf dipping at 10,000, 1,000 and 100 p.p.m. There were no significant increases or decreases in fecundity among aphids caged on the treated plants and no significant adult or nymphal mortality.

Dalapon

Dalapon is known also by the trade names Dowpon and Radapon. The chemical name is 2,2-dichloropropionic acid.

TABLE LXIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH MONURON (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 7, 1960	1,000 p.p.m.	14	6	480	22	30.2	5.52	18-38
	100 p.p.m.	16	4	478	10	28.2	5.23	2-40
	10 p.p.m.	18	2	595	0	30.4	5.53	16-40
	Water only	20	0	543	0	27.1	5.20	8-38

TABLE LXIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH TCA (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Jan. 5, 1960	4,000 p.p.m.	20	0	562	0	28.1	5.33	20-44
	3,000 p.p.m.	14	6	394	0	28.1	5.32	19-35
	2,000 p.p.m.	19	1	607	14	31.2	5.54	4-49
	Water only	20	0	590	2	29.4	5.44	16-40

TABLE LXV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH TCA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 14 1960	10,000 p.p.m.	19	1	693	6	35.6	5.97	23-52
	1,000 p.p.m.	18	2	717	0	39.3	6.24	14-51
	100 p.p.m.	20	0	744	0	37.2	6.09	16-48
	Water only	20	0	742	0	37.1	6.07	11-52

Its main use is to control patches of quack grass. The formulation used was sodium 2,2-dichloropropionate, seventy-four per cent acid equivalent. Dalapon was applied to broad bean plants by root absorption at rates of 1,000, 100 and 10 p.p.m. (Table LXVI) and by leaf dipping at rates of 10,000, 1,000 and 100 p.p.m. (Table LXVII). When aphids were caged on the treated plants for five days there were no significant increases or decreases in fecundity and no significant adult or nymphal mortality compared with the checks.

DMTT

The chemical name of DMTT is 3,5-dimethyl-tetrahydro-1,3,5, 2H thiadiazine-2-thione. It is being tested experimentally as a soil fumigant against certain weeds and soil nematodes. It is available as an eighty-five per cent wettable powder known as Mylone. Rates of 10,000 and 1,000 p.p.m. killed broad bean plants when applied by root absorption. Table LXVIII shows results obtained when DMTT was applied by root absorption at concentrations of 100, 10 and 1 p.p.m. Table LXIX shows results obtained by leaf dipping at rates of 1,000, 100 and 10 p.p.m. When aphids were caged on the treated broad beans there were no significant differences among counts made of live progeny of surviving adults, nor was there any significant adult or nymphal mortality when compared with the checks.

TABLE LXVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH DALAPON (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
April 2 1960	1,000 p.p.m.	18	2	612	0	32.9	5.73	12-46
	100 p.p.m.	18	2	641	4	33.1	5.70	8-53
	10 p.p.m.	17	3	647	20	32.7	5.66	9-44
	Water only	17	3	622	28	34.6	5.85	17-52

TABLE LXVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH DALAPON (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 7, 1960	10,000 p.p.m.	18	2	514	0	27.6	5.26	13-40
	1,000 p.p.m.	19	1	573	9	29.7	5.46	16-37
	100 p.p.m.	18	2	459	0	25.5	5.05	14-35
	Water only	20	0	494	0	24.7	4.95	10-37

TABLE LXVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH DMTT (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
March 14 1960	100 p.p.m.	18	2	580	16	30.2	5.34	0-46
	10 p.p.m.	20	0	680	0	34.0	5.76	6-46
	1 p.p.m.	20	0	603	0	30.2	5.39	1-51
	Water only	19	1	591	25	29.3	5.39	15-49

TABLE LXIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH DMTT (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 28 1960	1,000 p.p.m.	19	1	732	0	37.5	5.98	1-50
	100 p.p.m.	19	1	725	0	36.6	6.03	15-49
	10 p.p.m.	19	1	786	0	39.4	6.17	3-52
	Water only	20	0	690	0	34.5	5.88	17-44

Chlorazine

Chlorazine is a "triazine", which has also been called CDT. Its chemical name is 2-chloro-4, 6-bis (diethylamino)-S-triazine. It is still undergoing experimental trials as a herbicide. It was available for the present study as a 49.5 per cent liquid formulation. It appeared to have little effect on broad bean plants when applied at rates of 1,000, 100 and 10 p.p.m. both by root absorption (Table LXX) and by leaf dipping (Table LXXI). There were no significant differences in fecundity of aphids caged on treated plants and no evident adult or nymphal mortality when compared with the check plants.

