Effect of Insecticides and Herbicides on Sugarbeet Establishment, Yield and Control of the Sugarbeet Root Maggot*

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INTRODUCTION

The sugarbeet root maggot, *Tetanops myopaeformis* (Roder), can be a serious problem in sugarbeet production areas of Western Canada (2,5) and the United States (9,10,13). Infestations of the sugarbeet root maggot are sporadic and, during years of severe infestations, can reduce sugarbeet yield by over 50%.

The biology of the sugarbeet root maggot has been reviewed by Hawley (7), Knowlton (8), Harper (6), and Whitfield (11). Whitfield et al. (12) published a bibliography that included papers on the control of the sugarbeet root maggot. Use of chemical insecticides is the only satisfactory method of reducing damaging populations. Harper (6) reported that the sugarbeet root maggot adult lays its eggs close to the root of the young plant, and thus a practical, effective, and economical method of controlling this pest has consisted of applying granular insecticides into the seed furrow at planting time to kill the newly emerged larvae (2,5). It is known that some insecticides applied close to the seed may be phytotoxic (1,2,5). In this paper, we report on a series of field experiments conducted between 1970 and 1982 to evaluate the insecticidal and phytotoxic properties of several granular insecticides applied in-furrow, and the interaction of several of these with commonly used soil-applied herbicides.

MATERIALS AND METHODS

The following granular insecticides were included in the experiments: Temik 10G (aldicarb), Furadan 10G (carbofuran), Lorsban 15G (chlorpyrifos), CGA 12223 5G(O-

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(5-chloro-1-isopropyl-1,2,4-triazol-3-yl)O,O-diethyl-phosphorothioate), Basudin 5G (diazinon), Dasanit 15G (fensulfothion), Dyfonate 10G (fonofos), Bay 92114 10G (isofenphos), Counter 15G (terbufos), heptachlor 5G, Trithion 10G (carbophenothion), and Ofunack 10G (pyridaphenthion). A tractor-mounted, modified-cone metering device was used to accurately dispense preweighed quantities of insecticides. All insecticides were applied in the seed furrow as it closed in such a manner that some soil fell onto the seed first. This ensured that the insecticides were directly above but not in direct contact with the beet seed. The soil was then firmed by the planter press-wheels. Several tines, which were adjusted to penetrate the firmed soil to a depth of 1 cm, were used to create a fine granular soil mulch that reduced soil crusting and contributed to better beet emergence. Monogerm seed (CS-43 in 1970-75 and Primahill in 1982) was planted at a depth of 3.5 cm and a row spacing of 56 cm. Experiments conducted in 1970, 1971 and 1982 were irrigated with overhead sprinklers and experiments conducted in 1973 and 1975 were furrow-irrigated.

For those experiments that were harvested, all beets from the center two rows of each plot or sub-plot were topped and lifted by machine. In the laboratory the beets were washed and weighed. A multi-saw rasp was used to obtain samples of beet root brei from each plot for use in percent sugar determination. All harvested beets from each plot were rated for damage based on methods described by Yun (13) according to the following categories: 1 = no damage; 2 = light damage (< 3 small feeding scars); 3 = moderate damage (< ½ root area scarred); 4 = heavy damage (½ to all of root area scarred); 5 = severe damage. Beets killed by the root maggot during the growing season were not included in the rating as this damage was reflected in the plant stand loss observed between plant establishment and harvest.

Insecticide Efficacy Trials

Beets were planted at Cranford, Alberta, into a loam soil on 13 May 1970 on a field that had been planted to sugarbeets every third year for many years and had been treated with heptachlor each time beets were planted since 1958 for control of the sugarbeet root maggot. Treatment plots were replicated eight times and were four rows wide and 15 meters long with a 5-cm seed spacing. After seedling emergence the plant stand was reduced by manual thinning. Plant stand was determined before thinning, after thinning, and at harvest. The beets were harvested on 8 October and yield, percent sugar content, and root damage by the sugarbeet root maggot were determined.

