THE EFFECT OF SOME ORGANIC INSECTICIDES ON THE CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.) (DIPTERA: ANTHOMYIIDAE), AND THE GERMINATION OF ONION AND TURNIP SEED

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by

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ABSTRACT

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THE CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.) (DIPTERA: ANTHOMYIIDAE), WITH SOME OF THE NEWER ORGANIC INSECTICIDES AND THE EFFECT OF THESE INSECTICIDES ON THE GERMINATION OF ONION AND TURNIP SEED

The purpose of this study was to find a method of chemical control of the onion maggot, *Hylemya antiqua* (Meig.), and to determine the effect of certain insecticides on the germination of onion and turnip seed. Tests were conducted in field plots and in flats in the greenhouse.

In seed treatment or pelleting tests, aldrin, chlordane, DDT, dieldrin, heptachlor, lindane and toxaphene were used as wettable powders with Arasan as a fungicide and Methocel as a sticker. In furrow treatment control tests, aldrin, heptachlor and toxaphene were used in the granular form, and malathion as a dust. In a delayed sprinkling experiment dieldrin and heptachlor emulsifiable concentrates were used. In seed treatment germination tests the same wettable powders as those mentioned for seed treatment control tests were used. For furrow treatment tests the following insecticides were used: aldrin wettable powder, granular aldrin, dieldrin wettable powder, heptachlor wettable powder granular heptachlor, malathion dust, toxaphene dust and

granular toxaphene. Most of the above mentioned insecticides were used at one or more strengths.

Of the seed treatments, most satisfactory control, with minimum germination injury, was obtained with 25 per cent heptachlor wettable powder or 25 per cent dieldrin wettable powder. In furrow treatment tests, the most satisfactory control was by granular toxaphene. In the delayed sprinkling tests, both dieldrin and heptachlor treatments reduced further infestation.

Seed treatment germination tests with turnip seed indicated that DDT, toxaphene, aldrin and dieldrin treatments caused the least reduction in germination. In the furrow treatment germination tests with turnip seed, dieldrin, malathion and granular toxaphene caused little or no reduction in germination.

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CHAPTER I

INTRODUCTION

The development of the Winnipeg area of Manitoba into one of the outstanding Dutch set onion growing areas of Canada has brought with it problems of controlling insects. The onion maggot, *Hylemya antiqua* (Meig.), is by far the most important pest of onions in this area and in most years causes severe economic losses in market gardens. In addition to Dutch sets, cooking onions and pickling onions have been severely damaged in the past by this pest. The occurrence of serious infestations has been unpredictable, varying from little or no damage one year to complete destruction of onion crops another year. No satisfactory method of control has been developed that will control the maggots once they have infested the onions. For this reason, an attempt has been made to develop a preventative method of control which could be used each spring as a precaution against these sporadic infestations.

Problem

The purpose of this study was: (1) to find an economical and practical chemical method for controlling the onion maggot, *H. antiqua*; and (2) to test the effect on germination of onion and turnip seed of certain newer insecticides, used in control work.

Economic importance

In the 1953 Report on crops in Manitoba, Weir (38) stated that the control of the onion maggot seemed to be still the major insect problem in market gardens. Damage to Dutch sets is caused in two ways. The maggots infest the small sets and destroy them. Consequent thinning of the rows by the maggots results in the remaining onions growing to a size larger than that permitted for sets. Damage to other types of onions is caused by the maggot feeding in the bulbs. In this case, the onion plant may be destroyed by the maggot itself or by decay resulting from initial damage by the maggot.

Control of the onion maggot in Manitoba has been unsuccessful in past years, and there has been an urgent demand from the market gardeners for a practical, economical and effective control. Indications from workers (5, 9, 29, 37) have shown that the use of a seed treatment, or application of an insecticide to the furrow at the time of planting, have given effective control. It was decided to test these control recommendations in Manitoba. In addition to the above control recommendations, a preliminary experiment was conducted to determine the possibilities of preventing further damage to onions once the maggot had entered the soil and begun feeding.

Since both the recommended measures require a direct contact between the seed and a chemical insecticide, a study had to be made of the effect of such chemicals on the germination and early growth of the seeds. Both onion and turnip seeds were used in these germination tests. The use of turnip seeds was prompted by yet another problem, that of a need for control of another species of *Hylemya* infesting turnips.

CHAPTER II

REVIEW OF LITERATURE

Control of onion maggot

The onion maggot, *Hylemya antiqua* (Meig.) has plagued onion growers across Canada for many years. As early as 1921 Gibson (14) stated that this insect was a regularly occurring pest in every province from Nova Scotia to British Columbia. It is interesting that at that time a poison bait was used for controlling the pest. Gibson (14) recommended dissolving one quarter of an ounce of commercial sodium arsenite in a gallon of boiling water with one pint of cheap molasses added. This mixture was then applied as a coarse spray of drops in V-shaped strips across the plot or field, the strips being 15 to 20 feet apart. Four to five applications were necessary per season. Six years later Caesar (4) recommended spraying the plants with a lubricating oil emulsion containing lubricating oil, bluestone, hydrated lime and water. Another control method recommended by Caesar (4) was to plant multipliers or culled onions in the rows when sowing the seed. These would grow much faster than the seedlings and attract the flies to lay eggs upon them and thus save the seedlings. When the maggots in these culls or multipliers were fully grown, the plants were removed and destroyed.

In 1932 Dustan (8) recommended the use of corrosive sublimate as a suitable insecticide to control the onion maggot in the prairie provinces. The material was mixed with water and poured over the seedling plants and surrounding soil. Hutson (16) however, stated that because of the corrosive effect of corrosive sublimate on metal, special containers of wood, pottery or glass were required. This together with the amount of labor required in applying the material limited its use to small plots of onions. For large plots or fields, Hutson (16) recommended a homemade emulsion spray containing "caseinate calcium" or Bordeaux mixture. Bird (1) recommended the use of corrosive sublimate as late as 1943.

Preliminary experiments by McLeod (20) in 1945 for the control of onion maggot showed that a calomel seed treatment gave excellent control, but due to its high cost and retarded growth of treated plots it was deemed impractical. Hexachlorocyclohexane, then a newly formulated insecticide, gave good control for this pest. Three years later, Dustan (9) stated that the most satisfactory control up to that time was the use of calomel applied to the seed before planting. The onion seed was moistened with water and mixed with an equal weight of calomel. Where onions were grown from sets or transplants, Dustan (9) recommended applying a four per cent calomel dust to the soil.

The use of new methods of application and new insecticides began about 1950. Rawlins and Newhall (32) dusted the surface of the soil at seeding time with a 25 per cent dieldrin wettable powder and recorded only three per cent damage in the treated rows as compared with 83.6 per cent in the check rows. In 1951-52 tests, Morrison and Crowell (26) reported that aldrin gave good commercial control of the onion maggot in Oregon when applied to the soil. About this time Doane and Chapman (7) conducted control tests in Wisconsin. They found that one per cent dusts of dieldrin and aldrin applied at the rate of 50 pounds an acre gave excellent control of the onion maggot in onions grown for sets. One per cent parathion and five per cent chlordane gave fair control.

A preliminary report by Merrill (24) in 1953 states that doses as low as 0.75 pound of heptachlor and dieldrin per acre with addition of thiram markedly increased the stand of onions. In 1953 and 1954 a variety of methods was tried and a few practical and effective ones were found. Peterson et al. (29) found that good control could be obtained by pelleting the seed with an insecticide-fungicide mixture. The insecticides used were aldrin, dieldrin and heptachlor. The same insecticides were used successfully as broadcast and furrow treatments. Sprays and dusts were used but special attention was given to the timing of applications. Chapman (5) states that in various tests conducted at

Wisconsin, heptachlor and dieldrin stood out as the two most efficient insecticides but were followed closely by aldrin. All three insecticides gave good control as seed, granular-furrow and soil treatments. Tozloski (36) conducted tests using spray, pelleting and dry seed treatments. Ten per cent DDT and one per cent dieldrin applied to onion seed as dry materials gave the best control. These same materials also gave good control if used in a pelleting treatment. Control by spraying was listed as ineffective, inconvenient and more costly than the first mentioned controls.

Effect on seed germination

Literature on the effect of insecticides on seed germination is somewhat limited. Lange *et al.* (19) employed seed treatment for controlling the seed-corn maggot, *Hylemya cilicrura* (Rond.), in beans and found that the insecticides used had a definite effect on seed germination. He found that the use of aldrin and dieldrin resulted in a delay in germination. Chlordane gave less delay and in one case gave a stimulating effect. There was reduced total emergence for all treatments in comparison with untreated seed. Merrill (24) found that dieldrin, when used in contact with the seed at the rate of 1.5 pounds per acre, resulted in injury to the stand of onions. This, however, was thought to be partly due to the solvent contained in the insecticide formulation. Cox and Lilly (6) conducted tests on the effect of aldrin and dieldrin on germination and early growth of field crop seeds. The insecticides were used in a soil treatment form. Marked differences could be seen both between seeds used and rate of application.