Simazine

The chemical name of simazine is 2-chloro-4,6-bis (ethylamino)-S-triazine. It is being tested for pre-emergence control of weeds in corn, tomatoes and fruit crops. Used at 10-20 pounds per acre it is an effective soil sterilant. It was used in the present tests as a fifty per cent wettable powder. Broad bean plants were killed when simazine was applied by root absorption at a rate of 10 p.p.m. Table LXXII shows results obtained by root absorption at 1, 0.1 and 0.01 p.p.m. There was some plant mortality even at 1 p.p.m. Table LXXIII gives the data for application of simazine by leaf dipping at rates of 100, 10 and 1 p.p.m. There were no significant differences in numbers of live progeny of

TABLE LXX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CHLORAZINE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Feb. 10, 1960	1,000 p.p.m.	15	5	568	6	36.6	6.01	13-51
	100 p.p.m.	11	9	415	48	28.9	5.36	16-48
	10 p.p.m.	16	4	541	31	31.2	5.59	13-47
	Water only	17	3	688	46	36.0	5.76	0-53

TABLE LXXI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH CHLORAZINE (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 1, 1960	1,000 p.p.m.	17	3	512	24	28.7	5.36	14-38
	100 p.p.m.	20	0	524	5	25.9	5.03	3-36
	10 p.p.m.	19	1	485	0	25.5	4.99	8-41
	Water only	17	3	472	0	27.3	5.24	16-37

TABLE LXXII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH SIMAZINE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
April 27 1960	1 p.p.m.	11	9	380	71	23.7	4.85	10-34
	0.1 p.p.m.	16	4	377	0	21.4	4.63	11-31
	0.01 p.p.m.	20	0	536	0	26.8	5.15	15-43
	Water only	19	1	533	0	27.3	5.25	16-36

TABLE LXXIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH SIMAZINE (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
July 5, 1960	100 p.p.m.	20	0	759	0	37.9	6.18	25-48
	10 p.p.m.	19	1	680	0	35.8	6.01	23-48
	1 p.p.m.	20	0	766	0	38.3	6.21	32-47
	Water only	18	2	674	0	36.1	5.88	0-51

surviving adults of aphids caged on the plants and no significant adult or nymphal mortality when compared with the untreated plants.

Atrazine

The chemical name of atrazine is 2-chloro-4, ethyl-amino-6-isopropyl amino-S-triazine. Experimental results are not yet sufficiently conclusive to evaluate its value as a herbicide. It is available as a fifty per cent wettable powder. When atrazine was applied by root absorption to broad beans plant mortality was high even at a rate of 0.1 p.p.m. Table LXXIV shows results obtained when aphids were caged on plants treated by root absorption at 0.01, 0.001 and 0.0001 p.p.m. Table LXXV gives the results from applications by leaf dipping at 100, 10 and 1 p.p.m. There were no significant differences in fecundity of aphids on the various treatments and no significant adult or nymphal mortality.

2,3,6-TBA

2,3,6-TBA is an experimental herbicide with the chemical name of 2,3,6-trichlorobenzoic acid. Tests have shown that it is translocated in some plants and that it has a residual herbicidal activity in the soil. It was used in the present tests against broad bean plants as a 24.8 per cent liquid formulation at rates of 100, 10 and 1 p.p.m. by root absorption (Table LXXVI) and at 1,000, 100 and 10 p.p.m. by leaf application (Table LXXVII). There were no significant

TABLE LXXIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH ATRAZINE (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 4, 1960	0.01 p.p.m.	17	3	500	24	26.5	5.15	13-39
	0.001 p.p.m.	19	1	448	38	21.6	4.60	5-37
	0.0001 p.p.m.	19	1	557	12	28.7	5.33	11-44
	Water only	19	1	456	14	22.9	4.74	7-34

TABLE LXXV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH ATRAZINE (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Trans-formed average	Range of fecundity
June 28 1960	100 p.p.m.	18	2	554	0	30.8	5.55	18-46
	10 p.p.m.	20	0	699	0	34.9	5.91	16-45
	1 p.p.m.	20	0	649	0	32.4	5.69	17-42
	Water only	19	1	671	0	35.1	5.92	20-46