Sugarbeets were planted at a 13-cm seed spacing into a sandy loam soil at Taber, Alberta, on 10 April and 3 May 1973. For both planting dates the plots were four rows wide, 8 meters long and treatments were replicated 10 times. Plant stand was determined at seedling emergence and at harvest on 26 September by counting all plants in the center two rows.

On 29 May 1975, sugarbeets were planted at a 15-cm seed spacing into a sandy loam soil at Taber, Alberta. Plots were four rows wide, 8 m long and treatments were replicated 10 times. Plant stand was recorded as described above and all plots were harvested on 1 October.

Insecticide-Herbicide Interaction Trials

Field trials were designed to measure the interaction between several insecticides and the most common commercial soil-applied herbicides used in sugarbeets. On 7 May 1971, sugarbeets were planted at Cranford into a loam soil in a split-plot design with eight replications. Insecticide treatments constituted the main plots (eight rows wide and 15 m long) and the herbicide treatments the subplots (four rows wide). Herbicide treatments included a control with no herbicide and a tank-mix of Ro-Neet 72EC (cycloate) and Avadex 40EC (diallate) at 3 and 1 kg ai/ha, respectively, in 450 liters of water per hectare (broadcast basis). The herbicide treatments were applied to the soil in an 18-cm wide band and immediately incorporated to a depth of 4 cm with a power take-off driven rototiller.

The treated soil was then lightly packed using press-wheels and beet seeds were planted 8 cm apart in the center of the herbicide-treated band. All operations were performed at the same time with tractor-mounted equipment. After seedling emergence, plant stand was recorded and plots were thinned by hand. All plots were harvested on 21 September.

In another experiment, a split-plot design with eight replications was planted in a loam soil at Taber, Alberta, on 5 May 1982. The seven main plots consisted of three herbicide treatments, each at two rates. These were Nortron 18EC (ethofumesate) at 3.5 and 4.7 kg/ha, Pyramin 47FL (pyrazon) at 4.36 and 5.83 kg/ha, the tank-mix of ethofumesate and cycloate at 2.64 + 3.17 kg/ha and 3.52 + 4.22 kg/ha, respectively, and an untreated control. Each main plot consisted of three two-row sub-plots 8 meters long: one sub-plot received the herbicide only; the second sub-plot received both the herbicide and insecticide, and the third sub-plot received neither. Herbicides were applied the previous fall on 13 November 1981. A method of fall ridging was used whereby the herbicides were sprayed onto an 18-cm wide band of level moist soil at ca. 1 cm below ground level and immediately covered with a ridge of soil. The herbicides were applied with flat fan nozzles in 450 liters of water per hectare (broadcast basis). The following spring the ridge of soil was removed to ca. 2 cm above original ground level. On 5 May 1982 beet seed was planted at a spacing of 15 cm into the center of this herbicide-treated band of soil. The granular insecticides were applied as described above. This experiment was not harvested but plant stand was recorded in each of the sub-plots on 12 July.

RESULTS AND DISCUSSION

Insecticide Efficacy Trials

The insecticides varied in their effect on stand establishment (Tables 1-5). In plots treated with pyridaphenthion, plant establishment was the least affected and for those treated with fonofos, seedling emergence was the lowest. Although not all of the insecticides were included in each of the experiments, they were ranked for phytotoxicity by determining the percent reduction in plant establishment compared with the control for each test that the treatment was included. This value is given in brackets for the following insecticides and an asterisk is used to indicate that the reduction in stand was statistically significant ($P = 0.05$): pyridaphenthion (1), carbophenothion (19*,14*,3,1,0), carbofuran (17*,14,9,6,6,6), chlorpyrifos (10), isophenphos (10*), aldicarb (24*,11*,11,10,3), terbufos (37*,22*), heptachlor (54*), fensulfothion (56*), CGA 12223 (64*), diazinon (75*57*), and fonofos (94*,86*). These results indicate that the insecticides differ greatly in their effect on plant establishment, the majority of those tested being very phytotoxic and thus unacceptable for use in this manner.