CHAPTER III

BIOLOGY OF THE ONION MAGGOT

Life history

The life history of the onion maggot consists of four stages, (a) egg, (b) larva, (c) pupa and (d) adult. The winter is spent in the pupal stage either in the soil or in piles of culled onions in the field. In Manitoba the first adults appear around the beginning of June and continue to emerge until the end of June. They fly around for about 10 days and, after mating, the females begin to lay eggs. The eggs are laid either on the base of the onion plant or in the soil around the base of the plant. In approximately a week the eggs hatch and the resulting larvae make their way to the onion bulb. The maggots feed inside the bulb and if the plant dies before the maggot matures, the maggot crawls to another plant. In this manner, several seedling plants may be destroyed by one maggot. Feeding continues for about three weeks following which pupation takes place in the soil. According to Bird (1) two generations a year are found in Manitoba while in Eastern Canada, Ross (34) states that three generations may occur.

The outline above is essentially a typical life history since the date of emergence and the length of time spent in the various stages vary with climatic conditions. Cool, wet weather in the spring and early summer tends to delay emergence of the adults and in some years greatly reduces the damage. In 1953 for example, abnormally cool, wet weather was sufficient to prevent damage by the first generation. Hot dry weather during the late summer period caused serious infestations by the second generation on experimental plots in September. A wet spring in 1954 delayed serious infestations until about mid-July. Dry weather followed and heavy damage occurred. In some cases entire fields of onions were rendered useless. Eggs and newly hatched larvae were seen on plants as late as July 26. The eggs which are generally laid at the base of the plants were occasionally found on the bulbs of the onions this year. In a few instances the eggs were found as high as two and three inches up the stem.

Appearance

The adult is a two-winged fly which is similar in appearance to the common house fly except that it is smaller and of greyish color. The male fly is darker and slightly smaller than the female. The egg measures about one-sixteenth of an inch in length and is white. The maggot is creamy-white, legless and possesses small mouth hooks which enable it to feed on plant tissue. When fully grown, the maggot measures about one quarter of an inch in length. The pupa, which is reddish-brown in color, measures about one quarter inch in length and somewhat resembles a plump grain of wheat.

CHAPTER IV

MATERIALS

Control experiments

Seven insecticides were used in the seed treatment tests against the onion maggot: (1) 40 per cent aldrin, (2) 50 per cent chlordane, (3) 50 per cent DDT, (4) 25 per cent dieldrin, (5) 25 per cent heptachlor, (6) 50 per cent lindane and (7) 40 per cent toxaphene. All were wettable powders. Arasan was used as the fungicide. A four per cent solution of Methocel (methyl cellulose) was used as a sticking agent to enable the insecticide-fungicide mixture to adhere to the seed coat. In the furrow treatment tests, three granular formulations and one dust were used. The granular insecticides consisted of (1) five per cent aldrin, (2) five per cent heptachlor, and (3) 25 per cent toxaphene. A four per cent malathion dust was used as the fourth insecticide. For the delayed sprinkling experiment, started after infestation had begun, an 18 per cent dieldrin emulsifiable concentrate and a 25 per cent heptachlor emulsifiable concentrate were used. The insecticides in this test were applied by means of a one gallon sprinkling can. Although most of the seeding for the control experiments was done by hand, a Planet Jr. seeder was used in one case where sowing by hand was impractical. All treatments were marked with 12 inch garden stakes.

Seed germination experiments

. Seed germination experiments were of two types: (1) seed treatment and (2) furrow treatment. The seed treatment experiments employed the same insecticides as those mentioned above for seed treatment control. Eight insecticides, consisting of (1) 20 per cent aldrin wettable powder, (2) five per cent granular aldrin, (3) 25 per cent dieldrin wettable powder, (4) 25 per cent heptachlor wettable powder, (5) five per cent granular heptachlor, (6) four per cent malathion dust, (7) 10 per cent toxaphene dust and (8) 25 per cent granular toxaphene were used in the furrow treatment tests. All these tests were conducted in the greenhouse using wooden flats measuring 24 inches by 12 inches by three and one half inches. Fine sand was used as the germinating medium. Corrugated cardboard strips, measuring 12 inches long and three inches high were used as partitions between treatments in each flat. In the onion seed germination tests, Dutch set seed, variety Ebenezer (yellow) was used, while in the turnip seed tests, seeds of the variety Laurentian were used. Methocel was used as the sticker and half pint Atlas Liquid Tight cardboard containers were used for mixing.

CHAPTER V

METHODS

Seed treatment control tests

Seed treatment control tests were conducted in field plots at The University of Manitoba and at Bird's Hill. The plan for the seed treatment control plots at the University included eight replicates of each treatment. It was decided that each treatment or plot should have 500 seeds so that germination data as well as insect control data could be obtained. Since counting of the seeds presented a time consuming task, the average weight of five groups of 500 seeds each was taken. The average weight of 500 seeds was 1.75 grams and since eight replicates or 4,000 seeds were required, the total weight was 14 grams. Eight samples of seed, each containing 14 grams were weighed and placed in separate containers. The required amounts of each insecticide which would give a ratio of one part actual toxicant to 16 parts of seed by weight were then weighed and placed in separate containers. Three grams of Arasan were added to each test sample of insecticide and the mixture was shaken thoroughly. Each sample of seed was separately moistened with three millilitres of four per cent Methocel and emptied into a container holding the required insecticide-fungicide mixture. The mixture was then thoroughly stirred and shaken to insure proper coverage of seed with the insecticide-fungicide mixture. The seed was then exposed to room air to facilitate complete drying.

On the following day, the total amount of seed for each treatment was weighed into eight equal samples. This gave approximately 500 seeds to each separate sample. Each treated sample was then placed in a separate envelope.

The experimental area for these tests was divided into eight replicate plots each measuring 15 feet in length and 20 feet in width. Seventeen furrows, about one inch deep and spaced 15 inches apart were then made in each plot. Each treatment in each replicate plot consisted of one row and was separated from the next treatment by means of an untreated guard row. Seeding was done by hand in order to distribute the 500 treated seeds evenly in the 15 foot row. After all seeds has been sown in the furrows they were covered over by hand. The soil was packed down by means of a hoe.

For tests in the Bird's Hill location, seed treatment was done in a similar manner except that the seeds were not counted. Sowing was done with a Planet Jr. seeder. The seeding disc was set at 25 and gave a rate of approximately 40 pounds to the acre. The layout of the plot was essentially the same as the previous experiment except that only four replicates were used.

Counts for these seed treatment control tests were made at approximately four day intervals. This time interval was chosen since young plants, if seriously infested, could dry up and easily be overlooked at any longer interval. For counting purposes, all plants showing signs of infestation were pulled out of the ground and examined for definite maggot damage. This was done to prevent counting of any possible diseased onions. After examination, the plants were placed on the surface at the point of pulling to enable the maggots to re-enter the soil.

Furrow treatment control tests

The furrow treatment control tests were conducted at the University. An experimental area for these tests was marked off into five replicate plots each measuring 12 feet in length and 16.5 feet in width. Eleven furrows, each 18 inches apart were made in each plot. Each treatment in each replicate consisted of one 12 foot row separated from the next treatment by means of an untreated guard row. Approximately 500 seeds, measured by the weight method, were placed in each treatment furrow by hand. Aldrin, heptachlor and malathion were then distributed evenly over the seeds at the rate of 0.1 pound actual toxicant per 1,000 feet of row. Seeds were then covered by hand and the soil packed by means of a hoe. Counts of infested plants were made in the same manner as that described for the seed treatment control tests.

Delayed sprinkling control tests

The delayed sprinkling tests were conducted in a field of lightly infested Dutch set onions at Parkdale. This field had not been chemically treated in any way and was located approximately half a mile from a heavily infested field of set onions. Since the 1954 onion maggot infestations were late, it was believed that the few infested plants in this experimental field indicated the beginning of a serious infestation. This being the case, treatment of the onions would give some indication of the possibilities of stopping damage once the maggots were present in the soil and onions.

Only two insecticides, dieldrin and heptachlor, were used in these tests but each was applied at three different dosages: (1) 0.1 pound actual toxicant per 1,000 feet of row, (2) 0.3 pound actual toxicant per 1,000 feet of row and (3) 0.6 pound actual toxicant per 1,000 feet of row. Four replicate plots, measuring 15 feet in length were marked. Each replicate contained seven treatment rows separated from each other by a guard row. For each treatment, the required insecticide was placed in the watering can and one gallon of water added. This mixture was then applied liberally to one treatment row, surrounding the base of each plant and sufficiently soaking the soil to insure penetration of the insecticide below the surface. Counts were made in a manner similar to that mentioned in the previous control tests.

Seed treatment germination tests

Seed treatment germination tests were conducted both in the field and in the greenhouse. The germination tests in the field were included in the seed treatment control plots. Germination tests in the greenhouse were conducted in flats. Each flat was partitioned into 10 sections by means of corrugated cardboard strips. The eight inner sections were used for treated seed while the outer sections served as guard rows. In this manner each flat contained one replicate of each treatment. The flats were filled with fine sand to a depth of approximately two inches. Sand was chosen as the germination medium because it contained little or no organic matter which would tend to sorb the insecticides and thus slow down their effect on the germinating seed.

