Insecticidal Control of the Sugar-Beet Root Maggot and Yield of Sugar Beets[1]

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ABSTRACT

Two years' results in Manitoba have shown that heptachlor applied at 0.5 to 2 pounds per acre to the seed furrow on ammonium phosphate (11-48-0) reduced the sugar-beet root maggot, *Tetanops myopaeformis* (Roed.), about 80%. Some 20% of the maggots appear to tolerate this 4-fold increase in rate of heptachlor applied. This fact may represent an initial tolerance because heptachlor-fertilizers were used only 1 year prior to the tests reported. Sugar beet yields were increased 1 to 2.4 tons per acre by favoring the production of larger beets, but sugar content was not affected. However, yield was not increased when heptachlor was added at 1 pound per acre to the seed furrow as granules and sidedressed with fertilizer, although effective maggot control was obtained. Diazinon® (*0,0*-diethyl *0*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate) applied at 1 pound per acre to the seed furrow on ammonium phosphate (11-48-0) effectively reduced maggots but was phytotoxic. With the same formulation and rate, phorate and Trithion® (*S*-(*p*-chlorophenylthio)methyl *0,0*-diethyl phosphorodithioate) were not effective.

A direct bioassay did not detect residues of heptachlor, Diazinon, phorate or Trithion in harvested beets. Only a trace (0.01 p.p.m.) of heptachlor epoxide was detected chemically.

Seed treatments with heptachlor, Diazinon, phorate and Trithion were less effective for maggot control and did not increase the yield of sugar beets.

It was shown previously (Allen *et al.* 1959) that heptachlor or aldrin-fertilizer mixtures applied in the seed furrow to give 1 pound of toxicant per acre gave effective control of the sugar-beet root maggot, *Tetanops myopaeformis* (Roed.). The reduction in the number of maggots appeared to be associated with an increase in yield, when beet stands were at least 75% complete.

This paper reports control tests completed at Altona, Manitoba, in 1958 and 1959, with heptachlor and several organic phosphate insecticides. The method of formulation and application of these insecticides are considered in relation to larval control, beet stand, size and yield of beets.

MATERIALS AND METHODS.—Insecticides used for soil and seed treatments were heptachlor, phorate, Diazinon® (*0,0*-diethyl *0*-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothioate), and Trithion® (*S*-(*p*-chlorophenylthio) methyl *0,0*-diethyl phosphorodithioate). For soil treatments fertilizer mixtures were prepared with heptachlor 72% technical, phorate 44% on carbon powder, Diazinon 90% technical and Trithion 50% flowable. For seed treatments heptachlor 40% on talc, phorate 44% on carbon powder, Diazinon 25% wettable and Trithion 50% flowable were applied to seed (Allen *et al.* 1961). Tables 1 and 2 show the formulations, methods and rates at which the actual toxicants were applied in 1958 and 1959.

Plots were arranged in randomized blocks replicated eight times; each plot consisted of four 60-foot rows. Details were given previously on formulation of the fertilizer mixtures, method and rate of seeding, seed treatment with captan and the application of fertilizer (Allen *et al.* 1961).

The maggot infestations were estimated from each plot in mid-September by counting the maggots in 10 soil samples, 8" by 8" and 12" deep. Each sample was taken from the soil directly beneath a beet in the outside rows. In 1959 the beets taken out with each sample were cleaned and weighed to determine size at that time. Each randomized block was sampled in succession.

The yield and number of beets were determined in early October. Two 50-foot areas from the central rows of each plot were harvested and the beets were washed before weighing. Percentage sugar was determined by the Manitoba Sugar Company.

The data on number of maggots per beet, yield, beet number and size were examined by analysis of variance and the multiple range test (Duncan 1955).

In 1958 and 1959 preliminary bioassays were completed after harvest for beets treated with insecticides at 1 or 2 pounds per acre (table 3). The direct method of Sun & Pankaskie (1954) was used. *Drosophila melanogaster* Meig. was cultured on cornmeal-molasses-agar medium at 80 ± 1° F. and all tests were completed at this temperature. Twenty-five beets from treated plots were washed well, quartered and one-quarter from each beet was diced and the sample composited. Five-pound samples were selected and put in polyethylene bags for storage at 40° F. To each 150 grams of beet tissue, 100 ml. of water was added and the tissue macerated. Standards were prepared by adding insecticides at four dosage levels to untreated beets before they were macerated. About 20 grams of macerated beet was placed in 6-ounce jars; 10 male and 10 female, 2-day old CO_2 anaesthetized flies were introduced on paper trays. For each lot of insecticide-treated beets, five samples of beet tissue were assayed. Percentage mortality was calculated by totalling the number of dead flies and those unable to stand. Dosage mortality data were analyzed by the method of Litchfield & Wilcoxon (1949) and the 95% confidence interval of 0.2 LD_{50} was taken as a measure of sensitivity (Sun & Sun 1952) of the method for each insecticide.