Of the insecticides commercially available, only aldicarb and carbofuran, which generally exhibited a low level of phytotoxicity, can be recommended for use in sugarbeets in Alberta when applied as a granular treatment in the seed furrow during planting. In similar experiments conducted in Manitoba in 1971 and 1973, Askew et al. (3) reported no phytotoxic effects from aldicarb, carbofuran, terbufos and fonofos. The same sugarbeet cultivar was used in the Alberta and Manitoba studies, and the insecticide application techniques used were very similar. Although the phytotoxicity of terbufos and fonofos in our experiments cannot be explained on the basis of available data, it is suspected that differences in climate and soil type between southern Alberta and Manitoba may be responsible. For example, southern Alberta is semi-arid and production of sugarbeets is made possible only through irrigation, whereas production of sugarbeets in the Red River valley of Manitoba occurs under conditions of natural rainfall without the need for irrigation. In addition, soils in Manitoba generally have a lower pH and are less saline than soils of southern Alberta.

Efficacy of insecticides for root maggot control was assessed by rating root maggot damage, recording the reduction in plant stand after establishment, and by recording beet yield and percent sugar at harvest. Root maggot damage ratings and reduction in stand during the growing season are satisfactory indicators of maggot control. However, overall efficacy of an insecticide treatment can best be evaluated when root yield and sugar content are also considered. The latter two factors are a direct measure not only of root maggot larval mortality but also be of phytotoxicity by the treatment being evaluated. Not all insecticides were included in each experiment but they can be ranked by their effect on beet yield by determining percent yield at harvest compared with the untreated control. These values are presented in brackets and are in order of highest to lowest yield for each year that a treatment was tested. An asterisk indicates that the effect on yield was significant (P = 0.05): carbofuran (380*,331*150*,136*,98), aldicarb (365*,350*147*,96), carbophenothion (345*,328*,143*,123*, 101), fensulfothion (111*), diazinon (134*,65*), heptachlor (99), Bay 92114 (96), pyridaphenthion (96), terbufos (89*), CGA 12223 (58*), fonofos (75,36*). The treatments that resulted in significant reductions in beet yield also tended to result in significant reductions in percent sugar.

All the treatments in 1970 and 1973 with the exception of heptachlor resulted in significant reductions in root maggot damage (Table 1,2). Heptachlor was the first in-

Table 1. Efficacy of various insecticides in controlling the sugarbeet root maggot at Cranford, Alberta, 1970.

Insecticide	Rate (kg ai/ha)	No. of beets[a] Emerg.	Thin.	Har.	Damage rating	Sugar (%)	Beets (t/ha)
Carbofuran	0.84	131	63	62	1.08	16.21	45.24
Carbophenothion	1.12	128	63	62	1.40	16.03	43.09
Diazinon	1.12	39	45	45	1.14	15.72	40.72
Fensulfothion	1.12	69	31	31	1.18	14.97	33.36
Heptachlor	1.12	73	48	44	3.71	15.26	29.70
Untreated	-	159	65	55	3.88	15.11	30.08
L.S.D. (P = 0.05)		5	5	5	0.40	0.43	3.21

[a]Number of beets x 1000 = plants per hectare.

Table 2. Efficacy of various insecticides on two dates of planting in controlling the sugarbeet root maggot at Taber, Alberta, 1973.