TABLE LXXVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,3,6-TBA (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Dec. 16 1959	100 p.p.m.	16	0	500	0	31.3	5.59	20-48
	10 p.p.m.	20	0	649	0	32.5	5.59	0-44
	1 p.p.m.	20	0	718	0	35.9	6.01	27-50
	Water only	19	1	653	0	34.4	5.85	14-48

TABLE LXXVII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,3,6-TBA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 25, 1960	1,000 p.p.m.	18	2	653	41	33.4	5.73	6-44
	100 p.p.m.	18	2	624	0	32.9	5.58	0-50
	10 p.p.m.	19	1	663	48	32.2	5.61	10-47
	Water only	20	0	708	0	35.4	5.90	9-51

differences in fecundity among aphids caged on treated plants and no obvious adult or nymphal mortality.

2,3,5,6-TBA

The chemical name of 2,3,5,6-TBA is 2,3,5,6-tetrachlorobenzoic acid. It is still undergoing tests on its herbicidal value. A 47.7 per cent liquid formulation was used for the following tests. Epinasty was severe when broad bean plants were treated by root absorption at 100 p.p.m. Table LXXVIII shows results obtained when aphids were caged on plants treated by root absorption at rates of 100, 10 and 1 p.p.m. and Table LXXIX when the material was applied by leaf dipping at 1,000, 100 and 10 p.p.m. There were no significant increases or decreases in fecundity among aphids caged on any of the treated plants nor was there any significant adult or nymphal mortality.

NPA

The chemical name of NPA is N-1-naphthyl phthalamic acid. The formulation used in the present tests was a sodium salt known as Alanap-3. At the present time NPA is being used for pre-emergence control of grasses and broad-leaved weeds in cucumbers, squash, cantaloupes and other crops in the cucurbit group. It was applied to broad bean plants by root absorption at rates of 1,000, 100 and 10

TABLE LXXVIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,3,5,6-TBA (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Dec. 21, 1960	100 p.p.m.	18	2	639	0	35.5	5.98	19-44
	10 p.p.m.	20	0	620	0	31.0	5.58	18-44
	1 p.p.m.	20	0	667	0	33.4	5.78	18-50
	Water only	19	1	710	0	37.4	6.11	13-54

TABLE LXXIX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH 2,3,5,6-TBA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
July 5, 1960	1,000 p.p.m.	19	1	689	0	36.0	5.96	7-46
	100 p.p.m.	18	2	653	0	36.1	5.93	2-46
	10 p.p.m.	17	3	610	0	34.1	5.85	21-45
	Water only	19	1	642	0	33.2	5.67	0-51

p.p.m. (Table LXXX). Severe epinasty occurred at 1,000 and 100 p.p.m. Table LXXXI shows the results obtained by the leaf dipping method at rates of 1,000, 100 and 10 p.p.m. There were no significant increases or decreases in numbers of live progeny of surviving adults among any of the treatments and no significant adult or nymphal mortality.

Zytron

Zytron is the trade name for a new pre-emergence herbicide, 0-(2,4-dichlorophenyl) o-methyl isopropylphosphoro-amidothioate. The formulation used in the present tests was a twenty-five per cent emulsifiable concentrate. It has shown promise for control of crabgrass and chickweed in lawns, and for control of certain broadleaved weeds as a pre-emergence application. When Zytron was applied by root absorption to broad bean plants at rates of 3,000, 2,000 and 1,000 p.p.m. only slight phytotoxicity was evident. However, adult and nymphal mortality of aphids was very high, as shown in Table LXXXII. At rates of 100 and 10 p.p.m. by root absorption there was no significant increase or decrease in fecundity and no significant adult or nymphal mortality. When Zytron was applied by leaf dipping at rates of 1,000, 100 and 10 p.p.m. there was no evidence of toxicity to adults or nymphs on the treated plants. When the rates were increased to 8,000, 4,000 and 2,000 p.p.m. there was further evidence of both adult and nymphal mortality, as shown in

TABLE LXXX

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH NPA (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Jan. 11 1960	1,000 p.p.m.	19	1	671	0	35.3	5.96	19-45
	100 p.p.m.	20	0	695	0	34.8	5.90	20-46
	10 p.p.m.	19	1	645	0	33.9	5.85	25-43
	Water only	20	0	746	0	37.3	6.10	16-54