As mentioned earlier, seven insecticides were used in the seed treatment germination experiments. The check constituted the eighth treatment. For the first experiment conducted with onion seed, each insecticide treatment was applied at three different rates and each rate was replicated seven times. The first rate of application consisted of one part actual toxicant by weight to 16 parts of seed by weight. The second and third rates of application consisted of 1.5 parts of actual toxicant to 16 parts of seed and two parts of actual toxicant to 16 parts of seed respectively. The onion seed was weighed in 21 samples, each sample containing 16 grams of seed. Preliminary tests showed that four millilitres of four per cent Methocel were sufficient to moisten 16 grams of seed. Each 16 gram sample of seed was separately treated with the required insecticide and rate in a manner similar to that described for seed treatment control. After treatment, the seed was spread out in a thin layer to dry.

The turnip seed treatment tests were conducted in a manner similar to those on onion seed germination except that only two different rates of each insecticide were used. The lightest rate consisted of one part of actual toxicant by weight to 16 parts of seed by weight and the heaviest rate consisted of two parts of actual toxicant to 16 parts of seed. The turnip seed was weighed in 14 samples, each sample containing four grams of seed. Each sample of seed was moistened with one millilitre of four per cent Methocel and treated with the required insecticide in the usual manner.

Seeding of both onion and turnip seed was carried out in the same way. One hundred treated seeds were placed on the surface of the sand in each section. In this way each flat contained a total of 800 seeds. When all the seeds had been placed, they were covered with a half inch layer of sand that had been sifted through a 16 mesh screen.

Germination counts were begun 11 days after seeding and were made every two days until maximum germination had been reached for all treatments. These counts were based on the number of seedlings appearing above the surface from the hundred seeds planted per row. By making counts every two days, any delay in germination of treatments could be compared. Notes were also made on post-emergence growth.

Furrow treatment germination tests

Furrow treatment germination tests for both onion and turnip seed were conducted in wooden flats in the greenhouse. In addition to greenhouse tests, onion seed germination was also tested in the furrow treatment control plots in the field. In the greenhouse tests, each insecticide was applied at two different rates. The first rate of application was equivalent to 0.1 pound of actual toxicant to 1,000 feet of row. Toxaphene, which was considered a less toxic insecticide, was applied at the rate of 0.3 pound of actual toxicant to 1,000 feet of row. The second rate of application was equivalent to 0.3 pound of actual toxicant to 1,000 feet of row. The second rate of toxaphene was applied at three times this rate or the equivalent of 0.9 pound of actual toxicant to 1,000 feet of row.

The tests were conducted in wooden flats. Each flat was partitioned in 11 sections by means of corrugated cardboard strips and filled with sand to a depth of about two inches. Only the inner nine sections were used for treatments. The two outer sections served as guard rows. One hundred seeds were then placed in a shallow furrow in each treatment section. The insecticides were then applied to the seeds in their respective sections. In some cases the seed was completely covered with insecticide. Following this procedure, a half inch of sifted sand was added to each section to cover the seed. Counts were made in a manner similar to that described for seed treatment germination tests.

CHAPTER VI

RESULTS AND DISCUSSIONS

Seed treatment control

Seed treated with insecticide-fungicide mixtures gave varying degrees of control of the onion maggot. As can be seen in Table I, the treatments of the experiment conducted at the University were highly significant at the one per cent level. An analysis of the treatments is given in Table II.

According to Goulden (15), percentages are particularly likely to show deviations from the normal distributions. He therefore, recommends transformation of percentages unless nearly all the data lie between 30 and 70 per cent. The inverse sine transformation was used and transformed values were obtained from Snedecor (35).

All treatments except DDT and toxaphene differ significantly from the check at the one per cent level. DDT and toxaphene show significant difference at the five per cent level. Lindane gave complete control but caused a marked decrease in germination of onion seed which will be discussed under germination results. Heptachlor, aldrin, dieldrin and chlordane all gave excellent control, showing significant differences from DDT and toxaphene at the one per cent level. The four successful treatments did not differ from one another significantly. Aldrin and chlordane treated seed shows some reduction in germination and will be discussed under germination results. Individual variates are given in Appendix A.

Results of seed treatment control plots at Bird's Hill differed somewhat from those on the University plots. Table III shows all treatments to be highly significant at the one per cent level. Table IV shows the results of the separate treatments. The transformed percentage control of all treatments differ significantly from the check. Although DDT gave some control it is significantly lower at the one per cent level than all other treatments including toxaphene. Toxaphene in turn is significantly lower than the remaining treatments at only the five per cent level. Lindane gave complete control but a glance at the column showing total number of plants indicates very poor germination. Dieldrin, heptachlor, aldrin and chlordane gave the best control. Aldrin and chlordane showed decreased germination. Germination results will be more thoroughly discussed later in the chapter. Readings for individual variates can be found in Appendix B.

Furrow treatment control

The furrow treatment control tests, conducted at the University, included only four insecticides but gave a

TABLE I

ANALYSIS OF VARIANCE OF THE PER CENT CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY SEED TREATMENT (UNIVERSITY PLOTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	7	32.11	1.35	--	--
Treatments	7	839.18	35.38**	3.30	2.21
Error	49	23.72			
Total	63				

TABLE II

PER CENT CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY SEED TREATMENT ON UNIVERSITY PLOTS (EIGHT REPLICATES)

Treatment	Infested plants	No. of plants in eight replicates	Per cent control	Transformed percentage
Aldrin	5	2,804	99.82	88.50
Chlordane	13	2,601	99.50	85.86
DDT	357	3,195	88.83	72.01
Dieldrin	7	3,267	99.79	88.13
Heptachlor	3	3,368	99.91	89.17
Lindane	0	762	100.00	90.00
Toxaphene	349	3,337	89.54	72.12
Check	690	3,258	78.82	63.79
Probability	1%	5%		
L.S.D.	8.52	5.76	(transformed percentages)	

TABLE III

ANALYSIS OF VARIANCE OF THE PER CENT CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY SEED TREATMENT (BIRD'S HILL PLOTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	3	4.11	--	--	--
Treatments	7	290.46	49.15**	3.65	2.49
Error	21	5.91			
Total	31				

TABLE IV

PER CENT CONTROL OF THE ONION MAGGOT, *Hylemya anitqua* (Meig.), BY SEED TREATMENT ON BIRD'S HILL PLOTS (FOUR REPLICATES)

Treatment	Infested plants	No. of plants in eight replicates	Per cent control	Transformed percentage
Aldrin	0	3,115	100	90.00
Chlordane	0	1,444	100	90.00
DDT	128	5,568	97.7	82.12
Dieldrin	0	5,375	100	90.00
Heptachlor	0	4,495	100	90.00
Lindane	0	65	100	90.00
Toxaphene	20	5,109	99.61	86.70
Check	737	5,414	86.39	65.65
Probability	1%	5%		
L.S.D.	4.27	2.89 (transformed percentages)		

wider range of results than the preceding seed treatment control tests. Table V shows that treatments are significant at the one per cent level. Table VI shows the differences between treatments. Malathion dust shows no significant difference from the check at the five per cent level. Aldrin, heptachlor and toxaphene, all granular formulations, show significant control. Although the percentage of control varied somewhat, none of the three treatments differed from one another significantly. Results of germination will be discussed under germination tests. Counts of individual variates can be found in Appendix C.

Delayed sprinkling control

As mentioned earlier, this test was conducted in an attempt to stop further damage once the maggots had infested the crop of onions. Table VII shows that treatments were significant at the one per cent level. The transformed percentage column in Table VIII shows that all three rates of both dieldrin and heptachlor gave significant control. Further study of the treatments shows that no significant difference exists between either treatment or rate of treatment.