Insecticide	Rate (kg ai/ha)	No. of beets[a] May	No. of beets[a] Sept.	Damage rating	Sugar (%)	Beets (t/ha)
Planted - April 10						
Aldicarb	1.12	66	65	1.22	16.04	56.85
Carbofuran	0.84	64	62	1.20	16.03	53.71
Carbophenothion	1.12	67	66	1.26	16.24	53.22
Fonofos	1.12	8	8	1.68	12.77	12.13
Untreated	-	68	25	3.24	13.73	16.23
L.S.D. (P = 0.05)		7	8	0.54	0.69	7.08
Planted - May 3						
Carbofuran	0.84	69	67	1.17	15.87	52.79
Aldicarb	1.12	68	67	1.23	16.30	50.73
Carbophenothion	1.12	65	62	1.27	16.20	47.84
Fonofos	1.12	4	4	1.44	11.89	4.98
Untreated	-	76	22	3.25	13.67	13.88
L.S.D. (P = 0.05)		9	8	0.38	0.50	4.62

[a]Number of beets x 1000 = plants per hectare.

secticide to be recommended for control of the sugarbeet root maggot in Alberta but it has not been used since the early 1960's. It appears that it is now no longer effective in controlling root maggot populations in sugarbeets.

In the 1971 experiment, all treatments had significantly greater yield than the untreated and, except for carbophenothion, percent sugar content at harvest (Table 4). There were no significant differences in root maggot damage among treatments or the control. In 1970 and 1973, all treated plots with the exception of those treated with fonofos and fensulfothion resulted in significantly higher yields and sugar content than the untreated control (Tables 1,2).

Root maggot infestation was very light in the 1975 experiment (Table 3). The results are therefore mostly a measure of phytoxicity among treatments. Results indicate that in the absence of a root maggot infestation the application of potentially phytotoxic insecticide treatments may reduce yield and percent sugar content significantly.

Owing to the short growing season, growers of southern Alberta are advised to plant early and maintain adequate

Table 3. Efficacy of various insecticides in controlling the sugar-beet root maggot at Cranford, Alberta, 1975.

Insecticide	Rate (kg ai/ha)	No. of beets[a] June	No. of beets[a] Oct.	Damage rating	Sugar (%)	Beets (t/ha)
Carbophenothion	1.12	60	59	1.08	13.93	38.42
Carbofuran	0.84	55	54	1.05	13.87	37.55
Aldicarb	1.12	52	51	1.05	13.96	36.88
Isofenphos	1.12	53	52	1.03	13.72	36.81
Ofunack	1.12	58	56	1.07	13.82	36.65
Terbufos	1.12	46	44	1.03	13.70	34.01
Diazinon	1.12	25	25	1.02	13.24	24.91
CGA 12223	1.12	21	21	1.02	13.02	22.12
Untreated	--	59	58	1.12	13.91	38.33
L.S.D. (P = 0.05)		5	5	0.05	0.24	2.71

[a]Number of beets x 1000 = plants per hectare.

soil moisture for rapid beet establishment and growth to maximize yields. This practice normally contributes to a reduction in stand loss and yield loss caused by root maggot feeding. The results of the 1973 experiment indicate that insecticide treatments applied with early planting are as effective in controlling the maggots as the same treatments applied with late planting.

Insecticide-Herbicide Interactions

The effect of herbicides and their interaction with several insecticides in 1971 indicated that there was no interaction between the insecticides aldicarb, carbofuran, and carbophenothion and the herbicides cycloate and diallate (Table 4). In the 1982 study of the interaction between four insecticides (aldicarb, carbofuran, chlorpyrifos, and terbufos) and three herbicides (cycloate, ethofumesate, and pyrazon), root maggot infestation was low and the herbicides did not result in a reduction in beet stand establishment, nor was there a herbicide-insecticide interaction for phytotoxicity (Table 5). The insecticide treatments resulted in an average stand reduction of 15% with terbufos consistently being the most phytotoxic. These results are consistent with those observed in the experiments described above where application of some granular insecticides was shown to reduce plant stand over control plots when root maggot infestations were low.

Table 4. Effect of insecticide and herbicide treatments on stand, maggot damage, sugar content, and yield at Cranford, Alberta, 1971.