TABLE LXXXI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH NPA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 31, 1960	1,000 p.p.m.	19	1	639	0	33.5	5.77	14-58
	100 p.p.m.	18	2	604	13	31.4	5.52	5-45
	10 p.p.m.	15	5	516	10	30.8	5.50	8-48
	Water only	19	1	676	0	35.6	5.98	21-46

TABLE LXXXII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH ZYTRON (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 2, 1960	3,000 p.p.m.	0	20	15	15	---	---	---
	2,000 p.p.m.	0	20	29	29	---	---	---
	1,000 p.p.m.	1	19	70	69	---	---	---
	Water only	20	0	503	32	23.5	---	6-36

Table LXXXIII. At the rates of 4,000 and 2,000 p.p.m. the effect seemed to be insecticidal, rather than some influence on reproductive metabolism, because adult aphids that survived produced the same number of young as those on the untreated plants. The insecticidal properties of Zytron have been noted also by Watson and Leasure (1959), who found that ants were killed in ant colonies in turf being treated with Zytron for crabgrass control.

Gibberellic Acid

The literature on the responses of plants to gibberellic acid is extensive. Current research has been summarized in Bulletin No. 512-3 of Velsicol Chemical Corporation, "Abstracts of Current Research on the Effects of Gibberellic Acid on Plants". The type of plant response varies among species and according to environmental conditions so that it is necessary to determine how each species or variety of plant will respond for a given set of conditions. A ninety-four per cent pure powder was available for the present series of tests. Etiolation occurred on broad beans when gibberellic acid was applied by root absorption at rates of 1,000, 100 and 10 p.p.m. Data for this experiment are reported in Table LXXXIV. Because of the possibility that plant response might differ over a period longer than five days, aphids were allowed to remain on the same plants for a further five days (Table LXXXV). In neither of these tests

TABLE LXXXIII

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH ZYTRON (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
May 2, 1960	8,000 p.p.m.	3	17	205	154	---	---	---
	4,000 p.p.m.	6	14	271	123	21.5	---	---
	2,000 p.p.m.	10	10	331	111	21.7	---	---
	Water only	17	3	402	18	21.2	---	---

TABLE LXXXIV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH GIBBERELLIC ACID (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 30 1959	1,000 p.p.m.	15	5	387	0	25.8	5.08	10-40
	100 p.p.m.	12	8	257	0	21.4	4.54	1-34
	10 p.p.m.	16	4	391	0	24.4	4.79	0-37
	Water only	18	2	440	0	24.4	4.89	4-39

TABLE LXXXV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER A SECOND FIVE DAY PERIOD CAGED ON BROAD BEANS TREATED WITH GIBBERELLIC ACID (ROOT ABSORPTION)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
Sept. 30 1959	1,000 p.p.m.	15	0	345	0	23.0	4.78	10-36
	100 p.p.m.	11	1	230	0	20.9	4.45	1-29
	10 p.p.m.	15	1	325	0	21.7	4.57	1-37
	Water only	15	3	448	0	28.7	5.32	6-46

were there any significant effects noted on fecundity or mortality. Table LXXXVI shows results obtained when gibberellic acid was applied by dipping lower leaves of broad bean at rates of 1,000, 100 and 10 p.p.m. In this test also no significant increases or decreases were noted, or adult or nymphal mortality. These findings agree with those of Siakotos and Dewey (1959) who included gibberellic acid in the diet of the American cockroach, *Periplaneta americana* L., and found no significant interaction between weight of insects and concentration fed, nor any significant differences in egg production by female cockroaches. Mitlin and Baroody (1958) found that potassium gibberellate introduced into larval or adult house flies had no effect on growth or as a toxic agent and no effect on ovarian development.

TABLE LXXXVI

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH GIBBERELLIC ACID (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 9, 1960	1,000 p.p.m.	18	2	211	3	11.1	2.99	0-36
	100 p.p.m.	19	1	300	0	15.8	3.61	0-36
	10 p.p.m.	17	3	275	7	17.0	3.80	0-39
	Water only	14	6	287	25	13.4	3.52	0-31

CHAPTER VIII

SUMMARY

The aim of the investigation was to determine possible effects of the widespread use of herbicides and plant growth regulators on the arthropod fauna. The test animal chosen was the pea aphid, *Acyrthosiphon pisum* (Harris), an economic pest of many leguminous plants, and the plants which were treated with the chemicals were broad beans, *Vicia faba* L. Thirty herbicides or plant growth regulators were tested, covering a wide range of chemicals and including all those at present in common usage or under test in Western Canada.