TABLE V

ANALYSIS OF VARIANCE OF THE PER CENT CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY FURROW TREATMENT (UNIVERSITY PLOTS)

Source of variation	D.F.	M.S.	F	.01	.05
Replicates	4	69.27	1.49	4.77	3.01
Treatments	4	1,072.41	23.14**	4.77	3.01
Error	16	46.35			
Total	24				

TABLE VI

PER CENT OF CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY FURROW TREATMENT ON UNIVERSITY PLOTS (FIVE REPLICATES)

Treatment	Infested plants	No. of plants in eight replicates	Per cent control	Transformed percentage
Aldrin	1	887	99.88	89.11
Heptachlor	27	698	94.74	79.21
Malathion	397	1,446	71.78	58.61
Toxaphene	14	1,403	98.98	84.53
Check	431	1,504	71.44	58.04
Probability	1%	5%		
L.S.D.	19.82	11.95 (transformed percentages)		

TABLE VII

ANALYSIS OF VARIANCE OF THE PER CENT CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY DELAYED SPRINKLING (PARKDALE PLOTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	3	6.92	--	--	--
Treatments	6	174.96	20.49**	4.01	2.66
Error	18	8.54			
Total	27				

TABLE VIII

PER CENT OF CONTROL OF THE ONION MAGGOT, *Hylemya antiqua* (Meig.), BY DELAYED SPRINKLING TREATMENT ON PARKDALE PLOTS (FOUR REPLICATES)

Treatment lb./1,000 ft. of row	Infested plants	No. of plants in four replicates	Per cent control	Transformed percentage
Dieldrin(0.1)	49	7,057	99.31	85.45
Dieldrin(0.3)	36	6,498	99.45	85.92
Dieldrin(0.6)	12	6,455	99.81	87.61
Heptachlor(0.1)	46	7,115	99.35	85.61
Heptachlor(0.3)	18	7,015	99.74	87.46
Heptachlor(0.6)	24	6,559	99.63	86.75
Check	775	5,779	86.59	69.12
Probability	1%	5%		
L.S.D.	5.78	3.82 (transformed percentages		

Seed treatment germination

As stated earlier, the seed treatment germination tests for onion seed were conducted both in the greenhouse and in outdoor plots. Table IX shows an analysis of variance of results from outdoor seed treatment plots at the University where only one rate of each insecticide was used. Replicates and treatments are both significant at the one per cent level. An analysis of the treatments is given in Table X.

DDT, dieldrin, heptachlor and toxaphene treated seed show no significant difference in germination from the check. Seed treated with aldrin, chlordane and lindane shows a significant reduction in germination at the one per cent level. Lindane is significantly lower than both aldrin and chlordane at the one per cent level. Individual variates will be found in Appendix A.

A definite number of seeds were not planted per row in the Bird's Hill seed treatment tests. Use of a mechanical seeder, however, gave approximately an equal amount of seed per treatment row. Table IV gives the total number of plants for eight replicates. A definite reduction in number of plants is shown in the aldrin, chlordane and lindane treatments.

Seed treatment germination tests with onion seed in the greenhouse involved the use of three different rates of each insecticide. Table XI shows treatments to be highly significant at the one per cent level. Replicates are significant at the

TABLE IX

ANALYSIS OF VARIANCE OF PER CENT GERMINATION OF ONION SEED TREATED WITH VARIOUS INSECTICIDES BY THE SEED TREATMENT METHOD (FIELD PLOTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	7	49.26	3.30**	3.03	2.205
Treatments	7	1,562.07	104.77**	3.03	2.205
Error	49	14.91			
Total	63				

TABLE X

FIELD PLOT GERMINATION RESULTS OF ONION SEED TREATED WITH VARIOUS INSECTICIDES BY THE SEED TREATMENT METHOD (EIGHT REPLICATES)

Treatment	Number of plants from 4,000 seeds	Per cent germination	Transformed percentage
Aldrin	2,804	70.10	56.58
Chlordane	2,601	65.03	53.81
DDT	3,195	79.88	64.26
Dieldrin	3,267	81.67	66.71
Heptachlor	3,368	84.20	66.66
Lindane	762	19.05	25.73
Toxaphene	3,337	84.43	66.32
Check	3,258	81.45	64.83

Probability	1%	5%	
L.S.D.	6.75	4.57	(transformed percentages)

five per cent level. The effect of the three different rates is not significant. The treatments are analyzed in Table XII. All treatments except DDT and toxaphene show significantly lower germination than the check. Dieldrin and heptachlor treated seed shows lower germination at the five per cent level. Aldrin, chlordane and lindane differ significantly at the one per cent level. Chlordane treated seed shows a significantly lower germination than seed treated with dieldrin and heptachlor at the one per cent level. It is also significantly lower than aldrin treated seed at the five per cent level. Lindane treatment results in significantly lower germination at the one per cent level than all other treatments. Counts of individual variates can be found in Appendix E.

The check rows showed excellent post-emergence growth despite the use of sand as the germination medium. DDT and toxaphene treatments displayed almost equivalent growth to the check. Dieldrin and heptachlor showed slightly poorer growth than the above three treatments. Rate of germination was more uneven, with plants ranging from newly germinated seedlings to plants past the loop stage. Aldrin and chlordane treatments caused slight dwarfing and deformity of the young onion plants which later recovered to show normal growth. Plant stems however, remained slightly thicker than normal. Lindane treatment had the severest effect on germination and post-emergence growth. Plants were dwarfed and some were extremely deformed.

TABLE XI

ANALYSIS OF VARIANCE OF PER CENT GERMINATION OF ONION SEED TREATED WITH VARIOUS INSECTICIDES AT THREE DOSAGES USING THE SEED TREATMENT METHOD (GREENHOUSE TESTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	6	54.31	2.64*	2.93	2.16
Treatments	7	4,112.63	200.23**	2.78	2.07
Rates	2	39.10	--	--	--
Interaction	14	23.51	--	--	--
Error	138	20.54	--	--	--
Total	167				

TABLE XII

GREENHOUSE GERMINATION RESULTS OF ONION SEED TREATED WITH VARIOUS INSECTICIDES BY THE SEED TREATMENT METHOD (SEVEN REPLICATES)

Treatment	Number of plants from 2,100 seeds	Per cent germination	Transformed percentage
Aldrin	1,429	68.05	55.74**
Chlordane	1,217	57.95	49.68**
DDT	1,613	76.81	61.32
Dieldrin	1,550	73.81	59.39*
Heptachlor	1,508	71.81	57.98*
Lindane	308	14.67	21.76**
Toxaphene	1,643	78.24	62.38
Check	1,748	83.24	65.90
Probability	1%	5%	
L.S.D.	7.94	5.37 (transformed percentage)	

In seed treatment germination tests with turnip seed only two rates of each insecticide were used. These tests were conducted in the greenhouse. An analysis of variance in Table XIII shows replicates, treatments and the interaction to be significant at the one per cent level. Table XIV gives an analysis of the treatments. Chlordane, heptachlor and lindane treated seed show significantly lower germination than the check at the one per cent level. DDT treatment shows no significant difference while aldrin, dieldrin and toxaphene show significance at the five per cent level. Lindane treated seed shows significantly lower germination than heptachlor treated seed at the five per cent level and significantly lower than dieldrin treated seed at the one per cent level.

Table XV gives an analysis of the interaction between rates and treatments. Lindane treated seed shows significantly lower germination than all treatments at the one per cent level. Aldrin and DDT treated seed show a significant increase in germination over dieldrin and heptachlor treated seed at the five per cent level. Individual variate counts can be found in Appendix F.

DDT, dieldrin and toxaphene treated seed showed excellent post-emergence growth, being equivalent to the check. Heptachlor followed closely but showed some signs of dwarfing in early stages. This dwarfing was overcome

TABLE XIII

ANALYSIS OF VARIANCE OF PER CENT GERMINATION OF TURNIP SEED TREATED WITH VARIOUS INSECTICIDES AT TWO DOSAGES USING THE SEED TREATMENT METHOD (GREENHOUSE TESTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	6	150.80	4.10**	3.02	2.20
Treatments	7	547.53	14.90**	2.85	2.11
Rates	1	27.49	--	--	--
Interaction	7	170.99	4.65**	2.85	2.11
Error	90	36.75			
Total	111				

TABLE XIV

GREENHOUSE GERMINATION RESULTS OF TURNIP SEED TREATED WITH VARIOUS INSECTICIDES BY THE SEED TREATMENT METHOD (SEVEN REPLICATES)

Treatment	No. of plants from 1,400 seeds	Per cent germination	Transformed percentage
Aldrin	1,137	81.21	64.97
Chlordane	1,022	73.00	58.98
DDT	1,212	86.57	68.97
Dieldrin	1,116	79.71	65.66
Heptachlor	1,067	76.21	61.03
Lindane	878	62.71	52.52
Toxaphene	1,154	82.43	65.76
Check	1,272	90.86	72.96
Probability	1%	5%	
L.S.D.	10.61	7.15(transformed percentage)	

TABLE XV

GREENHOUSE SEED TREATMENT GERMINATION RESULTS WITH TURNIP SEED SHOWING INTERACTION BETWEEN TREATMENTS AND RATES

Treatment	Average % germination rate 1 (1:16)	Average % germination rate 2 (1:8)	Av. difference rate 2 - rate 1
Aldrin	62.04	67.90	5.86
Chlordane	59.04	58.92	- 0.12
DDT	66.52	71.43	4.91
Dieldrin	65.51	61.81	- 4.70
Heptachlor	63.25	58.81	- 4.44
Lindane	60.25	44.80	-15.45
Toxaphene	65.43	66.10	0.67
Check	70.79	75.13	4.34

Probability	1%	5%	
L.S.D.	11.34	7.65	(differences)

in later stages of growth. Aldrin and chlordane treatments showed dwarfing and uneven growth. Lindane treated plants displayed short, thickened stems and a reduced root system which caused early drying up of the plants.