In 1959, chemical analyses were completed on heptachlor-treated beets by Velsicol Chemical Corp., Chicago. The samples of beet tissue were divided, one portion was bioassayed and the remainder was analysed for hepta-

[1] Contribution No. 56 from the Canada Department of Agriculture Research Station, Winnipeg, Manitoba. Accepted for publication May 31, 1960.
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[4] The authors gratefully acknowledge assistance from W. B. Fox, Chipman Chemical Company, Winnipeg, Man., for preparing special formulations and from the Velsicol Chemical Corporation, Chicago, Ill., for chemical determination of insecticide residues.

Table 1.—Effect of insecticide, formulation and method of application on average number of root maggots and yield of sugar beets at Altona, Manitoba, 1958.

Insecticides	Toxicant (oz./a.)	Number of: Maggots per Beet[b]	Number of: Beets per 100 Feet of Row	Weight per Beet at Harvest (lb.)	Yield (tons/a.)
Soil treatment[a]					
Heptachlor 1.0%	12.8	4.1±1.0 [c]	80.0	1.5	13.1
1.0%	16	3.8±0.9	70.1	1.8 [d]	13.4
1.25%	16	4.5±0.9	73.0	1.8	13.9 [d]
1.25%	16	4.3±1.0	77.5	1.7	13.9
Diazinon 1.25%	16	3.1±0.9	58.2 [d]	2.1	12.7
Phorate 1.25%	16	10.2±2.5	65.4	1.8	12.3
Seed treatment					
Heptachlor 40%	1	10.8±2.2	83.1	1.4	12.6
Diazinon 25%	1	11.1±2.3	75.9	1.6	13.0
Phorate 44%	1	18.8±3.2	79.4	1.6	14.0
Untreated (fertilizer)	—	19.5±3.7	78.4	1.5	12.1

[a] Details on formulation of fertilizer mixtures as shown Allen *et al.* (1961, table 4).
[b] Mean and 95% confidence interval for 80 beets.
[c] Means not connected by the same vertical line significantly different at 1% level (Duncan 1955).
[d] Means connected by a vertical line significantly different from means of untreated plots at 5% level.

chlor by the method of Ordas *et al.* (1956) and heptachlor epoxide was determined by a tentative method (Velsicol Corp. 1960).

RESULTS AND DISCUSSION.—*Root Maggot Reduction.*—In 1958 and 1959 soil treatments with heptachlor applied as fertilizer mixture (tables 1 and 2) to give 1 pound of toxicant per acre reduced the number of maggots about 78% and 80%, respectively. The method of applying heptachlor to the seed furrow (table 2) did not alter the effectiveness of this insecticide. The result was the same when it was applied as 20% granules or on fertilizers constituted with various solvents (table 1). It is remarkable that dosages of 0.5, 1, 1.5 and 2 pounds per acre of heptachlor applied on fertilizer all gave essentially the same result suggesting that some 20% of the maggots tolerated a 4-fold increase in heptachlor. Furthermore the 95% confidence limits (tables 1 and 2) show that effective insecticides consistently reduced the number of maggots to a low level. This preventive method was designed to treat the soil area surrounding the beets where the egg clutches are laid. Direct evidence of insecticide tolerance is required because we do not know the proportion of young larvae that survive treatment and whether or not the insects are able in some way to avoid the treated area. Heptachlor-fertilizer mixtures were first used for sugar-beet root maggot control in 1957.

Table 2.—Effect of insecticide, formulation and method of application on average number of root maggots and yield of sugar beets at Altona, Manitoba, 1959.

Insecticides	Toxicant (oz./a.)	Number of: Maggots per Beet[a]	Number of: Beets per 100 Feet of Row	Weight per Beet (lb.): September	Weight per Beet (lb.): October	Yield (tons/a.)
Soil treatments[b]						
Heptachlor 2.5%	32	5.8±1.4 [c]	85.0	1.3 [d]	1.4 [d]	12.4 [d]
1.87%	24	5.2±1.5	84.7	1.3	1.4	12.7
1.25%	16	6.3±1.3	87.6	1.3	1.3	12.3
0.62%	8	5.9±1.3	84.2	1.4	1.3	11.9
Heptachlor[e] 1.25%	16	5.1±1.0	89.9	1.2	1.3	12.4
Heptachlor[f] 20%	16	6.6±1.4	92.0 [d]	1.1	1.1	11.2
Trithion 1.25%	16	19.4±3.6	81.9	1.2	1.3	11.4
Untreated (fertilizer)		29.6±4.5	79.1	1.0	1.2	10.3
Seed treatment						
Heptachlor 40%	1	14.4±3.3	84.5	1.2	1.2	11.2
	2	19.1±3.1	87.1	1.3	1.2	11.7
Trithion 50%	1	21.0±3.8	83.1	1.2	1.3	11.4
	2	20.0±3.4	80.7	1.2	1.3	11.0
Phorate 44%	1	22.2±3.4	80.7	1.2	1.2	10.7
Untreated (fertilizer)	—	24.8±4.0	79.7	1.2	1.2	10.2

[a] Mean and 95% confidence interval for 80 beets.
[b] Details on formulation of fertilizer mixtures as shown Allen *et al.* (1961, table 4).
[c] Means not connected by the same vertical line significantly different at 1% level (Duncan 1955).
[d] Means connected by a vertical line significantly different from means of untreated plots at 5% level.
[e] On triple superphosphate, sidedressed with nitrogen.
[f] Granulated insecticide, sidedressed with ammonium phosphate.