Broad beans were germinated in soil in the greenhouse, and transferred to pots containing vermiculite when 2-4 inches high. Plants were treated with the chemicals either by root absorption for forty-eight hours or by dipping lower leaves in various concentrations. During the time that aphids were caged on the plants, the plants were fed a nutrient solution of Plant Prod 20-20-20, and kept in a Plant Growth Cabinet.

The pea aphids were a clone maintained continuously as summer viviparae in the greenhouse. In all the tests reported here the aphids used were within forty-eight hours of being the same age, and with two exceptions were wingless adult females. After treatment of the plant by root absorption or leaf dipping, aphids were caged for five days on the treated

plants after which time possible mortality of nymphs and adults and number of young produced were recorded.

Seventy-four such tests are reported here, in separate tables. For each test the data on live progeny of surviving adult aphids after five days caged on treated and untreated plants were subjected to statistical analysis to evaluate possible increases or decreases in fecundity due to the applications of herbicides or plant growth regulators to the plants.

During the course of the investigations certain aspects of the life history of the pea aphid under greenhouse conditions were noted. Winged aphids produced a significantly smaller average number of nymphs than did the wingless. Aphids confined to the upper surface of a leaf produced the same number of young as those on a lower surface, although unconfined females established their colonies usually on lower surfaces. There was no significant difference between the number of young produced on the lowest leaf pair of broad beans or on the next higher pair. The longest life of any one female in a cage, including nymphal instars, was thirty days. Most females began producing young on the eighth day of life, although a few produced young on the seventh day. The peak of production was usually the thirteenth to fourteenth day of life. The greatest number of young born to any one female in a twenty-four hour period was twenty-one, but the average number was ten to fifteen. One female produced one hundred and twenty-three young during its reproductive period and several gave birth to more than one hundred.

An attempt was made during these investigations to determine the amount of intake of plant sap by aphids, by starving the aphids, weighing them, allowing them to feed, and then weighing them again. This method was unsuccessful because the aphids ceased reproduction and excretion of honeydew during the period of starving, and recommenced immediately when allowed to feed, which caused decreases in weight that more than compensated for increases due to ingestion of plant sap.

When maleic hydrazide was introduced by root absorption into broad bean plants at rates of 4,000, 3,000 and 2,000 p.p.m., the average number of live progeny of surviving adults, both winged and wingless, after five days on the treated plants differed significantly at the one per cent level from that on the untreated check. There was no significant adult mortality but nymphal mortality was high and many of the nymphs appeared to have been born dead. This injurious effect on the reproductive metabolism of the female aphids persisted after they were removed from the treated plants and placed on untreated plants for a further five days. Nymphs which had been born and reared on plants treated with maleic hydrazide by root absorption were removed on becoming adults and caged for the remainder of their lives on untreated plants. These adults also showed a significant decrease in fecundity. When MH was applied by root absorption at rates of 1,500 and 1,000 p.p.m. plant growth was inhibited but there was no significant decrease in fecundity.

When adult female pea aphids were sprayed with a contact spray of maleic hydrazide at 4,000 p.p.m. there was no significant adult or nymphal mortality and no increase or decrease in fecundity. When aphids were caged on broad bean plants treated with maleic hydrazide by leaf dipping, no apparent effects were noted on adults or nymphs even at a concentration as high as 40,000 p.p.m.

Adult wingless female pea aphids were caged for five days on plants treated with maleic hydrazide by root absorption at 4,000 p.p.m., and on untreated plants. They were then killed, fixed and embedded in paraffin wax. Serial sections were stained with Mallory's Triple Stain. An examination of the embryos under 120X magnification showed no apparent histological differences among aphids from treated or from untreated plants. Embryos in aphids from plants treated with maleic hydrazide apparently developed normally but parturition was greatly delayed or suppressed.