Furrow treatment germination

Furrow treatment germination tests on onion seed were conducted both in the field and in the greenhouse. Table XVI gives an analysis of variance of tests conducted on the outdoor plots at the University. Replicates and treatments show significance at the one per cent level. A treatment analysis is given in Table XVII. Granular aldrin and granular heptachlor treated seed shows significantly lower germination at the one per cent level than the seed treated with malathion dust or granular toxaphene. Individual variates are given in Appendix C.

In furrow treatment germination tests conducted in the greenhouse with onion seed, each insecticide was used at two different rates. Table XVIII shows that the effects of treatments, rates, and the interaction of treatments with rates are significant at the one per cent level. An analysis of treatments, given in Table XIX, shows all treatments to be significantly lower in germination than the check at the one per cent level. Dieldrin treated seed shows significantly higher germination than any of the other treatments at the one per cent level. Malathion

TABLE XVI

ANALYSIS OF VARIANCE OF PER CENT GERMINATION OF ONION SEED TREATED WITH VARIOUS INSECTICIDES BY FURROW TREATMENT METHOD (FIELD PLOTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	7	49.26	3.30**	3.03	2.205
Treatments	7	1,562.07	104.77**	3.03	2.205
Error	49	14.91			
Total	63				

TABLE XVII

FIELD PLOT GERMINATION RESULTS OF ONION SEED TREATED WITH FOUR DIFFERENT INSECTICIDES BY THE FURROW TREATMENT METHOD (FIVE REPLICATES)

Treatment	No. of plants from 2,500 seeds	Per cent germination	Transformed percentage
Aldrin (granular)	887	35.48	36.54
Heptachlor (granular)	698	27.92	31.65
Malathion (dust)	1,446	57.84	49.53
Toxaphene (granular)	1,403	56.12	48.53
Check	1,504	60.16	50.89

Probability	1%	5%
L.S.D.	10.58	6.38

treated seed differs significantly from seed treated with granular toxaphene and heptachlor wettable powder at the five per cent level, thereby indicating a higher degree of germination. Seed treated with aldrin wettable powder, granular aldrin and granular heptachlor shows significantly lower germination than all other treatments at the one per cent level. They do not, however, differ significantly from one another.

Table XX is an analysis of the interaction between treatments and rates. All differences in the last column show that the second rate of application resulted in a significant reduction in germination. All treatments differ significantly from the check. Aldrin wettable powder, granular aldrin and granular heptachlor treatments showed significant differences from one another. Seed treated with dieldrin shows a significant reduction from seed treated with granular heptachlor at the five per cent level. The second rate of application of toxaphene dust and granular toxaphene caused significantly reduced germination in comparison to the previously mentioned treatments at the one per cent level. Seed treated with heptachlor wettable powder and malathion dust shows a significant decrease in germination at the five per cent level when compared with the toxaphene treatments. Counts of individual variates can be found in Appendix G.

Dieldrin and malathion treated seed showed fairly normal post-emergence growth when applied at the first rate equivalent

TABLE XVIII

ANALYSIS OF VARIANCE OF PER CENT GERMINATION OF ONION SEED TREATED WITH VARIOUS INSECTICIDES, EACH AT TWO DOSAGES, AND APPLIED AS FURROW TREATMENTS (GREENHOUSE TESTS)

Source of variation	D.F.	M.S.	F.	.01	.05
Replicates	6	71.71	1.99	--	--
Treatments	8	5,142.75	142.46**	2.69	2.03
Rates	1	32,176.37	891.31**	3.49	6.90
Interaction	8	988.90	27.39**	2.69	2.03
Error	102	36.10			
Total	125				

TABLE XIX

GREENHOUSE GERMINATION RESULTS OF ONION SEED TREATED WITH VARIOUS INSECTICIDES BY THE FURROW TREATMENT METHOD (SEVEN REPLICATES)

Treatment	No. of plants from 1,400 seeds	Per cent germination	Transformed percentage
Aldrin (wettable)	107	7.64	11.32
Aldrin (granular)	130	9.29	12.96
Dieldrin (wettable)	845	60.36	52.01
Heptachlor (wettable)	397	28.36	25.68
Heptachlor (granular)	128	9.14	14.01
Malathion (dust)	568	40.57	34.47
Toxaphene (dust)	451	32.21	29.65
Toxaphene (granular)	396	28.29	25.73
Check	1,206	86.14	68.79

Probability	1%	5%	
L.S.D.	9.51	6.54	(transformed percentages)

TABLE XX

GREENHOUSE FURROW TREATMENT GERMINATION RESULTS OF ONION SEED SHOWING INTERACTION BETWEEN TREATMENTS AND RATES

Treatment	R Rate one lb./1,000 row feet	Average per cent germination	Rate two lb./1,000 row feet	Average per cent germination	Average difference: rate 2 - rate 1
Aldrin (wettable)	0.1	22.64	0.3	0.0	-22.64
Aldrin (granular)	0.1	25.09	0.3	0.82	-24.27
Dieldrin (wettable)	0.1	67.11	0.3	36.92	-30.19
Heptachlor (wettable)	0.1	58.35	0.3	3.01	-55.34
Heptachlor (granular)	0.1	24.18	0.3	3.83	-20.35
Malathion (dust)	0.1	61.22	0.3	7.72	-53.50
Toxaphene (dust)	0.3	52.30	0.6	6.99	-45.31
Toxaphene (granular)	0.3	48.39	0.6	3.07	-45.32
Check	--	69.14	--	68.43	- 0.71

Probability	1%	5%
L.S.D.	10.79	7.42

to 0.1 pound per 1,000 feet of row. The malathion treated plants tended to have thinner stems. Both toxaphene treatments resulted in some uneven and dwarfed growth. Granular heptachlor treated seed resulted in deformed plants which eventually dried up. The remaining treatments also showed dwarfed, deformed plants with thickened stems. At the second rate of application all insecticides caused injury to all emerging plants.

Furrow treatment germination tests with turnip seed were conducted in the greenhouse. Table XXI shows that treatments, rates and interaction are all significant at the one per cent level. Treatment analysis is given in Table XXII. Granular aldrin and dieldrin are the only two treatments which did not cause significantly lower germination than the check at the five per cent level. Seed treated with toxaphene dust, granular toxaphene and heptachlor wettable powder shows significantly lower germination at the five per cent level. Malathion treated seed shows significantly lower germination at the one per cent level than the above mentioned treatments and significantly higher germination at the one per cent level than granular heptachlor and aldrin wettable powder treatments. Aldrin wettable powder and granular heptachlor treatments do not differ significantly.

Table XXIII shows the different effect of rates and treatments on the germination of turnip seed. In all but two instances the average germination was decreased by an increased

TABLE XXIII

FURROW TREATMENT GERMINATION OF TURNIP SEED SHOWING INTERACTION BETWEEN TREATMENTS AND RATES

Treatment	Rate one lb./1,000 row feet	Average per cent germination	Rate two lb./1,000 row feet	Average per cent germination	Average difference rate 2 - rate 1
Aldrin (wettable)	0.1	34.02	0.3	23.84	-10.18
Aldrin (granular)	0.1	70.58	0.3	68.26	- 2.32
Dieldrin (wettable)	0.1	74.43	0.3	69.41	- 5.02
Heptachlor (wettable)	0.1	64.82	0.3	67.98	3.16
Heptachlor (granular)	0.1	20.90	0.3	23.45	2.55
Malathion (dust)	0.1	48.52	0.3	32.39	-16.13
Toxaphene (dust)	0.3	67.07	0.6	63.30	- 3.77
Toxaphene (granular)	0.3	69.48	0.6	57.72	-11.76
Check	- -	76.63	- -	75.81	- 0.82

Probability	1%	5%
L.S.D.	14.92	10.26

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The onion maggot, Hylemya antiqua (Meig.), is the most serious pest of onions grown in the Winnipeg area. A review of literature indicated that seed treatment and furrow treatment were the two methods which might prove most satisfactory for control studies in this area. The possibility of toxicity of insecticides to seed prompted a study of the effect of toxicants on germination. Both onion and turnip seed were included in the germination tests. A preliminary experiment involving delayed sprinkling was conducted to determine the possibility of preventing further damage to onions once the maggot had entered the soil and begun feeding.

Seven insecticides in the wettable powder form were used in seed treatment control experiments: (1) 40 per cent aldrin, (2) 50 per cent chlordane, (3) 50 per cent DDT, (4) 25 per cent dieldrin, (5) 25 per cent heptachlor, (6) 50 per cent lindane and (7) 40 per cent toxaphene. Arasan was used as the fungicide and four per cent Methocel was used as the sticker. In the furrow treatment control experiments, the following insecticides were used: (1) five per cent granular aldrin, (2) five per cent granular heptachlor, (3) 25 per cent granular toxaphene and (4) four per cent malathion dust. In the delayed sprinkling experiment an 18 per cent dieldrin emulsifiable concentrate and a 25 per cent heptachlor emulsifiable concentrate were used.