Insecticide	Rate (kg ai/ha)	No. of beets[a] Emerg.	Thin.	Har.	Damage rating	Sugar (%)	Beets (t/ha)
Aldicarb	1.12	69	59	59	1.37	16.82	30.24
Carbofuran	0.84	85	72	71	1.46	16.76	27.95
Carbophenothion	1.12	88	72	70	1.61	16.56	25.26
Untreated	-	91	75	69	1.49	16.39	20.51
L.S.D. (P = 0.05)		8	5	5	0.19	0.24	2.24
No herb. (all insect.)		79	67	65	1.62	16.57	24.77
Herb. (all Insect.)		82	69	67	1.54	16.57	26.13
Level of significance		.05	0.05	ns	0.01	ns	0.01

[a]Number of beets x 1000 = plants per hectare.

Sugarbeet growers are advised to apply available registered granular insecticides (aldicarb, carbofuran, terbufos) only when heavy infestations are expected and to apply them in the manner that minimizes phytotoxicity (4). The high phytotoxicity of terbufos requires extra caution during application.

CONCLUSIONS

The sugarbeet root maggot can severely damage the sugarbeet crop and significantly reduce the yield and sugar content when high infestations occur. Insecticides that were found to provide adequate root maggot control ranged from light to severe in phytotoxicity to the sugarbeet plant and therefore should be used only when root maggot infestations deem it necessary.

Aldicarb and carbofuran when applied as modified in-furrow at-planting treatments at 1.12 and 0.84 kg ai/ha, respectively, consistently provided good control of the sugarbeet root maggot, and resulted in an increased sugar content and greater beet yield compared with the control. There were no adverse interactions between the insecticides examined and the soil-applied herbicides used on sugarbeets in Alberta.

Table 5. Effect of insecticides and herbicides on sugarbeet stand establishment at Taber, Alberta 1982, a) for each insecticide and each herbicide, b) for each insecticide and all herbicides.

				Number of plants[a]		
Herbicide	Rate (kg ai/ha)	Insecticide	Rate (kg ai/ha)	Control	Herbicide	Herb + insect.
a) Each insecticide with each herbicide treatment						
Ethofumesate	4.70	Aldicarb	1.12	63	70	58
		Terbufos	1.13	59	56	47
		Carbofuran	0.84	62	63	48
		Chlorpyrifos	1.12	51	53	49
Pyrazon	5.82	Aldicarb	1.12	61	66	51
		Terbufos	1.12	61	61	40
		Carbofuran	0.84	62	60	50
		Chlorpyrifos	1.12	58	61	55
Ethofumesate	3.52	Aldicarb	1.12	59	57	52
+ Cycloate	4.22	Terbufos	1.12	58	53	32
		Carbofuran	0.84	61	54	46
		Chlorpyrifos	1.12	62	58	51
Ethofumesate	3.50	Aldicarb	1.12	55	62	61
		Terbufos	1.12	60	64	38
		Carbofuran	0.84	55	55	51
		Chlorpyrifos	1.12	54	54	45
Pyrazon	4.36	Aldicarb	1.12	58	54	53
		Terbufos	1.12	55	54	26
		Carbofuran	0.84	51	48	37
		Chlorpyrifos	1.12	60	58	54
Ethofumesate	2.64	Aldicarb	1.12	60	58	51
+ Cycloate	3.17	Terbufos	1.12	64	68	36
		Carbofuran	0.84	56	64	52
		Chlorpyrifos	1.12	52	50	47
Untreated		Aldicarb	1.12	59	61	55
		Terbufos	1.12	62	63	42
		Carbofuran	0.84	66	64	60
		Chlorpyrifos	1.12	63	65	58
L.S.D. (P = 0.05) (Among insecticides with same herbicide)				ns	ns	15
b) Each insecticide and all herbicide treatments						
All		Aldicarb	1.12	59	61	54
All		Terbufos	1.12	60	60	38
All		Carbofuran	0.84	60	59	50
All		Chlorpyrifos	1.12	58	58	52
L.S.D. (P = 0.05)				ns	ns	5

[a]Number of beets x 1000 = plants per hectare.

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