Table 3.—Residues of insecticides determined by bioassay and chemical analyses of sugar beets grown in soil treated with fertilizer mixtures.

		Bioassay			Chemical Analyses	
		Per Cent Mortality			1959	
Treatment	Toxicant (lb./a.)	1958	1959	Sensitivity[a] (p.p.m.)	Heptachlor (p.p.m.)	Heptachlor Epoxide (p.p.m.)
Heptachlor	1.0	0.0		0.12– .17		
	1.0	1.0	1.0	0.12– .17	0.01	0.02
	1.0[b]		1.0	0.12– .17	0.01	0.02
	2.0		2.0	0.12– .17	0.01	0.02
Diazinon	1.0	0.0		0.29– .37		
Phorate	1.0	1.0		0.17– .30		
Trithion	1.0		0.0	1.2 –1.9		
Untreated		0.0	0.0		0.01	0.01

[a] 95% confidence interval of 0.2 LD_{50}.
[b] Applied to seed furrow as 20% granules.

Applied as fertilizer mixtures to give 1 pound of toxicant per acre Diazinon and phorate reduced maggots 84% and 48%, respectively, but both were phytotoxic (Allen *et al.* 1961). Trithion was not effective.

In 1958 heptachlor and Diazinon seed treatments at 1 ounce per acre reduced maggots 46% and 43%, respectively. Phorate was not effective. In 1959 heptachlor and Trithion at a 1- or 2-ounce rate and phorate at the 1-ounce rate were not significantly different in number of maggots from untreated plots.

Insecticide Residues.—Preliminary direct bioassay with *Drosophila melanogaster* (table 3) showed that beets treated with heptachlor, Diazinon, phorate or Trithion at 1 pound per acre did not contain detectable residues. In 1959 chemical analyses for heptachlor and heptachlor epoxide supported bioassay evidence that residues were low and only trace quantities of heptachlor epoxide were indicated.

Sugar Beet Yield and Root Maggot Reduction.—Data presented in table 1 show that heptachlor applied in fertilizer mixtures at rates of 0.8 to 1 pound per acre increased yields 1 to 2 tons per acre and significantly reduced the number of maggots. However, the increase in yield was significant at the 5% level for only two of the treatments, and one gave significantly larger beets at harvest. For Diazinon and phorate the increase in beet size resulted from phytotoxicity that significantly altered the stand of beets at harvest.

Data given in table 2 show that heptachlor applied in fertilizer mixtures at rates of 0.5 to 2 pounds per acre increased the yield of beets 1.6 to 2.4 tons per acre. There was a definite association between the number of maggots and beet size measured in mid-September in relation to yield. This was not as clearly shown at beet harvest. Yield was not increased significantly when heptachlor at 1 pound per acre was applied to the seed furrow as granules and fertilizer was side dressed. When heptachlor was similarly applied on triple superphosphate yield was increased but not beet size. A Trithion-fertilizer mixture did not reduce the number of maggots or increase yield.

Seed treatments (tables 1 and 2) with heptachlor, Diazinon and Trithion were not effective in reducing the number of maggots and did not increase the yield of beets. The response to heptachlor seed treatments has not been consistent, although increased yields were previously reported by Gojmerac (1957) and Allen *et al.* (1959). Phorate appeared to increase yield, without causing a reduction of maggots in 1958, but this was not true in 1959.

We conclude that in Manitoba, heptachlor-fertilizer applied to the seed furrow to give 0.5 to 1 pound of toxicant per acre gave effective maggot control. The treatment usually resulted in a significant increase in yield, but the increase in beet size may not always be significant. Diazinon, phorate and Trithion were either too phytotoxic or ineffective and did not increase the yield. The same was true of seed treatments with heptachlor, Diazinon, phorate and Trithion which are ineffective.

It is noteworthy that, for the untreated plots in 1959, the correlation between the number of maggots and weight per beet in mid-September was −0.184, significant at the 1% level.

However, many agronomic factors affect the growth of sugar beets and there is evidence that yield is influenced by the type of fertilizer, its placement (Schmehl *et al.* 1952), or the stands established after thinning (Eckroth and Cormany 1957). Accordingly, in spite of effective maggot control, a fertilizer effect may account for the fact that heptachlor applied as granules in the furrow, with ammonium phosphate sidedressed, did not increase the yield; whereas the same quantity of insecticide similarly applied on triple superphosphate, sidedressed with nitrogen gave a significant increase in yield.

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