Seed germination experiments were of two types: (1) seed treatment and (2) furrow treatment. In the seed treatment germination tests, the same insecticides were used as those for seed treatment control tests. Furrow treatment germination tests included (1) 20 per cent aldrin wettable powder, (2) five per cent granular aldrin, (3) 25 per cent dieldrin wettable powder, (4) 25 per cent heptachlor wettable powder, (5) five per cent granular heptachlor, (6) four per cent malathion dust, (7) 10 per cent toxaphene dust and (8) 25 per cent granular toxaphene. Control experiments were conducted in field plots while germination experiments were conducted both in field plots and in the greenhouse.

For the seed treatment control tests, the insecticides were added to seed moistened with Methocel at the rate of one part of actual toxicant to 16 parts of seed by weight. The seed treatment control plots at the University were seeded by hand with approximately 500 treated seeds per treatment replicate, in order to obtain germination counts along with control results. The Bird's Hill seed treatment plots were seeded with a Planet Jr. seeder at the rate of approximately 40 pounds per acre. Counts of infested plants in all control tests were made every four days. Plants indicating infestation were pulled to establish definite damage.

In the furrow treatment control plots, 500 seeds were placed in each 12 foot furrow. Granular aldrin, granular heptachlor and malathion dust were then added to their respective rows at the rate of 0.1 pound of actual toxicant per 1,000 feet of row. Granular toxaphene was added at 0.4 pound actual toxicant per 1,000 feet of row.

In the delayed sprinkling experiment, dieldrin and heptachlor were the two insecticides used. Each insecticide was applied at (1) 0.1 pound actual toxicant per 1,000 feet of row, (2) 0.3 pound actual toxicant per 1,000 feet of row, and (3) 0.6 pound actual toxicant per 1,000 feet of row. Each rate of insecticide was diluted with one gallon of water and applied to a 15 foot row with a watering can.

Greenhouse seed treatment germination tests were conducted in wooden flats in sand. Sand was used as the germination medium because it lacked organic matter which would tend to sorb the insecticides and thus reduce their effect. Each flat was partitioned into sections to allow each treatment of the experiment to be replicated once per flat. One hundred treated seeds were used for each treatment replicate. Counts were made every two days, based on the number of plants germinating of the original 100 seeds planted.

For the seed treatment germination tests with onion seed, each insecticide was applied at the following rates: (1) one part actual toxicant to 16 parts of seed by weight, (2) 1.5 parts of actual toxicant to 16 parts of seed by weight, and (3) two parts of actual toxicant to 16 parts of seed by weight. In the turnip seed treatment germination test only two rates, one part of actual toxicant to 16 parts of seed and two parts of actual toxicant to 16 parts of seed were used. A four per cent Methocel solution was used as a sticker.

Furrow treatment germination tests for both onion and turnip seed were conducted in flats in the greenhouse. Onion furrow treatment tests were also conducted on field plots. Two rates of application were used in the greenhouse tests. All insecticides except the toxaphene formulations were applied at 0.1 pound of actual toxicant per 1,000 feet of row and 0.3 pound per 1,000 feet of row. Toxaphene formulations were applied at 0.3 pound actual toxicant per 1,000 feet of row for the first treatment and 0.6 pound actual toxicant per 1,000 feet of row for the second rate. Treatments were partitioned by means of cardboard strips. One hundred seeds were placed on the surface of the sand and then treated with the desired insecticide formulation and rate. Sifted sand was used for covering the treated seed. Counts were made in a manner similar to that described for seed treatment germination tests.

Results of the seed treatment control tests at the University showed that all treatments gave some degree of control. DDT and toxaphene, however, gave significantly poorer control than the other treatments. Aldrin, Chlordane, dieldrin, heptachlor and lindane gave the best control but lindane seriously reduced germination. Aldrin and chlordane also caused reduction in germination. Seed treatment control experiments at Bird's Hill showed that all treatments gave some control. Control with DDT was significantly lower than all other treatments. Toxaphene treatment gave less control but not as low as DDT. Aldrin, chlordane, dieldrin and heptachlor again gave excellent control although aldrin and chlordane treatments reduced seed germination. Lindane treatment again gave complete control but caused serious reduction of germination.

In the University furrow treatment control tests, malathion dust treatment proved ineffective. Aldrin, heptachlor and toxaphene, all granular formulations, gave significant control. In the delayed sprinkling experiments both 18 per cent dieldrin emulsifiable concentrate and 25 per cent heptachlor emulsifiable concentrate gave control. No significant difference in control was shown among rates of application or insecticides.

In the seed treatment germination plots at the University, DDT, dieldrin, heptachlor and toxaphene treated seed showed no difference in germination from the untreated seed. Seed treated with aldrin, chlordane and lindane showed a definite reduction in germination. Lindane treated seed was considerably lower in germination than both aldrin and chlordane treated seed. Although a definite number of seeds per treatment were not sown in the Bird's Hill plots, a definite reduction in germination could be seen in the seed treated with aldrin, chlordane and lindane.

In the greenhouse seed treatment germination tests, the increased rates of application of insecticides showed no reduction in germination. All treatments except DDT and toxaphene caused lower germination than the check. Germination of dieldrin and heptachlor treated seed was inhibited to a lesser degree than was seed treated with aldrin, chlordane and lindane. Lindane treated seed showed the lowest germination of all treatments. DDT and toxaphene treated seed resulted in excellent post-emergence growth while seed treated with dieldrin and heptachlor indicated slightly poorer growth. Aldrin and chlordane treatments caused slight dwarfing and deformity of seedlings. Lindane treatment caused extreme dwarfing and deformity.

Greenhouse seed treatment germination tests on turnip seed showed treatment to have an inhibiting effect on germination. Chlordane, heptachlor and lindane treatments gave the lowest germination. DDT showed no marked difference from the check. Aldrin, dieldrin and toxaphene treated seed showed some reduction in germination. Lindane treatment resulted in lower germination than any other treatments.

Interaction between treatment and rates indicated that lindane treatment had the severest effect on germination. Seed treated with aldrin and DDT showed an increase in germination over dieldrin and heptachlor treated seed but showed a decreased germination in comparison with the check. DDT, dieldrin and toxaphene treated seed exhibited the same post-emergence growth as the check. Heptachlor treated seed showed slight signs of dwarfing while aldrin and chlordane treated seed showed dwarfing and uneven growth. Lindane treatment resulted in plants with short, thickened stems and reduced root systems.

In furrow treatment germination tests with onion seed at the University, granular aldrin and granular heptachlor treatments caused lower germination than granular toxaphene and malathion dust treatments. Greenhouse furrow treatment germination tests with onion seed indicated that treatment, rate of treatment and interaction all had some effect on germination. All treated seed gave lower germination than the check. Dieldrin treated seed gave the highest germination followed by malathion. Seed treated with granular toxaphene and heptachlor wettable powder gave lower germination than seed treated with malathion. Aldrin wettable powder, granular aldrin and granular heptachlor treated seed gave significantly lower germination than all other treatments.

The increased rate of application caused a further decrease in germination, and all the treatments were significantly lower than the check. Seed treated with aldrin wettable powder showed best germination followed by seed treated with granular aldrin and granular heptachlor. The second rate of application of toxaphene dust and granular toxaphene reduced germination below the level of the above mentioned treatments. Application of heptachlor wettable powder and malathion dust further reduced germination.

Seedlings resulting from dieldrin and malathion treated seed showed fairly normal post-emergence growth. Toxaphene treated seedlings displayed uneven and dwarfed growth. Granular heptachlor treated seed produced deformed plants which eventually died. All other treatments produced dwarfed, deformed plants. When applied at the heaviest rate tested, all treatments caused injury to plants.

Furrow treatment germination tests with turnip seed showed that treatment, rate and interaction all affected germination. Granular aldrin and dieldrin gave similar germination to the check. Germination of seed treated with heptachlor wettable powder and toxaphene treatments gave lower germination. Malathion treated seed gave lower germination than the above treatments but was considerably higher than seed treated with aldrin wettable powder or granular heptachlor. Increased rate of application resulted in decreased germination in all but two treatments. Malathion treatment reduced germination but not to the same extent as granular toxaphene. Both heptachlor treatments showed slight stimulation and were significantly higher in germination than toxaphene treatment and aldrin wettable powder.

In post-emergence growth, dieldrin and granular aldrin treated seed gave growth equivalent to the check. Seed treated with toxaphene formulations followed these closely. Plants from seeds treated with aldrin wettable powder and granular heptachlor died shortly after emergence. Heptachlor wettable powder and malathion dust caused irregular yellowish growth.

Conclusions

The following wettable powder insecticides, when applied as seed treatments at the rate of one part of actual toxicant to 16 parts of seed by weight, gave good control of the onion maggot, *H. antiqua* (Meig.): (1) 40 per cent aldrin, (2) 50 per cent chlordane, (3) 25 per cent dieldrin, (4) 25 per cent heptachlor and (5) 50 per cent lindane. Fifty per cent DDT and 40 per cent toxaphene gave only poor control.