When amitrole was applied to broad bean plants by root absorption at 300, 200 and 100 p.p.m., there was no significant adult mortality to wingless aphids caged on them for five days, but nymphal mortality was high and there was a significant reduction in fecundity. Similar results were obtained when winged adults were caged for five days on plants treated by root absorption at 100 p.p.m. At rates of 10 and 1 p.p.m. no effects on the aphids were noted. Whentwenty adult wingless female aphids were sprayed with amitrole as a contact spray, adult mortality was high (thirteen died out of twenty) but those that lived produced almost the same number of progeny as those sprayed with water.

When adult wingless female pea aphids were caged for five days on plants treated with amitrole at 100 p.p.m. by root absorption, and then transferred for a further five days to untreated plants the average number of live progeny of surviving adults from treated plants was significantly lower than from those which had only been on untreated plants. Nymphal mortality was relatively low during the second five day test. This indicated that nymphal mortality on treated plants during the first five day test must have been due mainly to toxic plant sap ingested by the first instar nymphs. When aphids were caged on plants treated with amitrole by leaf dipping at rates of 300, 200 and 100 p.p.m. there was no adult or nymphal mortality, and no reductions in fecundity.

To ascertain if the reductions in fecundity of aphids caged on broad bean plants treated by root absorption were due at least in part to nonfeeding of the adult aphids, aphids were starved for twenty-four hours and then caged for five subsequent days on untreated plants, and compared with others from plants treated with maleic hydrazide at 4,000 p.p.m. and amitrole at 100 p.p.m. There was no significant reduction in fecundity of the aphids starved for twenty-four hours. This indicated that reductions in fecundity of the aphids caged on treated plants were not due to starving.

Adult wingless aphids were caged for five days on plants treated with amitrole at 100 p.p.m. Eleven nymphs were transferred from these plants to untreated ones but only three survived. There was no significant difference between average number of progeny of these three winged females and fifteen other winged females from untreated plants, based on number of nymphs produced during the remainder of their lives. This indicated that the reproductive capacity of the surviving aphids was not impaired.

When Zytron was applied to broad beans by root absorption at 3,000, 2,000 and 1,000 p.p.m., and by leaf dipping at 8,000, 4,000 and 2,000 p.p.m., both adult and nymphal mortality were high, indicating that Zytron must act on the aphids as a systemic insecticide. At rates of 100 and 10 p.p.m. by root absorption no harmful effects were noted.

The remaining twenty-seven herbicides or plant growth regulators tested had no effect at the rates used on fecundity of wingless female aphids and there was no evidence of adult or nymphal mortality. These data are presented in tabular form with the highest concentration of chemical used indicated for both root absorption and leaf dipping. In general each highest concentration gave some phytotoxicity, but not plant mortality.

Common name of chemical	Highest rate used in p.p.m., root absorption	Highest rate used in p.p.m., leaf dipping
2,4-D	2	1,000
2,4,5-T	0.1	0.1
MCPA	8	10
Sesone	1,000	8,000
Erbon	1,000	10,000
Silvex	100	100
4-(2,4-DB)	100	100
4-(MCPB)	100	1,000
DNBP	300	1,000
IPC	1,000	1,000
CIPC	3,000	10,000
EPTC	100	1,000
Barban	3,000	8,000
Avadex	4,000	4,000
CDEC	100	1,000
CDAA	100	1,000
Monuron	1	1,000

Common name of chemical	Highest rate used in p.p.m., root absorption	Highest rate used in p.p.m., leaf dipping
TCA	4,000	10,000
Dalapon	1,000	10,000
DMTT	100	1,000
Chlorazine	1,000	1,000
Simazine	1	100
Atrazine	0.01	100
2,3,6-TBA	100	1,000
2,3,5,6-TBA	100	1,000
NPA	1,000	1,000
Gibberellic Acid	1,000	1,000

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APPENDIX A

Aphid Counts on Treated Broad Beans

Material Used .....TCA..79.per.cent.acid.equivalent..............

Date Plants Treated ..June.14,.1960.(leaf.dipping)..............

Date Changed to Fertilizer ..June.16,.1960.........................

Date Aphids put on Plants ...June.16,.1960.........................

Date Aphids Counted ....June.21,.1960...........................