Granular formulations of (1) five per cent aldrin, (2) five per cent heptachlor and (3) 25 per cent toxaphene gave good control when applied as furrow treatments. Aldrin and heptachlor were applied at the rate of 0.1 pound actual toxicant per 1,000 feet of row and toxaphene at the rate of 0.4 pound actual toxicant per 1,000 feet of row. Malathion dust gave almost no control.

Both 18 per cent dieldrin emulsifiable concentrate and

25 per cent heptachlor emulsifiable concentrate, at a rate equivalent to 0.1 pound actual toxicant per 1,000 feet of row, were able to stop the spread of infestation of the maggot, when applied with one gallon of water per 15 feet of row.

Seed treated with wettable powders of DDT, dieldrin, heptachlor and toxaphene up to the rate of two parts actual toxicant to 16 parts of seed gave little or no reduction in germination. The germination of seed treated with aldrin, chlordane and lindane was reduced considerably.

Furrow treatment germination tests indicated that dieldrin wettable powder and malathion dust treatments resulted in good germination when applied at rates up to 0.1 pound actual toxicant per 1,000 feet of row. Granular toxaphene at 0.3 pound actual toxicant per 1,000 feet of row and heptachlor wettable powder at 0.1 pound actual toxicant per 1,000 feet of row caused a slight reduction in germination. The same rates of aldrin wettable powder, granular aldrin and granular heptachlor caused greater reduction in germination. Doubling the rate mentioned above caused serious reduction in germination for all treatments.

From the above statements it may be concluded that best control of the onion maggot, with minimum germination injury, can be obtained by treating or pelleting the seed with either 25 per cent heptachlor wettable powder or 25 per cent dieldrin wettable powder at the rate of one part of actual toxicant to 16 parts of seed by weight. For furrow treatment control, granular toxaphene is recommended at the rate of 0.4 pound actual toxicant to 1,000 feet of row.

Turnip seed treated with DDT gave good germination. This treatment was followed closely by toxaphene, aldrin and dieldrin seed treatments. Chlordane and lindane treatment gave lowest germination. Increased rate of application to two parts actual toxicant to 16 parts of seed had a greater inhibiting effect on seed treated with dieldrin and heptachlor than seed treated with DDT and aldrin.

In furrow treatment germination tests, germination was reduced by all treatments. Dieldrin treated seed gave the best germination followed closely by malathion dust and granular toxaphene. Heptachlor and aldrin formulations greatly reduced germination.

No tests for the control of the turnip maggot were conducted. Therefore, the following results are concerned only with the effect of the insecticides on germination. DDT, toxaphene, aldrin and dieldrin gave the highest percentage of germination when used as seed treatments. Where furrow treatments were used, seed treated with dieldrin, malathion and granular toxaphene gave the best results.

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APPENDIX A

INDIVIDUAL VARIATE COUNTS FOR SEED TREATMENT CONTROL PLOTS AT THE UNIVERSITY

Replicate	Treatment	Infested plants	Total No. of plants	Per cent damage	Per cent germination
1	: Aldrin	0	386	0	77.2
	: Chlordane	4	348	1.15	69.6
	: DDT	115	426	26.995	85.2
	: Dieldrin	1	459	0.22	91.8
	: Heptachlor	0	434	0.0	86.8
	: Lindane	0	104	0.0	20.8
	: Toxaphene	75	444	16.89	88.8
	: Check	80	381	20.997	76.02
2	: Aldrin	0	328	0	65.6
	: Chlordane	1	322	0.31	64.4
	: DDT	6	390	1.54	78.0
	: Dieldrin	0	398	0.0	79.6
	: Heptachlor	2	407	0.49	81.4
	: Lindane	0	89	0.0	17.8
	: Toxaphene	34	424	8.02	84.8
	: Check	90	395	22.78	79.0
3	: Aldrin	2	397	0.4	79.4
	: Chlordane	2	376	0.53	75.2
	: DDT	75	410	18.29	82.0
	: Dieldrin	0	457	0.0	91.4
	: Heptachlor	0	446	0.0	89.2
	: Lindane	0	132	0.0	26.4
	: Toxaphene	55	437	12.59	87.4
	: Check	15	343	4.37	68.6
4	: Aldrin	1	335	0.299	67.0
	: Chlordane	1	293	0.34	58.6
	: DDT	24	361	6.65	72.2
	: Dieldrin	1	373	0.27	74.6
	: Heptachlor	0	420	0.0	84.0
	: Lindane	0	58	0.0	11.6
	: Toxaphene	14	435	3.22	87.0
	: Check	20	455	4.4	91.0

APPENDIX A (continued)

INDIVIDUAL VARIATE COUNTS FOR SEED TREATMENT CONTROL PLOTS AT THE UNIVERSITY

Replicate	Treatment	Infested plants	Total No. of plants	Per cent damage	Per cent germination
	: Aldrin	0	385	0.0	77.0
	: Chlordane	2	314	0.64	62.8
	: DDT	58	465	12.47	93.0
5	: Dieldrin	0	422	0.0	84.4
	: Heptachlor	0	408	0.0	81.6
	: Lindane	0	112	0.0	22.4
	: Toxaphene	53	431	12.3	86.2
	: Check	127	436	29.13	87.2
	: Aldrin	2	297	0.67	59.4
	: Chlordane	1	286	0.35	57.2
	: DDT	31	397	7.81	79.4
6	: Dieldrin	2	331	0.60	66.2
	: Heptachlor	0	410	0.0	82.0
	: Lindane	0	69	0.0	13.8
	: Toxaphene	41	395	10.38	79.0
	: Check	165	399	41.35	79.8
	: Aldrin	0	346	0.0	69.2
	: Chlordane	1	338	0.3	67.6
	: DDT	31	418	7.42	83.6
7	: Dieldrin	3	428	0.7	85.6
	: Heptachlor	0	429	0.0	85.8
	: Lindane	0	105	0.0	21.0
	: Toxaphene	70	437	16.02	87.4
	: Check	105	419	25.06	83.8
	: Aldrin	0	330	0.0	66.0
	: Chlordane	1	324	0.31	64.8
	: DDT	17	358	4.74	71.6
8	: Dieldrin	0	400	0.0	80.0
	: Heptachlor	1	414	0.24	82.8
	: Lindane	0	93	0.0	18.6
	: Toxaphene	7	334	2.1	66.8
	: Check	88	430	20.47	86.0

APPENDIX B

INDIVIDUAL VARIATE COUNTS FOR SEED TREATMENT CONTROL PLOTS AT BIRD'S HILL

Replicate	Treatment	Infested plants	Total No. of plants	Per cent damage
1	: Aldrin	0	870	0.0
	: Chlordane	0	512	0.0
	: DDT	70	1,355	5.17
	: Dieldrin	0	1,440	0.0
	: Lindane	0	12	0.0
	: Heptachlor	0	1,165	0.0
	: Toxaphene	11	1,356	0.81
	: Check	164	962	17.05
2	: Aldrin	0	837	0.0
	: Chlordane	0	435	0.0
	: DDT	47	1,288	3.65
	: Dieldrin	0	1,411	0.0
	: Lindane	0	12	0.0
	: Heptachlor	0	1,303	0.0
	: Toxaphene	4	1,341	0.3
	: Check	141	1,141	12.36
3	: Aldrin	0	731	0.0
	: Chlordane	0	209	0.0
	: DDT	6	1,482	0.41
	: Dieldrin	0	1,310	0.0
	: Lindane	0	25	0.0
	: Heptachlor	0	1,011	0.0
	: Toxaphene	4	1,232	0.33
	: Check	194	1,389	13.97
4	: Aldrin	0	677	0.0
	: Chlordane	0	288	0.0
	: DDT	5	1,443	0.35
	: Dieldrin	0	1,214	0.0
	: Lindane	0	16	0.0
	: Heptachlor	0	1,016	0.0
	: Toxaphene	1	1,180	0.08
	: Check	238	931	25.56

APPENDIX C

INDIVIDUAL VARIATE COUNTS FOR FURROW TREATMENT CONTROL PLOTS AT THE UNIVERSITY

Rep.	Treatment	Infested plants	Total No. of plants	% damage	% germination
	Aldrin (granular)	0	194	0.0	38.8
	Heptachlor (granular)	6	97	6.19	19.4
1	Malathion (dust)	138	264	52.27	52.8
	Toxaphene (granular)	1	312	0.3	62.4
	Check	70	259	27.03	51.8
	Aldrin (granular)	0	181	0.0	36.2
	Heptachlor (granular)	0	202	0.0	40.4
2	Malathion (dust)	58	278	20.86	55.6
	Toxaphene (granular)	3	267	1.12	53.4
	Check	47	304	15.46	60.8
	Aldrin (granular)	0	148	0.0	29.6
	Heptachlor (granular)	15	92	16.30	18.4
3	Malathion (dust)	36	318	11.32	63.6
	Toxaphene (granular)	6	278	2.16	55.6
	Check	97	332	29.22	66.4
	Aldrin (granular)	1	175	0.57	35.0
	Heptachlor (granular)	2	139	1.44	27.8
4	Malathion (dust)	106	289	36.68	57.8
	Toxaphene (granular)	3	285	1.05	57.0
	Check	147	307	47.88	61.4
	Aldrin (granular)	0	189	0.0	37.8
	Heptachlor (granular)	4	168	2.38	33.6
5	Toxaphene (granular)	1	261	0.38	52.2
	Malathion (dust)	59	297	19.87	59.4
	Check	70	302	23.18	60.4

APPENDIX D

INDIVIDUAL VARIATE COUNTS FOR DELAYED SPRINKLING EXPERIMENT AT PARKDALE

Rep.	Treatment	Rate lb./1,000 row feet	Infested plants	Total No. of plants	Per cent damage
	: Dieldrin	0.1	10	1,551	0.65
	: Dieldrin	0.3	3	1,430	0.21
	: Dieldrin	0.6	1	1,535	0.06
1	: Heptachlor	0.1	3	1,314	0.23
	: Heptachlor	0.3	4	1,315	0.30
	: Heptachlor	0.6	5	1,278	0.39
	: Check	-	167	1,180	14.15
	: Dieldrin	0.1	4	1,733	0.20
	: Dieldrin	0.3	16	1,860	0.86
	: Dieldrin	0.6	3	1,490	0.20
2	: Heptachlor	0.1	16	1,883	0.85
	: Heptachlor	0.3	9	1,677	0.54
	: Heptachlor	0.6	8	1,815	0.44
	: Check	-	332	1,494	22.22
	: Dieldrin	0.1	19	1,959	0.97
	: Dieldrin	0.3	9	1,566	0.58
	: Dieldrin	0.6	4	1,444	0.28
3	: Heptachlor	0.1	17	1,855	0.92
	: Heptachlor	0.3	5	2,093	0.24
	: Heptachlor	0.6	2	1,701	0.12
	: Check	-	55	1,426	3.86
	: Dieldrin	0.1	16	1,814	0.88
	: Dieldrin	0.3	8	1,642	0.49
	: Dieldrin	0.6	4	1,992	0.20
4	: Heptachlor	0.1	10	2,063	0.49
	: Heptachlor	0.3	0	1,930	0.0
	: Heptachlor	0.6	9	1,765	0.51
	: Check	-	221	1,579	14.00

APPENDIX E

INDIVIDUAL VARIATE COUNTS OF SEED TREATMENT GERMINATION TESTS SHOWING NUMBER OF PLANTS EMERGING FROM 100 TREATED ONION SEEDS

Rate	Treatment	replicates 1	2	3	4	5	6	7	Total	Average
1	Aldrin	53	59	65	78	74	74	74	477	68.1
	Chlordane	58	57	61	61	74	49	57	417	59.6
	DDT	67	79	79	82	75	78	79	539	77.0
	Dieldrin	70	74	75	78	79	77	81	534	76.3
	Heptachlor	68	69	68	74	75	71	77	502	71.7
	Lindane	5	11	15	21	20	4	4	80	11.4
	Toxaphene	80	77	80	82	84	80	88	571	81.6
	Check	80	83	84	81	81	82	88	579	82.7
2	Aldrin	60	70	73	69	75	65	83	495	70.7
	Chlordane	52	62	72	67	40	54	81	428	61.1
	DDT	81	80	84	71	73	68	76	533	76.1
	Dieldrin	66	69	79	77	73	81	80	525	75.0
	Heptachlor	69	70	72	75	75	66	78	505	72.1
	Lindane	18	20	14	9	8	6	39	114	16.3
	Toxaphene	76	82	89	82	76	71	81	557	79.6
	Check	79	82	87	79	83	85	83	578	82.6
3	Aldrin	76	62	59	69	55	63	73	457	65.3
	Chlordane	67	47	61	55	26	59	57	372	53.1
	DDT	76	83	70	76	77	77	82	541	77.3
	Dieldrin	65	60	70	63	69	86	78	491	70.1
	Heptachlor	77	75	71	74	63	69	72	501	71.6
	Lindane	28	16	11	11	14	21	13	114	16.3
	Toxaphene	78	70	75	70	69	81	72	515	73.6
	Check	83	84	85	83	87	81	88	591	84.4

APPENDIX F

INDIVIDUAL VARIATE COUNTS OF SEED TREATMENT GERMINATION TESTS SHOWING NUMBER OF PLANTS EMERGING FROM 100 TREATED TURNIP SEEDS

Rate	Treatment	replicates 1	2	3	4	5	6	7	Total	Average
1	Aldrin	72	90	82	84	51	72	88	539	77.00
	Chlordane	80	80	59	74	51	84	82	510	72.86
	DDT	90	87	82	85	69	85	88	586	83.71
	Dieldrin	90	91	87	66	76	81	84	575	82.14
	Heptachlor	81	84	76	85	66	85	79	556	79.43
	Lindane	81	69	76	78	82	76	64	526	75.14
	Toxaphene	93	83	82	86	52	88	87	571	81.57
	Check	93	93	89	89	81	85	92	622	88.86
2	Aldrin	89	78	90	89	81	79	92	598	85.43
	Chlordane	78	77	60	72	75	80	70	512	73.14
	DDT	94	94	81	87	87	94	89	626	89.43
	Dieldrin	77	81	77	72	86	85	63	541	77.29
	Heptachlor	80	71	77	65	68	74	78	511	73.00
	Lindane	56	78	28	11	56	65	58	352	50.29
	Toxaphene	84	81	77	89	82	79	91	583	83.29
	Check	92	99	91	87	93	96	92	650	92.86

APPENDIX G

INDIVIDUAL VARIATE COUNTS OF GREENHOUSE FURROW TREATMENT GERMINATION TESTS SHOWING NUMBER OF PLANTS EMERGING FROM 100 TREATED ONION SEEDS

Rate	Treatment	replicates 1	2	3	4	5	6	7	Total	Av.
1*	Aldrin (W)	10	13	29	17	16	14	8	107	15.3
	Aldrin (G)	16	15	12	32	14	14	26	129	19.9
	Dieldrin (W)	84	84	75	77	94	85	91	590	84.3
	Heptachlor (W)	61	56	40	72	43	63	55	390	55.7
	Heptachlor (G)	26	10	19	19	12	22	12	120	17.1
	Malathion (D)	89	66	68	70	76	81	84	534	76.3
	Toxaphene (D)	53	38	66	72	58	58	88	433	61.9
	Toxaphene (G)	65	58	45	59	51	62	53	391	55.9
	Check	95	96	85	89	71	80	88	604	86.3
2**	Aldrin (W)	0	0	0	0	0	0	0	0	0.0
	Aldrin (G)	1	0	0	0	0	0	0	1	0.14
	Dieldrin (W)	41	50	22	43	35	42	22	255	36.4
	Heptachlor (W)	2	0	5	0	0	0	0	7	1.0
	Heptachlor (G)	0	0	1	0	5	2	0	8	1.1
	Malathion (D)	29	0	0	1	1	3	0	34	4.9
	Toxaphene (D)	11	0	3	1	1	2	0	18	2.6
	Toxaphene (G)	0	3	0	1	1	0	0	5	0.7
	Check	92	87	75	90	92	86	80	602	86.0

* 0.1 lb./1,000 row feet
** 0.3 lb./1,000 row feet

APPENDIX H

INDIVIDUAL VARIATE COUNTS OF GREENHOUSE FURROW TREATMENT GERMINATION TESTS SHOWING NUMBER OF PLANTS EMERGING FROM 100 TREATED TURNIP SEEDS

		replicates								
Rate	Treatment	1	2	3	4	5	6	7	Total	Av.
	Aldrin (W)	27	20	64	32	13	44	25	225	32.1
	Aldrin (G)	79	93	85	98	88	85	89	617	88.1
	Dieldrin (W)	97	88	100	90	88	94	81	658	91.1
	Heptachlor(W)	76	89	87	83	63	83	88	569	81.3
1*	Heptachlor (G)	27	35	4	23	9	1	7	106	15.1
	Malathion (D)	50	38	59	79	42	61	62	391	55.9
	Toxaphene (D)	88	89	84	89	84	83	75	592	84.6
	Toxaphene (G)	90	92	79	96	67	91	91	606	86.6
	Check	94	96	96	94	94	96	92	662	94.6
	Aldrin (W)	22	4	26	41	1	25	13	132	18.9
	Aldrin (G)	71	80	96	99	78	76	90	590	84.3
	Dieldrin (W)	82	77	86	97	86	87	93	608	86.9
	Heptachlor (W)	75	87	93	91	76	76	96	594	84.9
2**	Heptachlor (G)	1	10	29	9	35	24	17	125	17.9
	Malathion (D)	16	11	40	41	16	17	70	211	30.1
	Toxaphene (D)	87	46	65	99	84	90	68	539	77.0
	Toxaphene (G)	69	44	65	93	69	59	90	482	68.9
	Check	90	97	94	99	94	91	89	654	93.4

* 0.1 lb./1,000 row feet
** 0.3 lb./1,000 row feet