LA = Live Adults DA= Dead Adults LN = Live Nymphs DN= Dead Nymphs

Rates	10,000 p.p.m.				1,000 p.p.m.				100 p.p.m.				H20			
Plant No.	LA	DA	LN	DN	LA	DA	LN	DN	LA	DA	LN	DN	LA	DA	LN	DN
1		1	10		1		36		1		48		1		11	
2	1		30			1	10		1		45		1		39	
3	1		34		1		45		1		46		1		41	
4	1		32		1		51		1		41		1		37	
5	1		28		1		41		1		45		1		36	
6	1		34		1		49		1		32		1		39	
7	1		52		1		26		1		40		1		41	
8	1		46		1		23		1		16		1		43	
9	1		25		1		47		1		37		1		52	
10	1		23		1		21		1		43		1		38	
11	1		37		1		42		1		35		1		38	
12	1		35		1		40		1		34		1		42	
13	1		30	6	1		43		1		26		1		35	
14	1		33		1		45		1		44		1		30	
15	1		34		1		45		1		20		1		31	
16	1		51		1		47		1		37		1		45	
17	1		25			1	0		1		36		1		37	
18	1		47		1		14		1		38		1		16	
19	1		43		1		46		1		44		1		42	
20	1		38		1		46		1		37		1		49	
Totals	19	1	687	6	18	2	717	0	20	0	744	0	20	0	742	0

Remarks:

Average of live progeny of surviving adults: $\frac{677}{19} = 35.6$ $\frac{707}{18} = 39.3$ $\frac{744}{20} = 37.2$ $\frac{742}{20} = 37.1$

TABLE LXV

ADULT AND NYMPHAL SURVIVAL AND FECUNDITY OF THE PEA APHID AFTER FIVE DAYS CAGED ON BROAD BEANS TREATED WITH TCA (LEAF DIPPING)

Date applied	Rate of application	No. of surviving adults	No. of dead adults	Total progeny	Total no. of dead nymphs	Average no. of live progeny of surviving adults	Transformed average	Range of fecundity
June 14 1960	10,000 p.p.m.	19	1	693	6	35.6	5.97	23-52
	1,000 p.p.m.	18	2	717	0	39.3	6.24	14-51
	100 p.p.m.	20	0	744	0	37.2	6.09	16-48
	Water only	20	0	742	0	37.1	6.07	11-52

APPENDIX C

STATISTICAL ANALYSIS OF COUNTS MADE ON BROAD BEANS TREATED BY LEAF DIPPING WITH TCA ON JUNE 14, 1960

Rates	10,000 p.p.m.		1,000 p.p.m.		100 p.p.m.		H_2O	
No. of adults	19		18		20		20	
	Live nymphs	$\sqrt{x + 0.5}$	Live nymphs	$\sqrt{x + 0.5}$	Live nymphs	$\sqrt{x + 0.5}$	Live nymphs	$\sqrt{x + 0.5}$
	30	5.52	36	6.04	48	6.96	11	3.39
	34	5.87	45	6.75	45	6.75	39	6.28
	32	5.70	51	7.18	46	6.82	41	6.44
	28	5.34	41	6.44	41	6.44	37	6.12
	34	5.87	49	7.04	45	6.75	36	6.04
	52	7.25	26	5.15	32	5.70	39	6.28
	46	6.82	23	4.85	40	6.36	41	6.44
	25	5.05	47	6.89	16	4.06	43	6.60
	23	4.85	21	4.64	37	6.12	52	7.25
	37	6.12	42	6.52	43	6.60	38	6.20
	35	5.96	40	6.36	35	5.96	38	6.20
	30	5.52	43	6.60	34	5.87	42	6.52
	33	5.79	45	6.75	26	5.15	35	5.96
	34	5.87	45	6.75	44	6.67	30	5.52
	51	7.18	47	6.89	20	4.53	31	5.61
	25	5.05	14	3.81	37	6.12	45	6.75
	47	6.89	46	6.82	36	6.04	37	6.12
	43	6.60	46	6.82	38	6.20	16	4.06
	38	6.20			44	6.67	42	6.52
					37	6.12	49	7.04
Totals		113.45		112.30		121.89		121.34
$\bar{x}$ =		5.97		6.24		6.09		6.07

Grand Total = 468.98
Correction Factor = $(468.98)^2 \div 77 = 2855.42$
Total Sum of Squares = 2908.4024
Between Sample Sum of Squares = 2857.30

	df	Variance	F	5%	1%
S.S.-C.F. = 52.9824	76				
B.S.-C.F. = 1.8800	3	0.63	0.9	2.73	4.07
51.1024	73	0.70			

F is less than 2.73 or 4.07
No significance among treatments