EFFICACY OF SEVERAL ORGANOPHOSPHORUS COMPOUNDS AGAINST CYCLODIENE-RESISTANT ONION MAGGOTS[1]

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Introduction

Investigations in 1955 and 1956 (Finlayson *et al.*, 1959) demonstrated that some degree of resistance had developed which allowed the onion maggot, *Hylemya antiqua* (Meig.), to inflict serious damage in Washington and Idaho. Crops in Oregon and British Columbia were not affected. By 1957, however, the condition had become general across the continent. Laboratory experiments showed that strains of the onion maggot resistant to cyclodiene organochlorine insecticides had developed independently in almost all areas of its economic distribution in North America (Elmosa *et al.*, 1959; McClanahan *et al.*, 1959; Howitt, 1958; and Crowell and Terriere, 1959).

Preliminary experiments in 1958 indicated that certain organophosphorus compounds would control resistant strains in British Columbia. However, some formulations of these insecticides caused severe phytotoxicity. The following experiment was designed to compare the effectiveness of the organophosphorus compounds, carbophenothion (Trithion), diazinon, and ethion, with that of endrin, the recommended insecticide (Finlayson *et al.*, 1959).

Materials and Methods

The experiment was conducted at 4 localities in British Columbia; on sandy clay loam at Kamloops, North Kamloops, and Kelowna and on peat at Kelowna. The design was a 5 x 5 latin square. Each plot was split into 3 sub-plots consisting of seed treatments with wettable powders at 1 oz of toxicant per lb of seed and furrow treatments with granular formulations at 1 and 2 lb of insecticide per acre. Half of each sub-plot received additional treatments with the fungicide captan. The materials, methods and rates of application are given in Table 1. The untreated plots consisted of 6 rows: 2 untreated, 2 in which the seed was treated with captan at 2 oz per lb of seed, and 2 in which captan was applied to the furrow at 2 lb per acre. Furrow treatments were applied by placing the chemicals in the V-belt of the seeder in contact with the seed; seed treatments were applied after the seed had been moistened with 5 per cent Methocel solution for a sticker. Seed of the variety Yellow Globe Danvers was sown at 6 lb per acre with 16-inch spacing between rows.

The effects of the insecticides were measured in three ways: by counting the number of seedlings which emerged, by assessing at weekly intervals the percentage of emerged plants that were damaged, and by weighing the yields of undamaged bulbs at harvest. Data were collected from 20 feet of row of each treatment for each of the 5 replicates at all locations.

Results

Effect on plants—Although the organophosphorus (OP) insecticides did not appear to affect the onion seedlings once they were above ground, some treatments significantly reduced the numbers which emerged (Table 2). This was more noticeable in loam soils than in peat and especially in plots treated with diazinon. Even in peat both diazinon seed treatments resulted in significantly fewer seedlings than the untreated check. In the loam soils, 17 of the 18 treatments with diazinon resulted in considerable reduction. Carbophenothion furrow treatments in particular, applied at 1 and 2 lb

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[1] Contribution No. 90, Research Station, Research Branch, Canada Department of Agriculture, 6660 N.W. Marine Drive, Vancouver 8, B.C. from a thesis submitted to the University of Western Ontario in partial fulfilment of the requirements for the Ph.D. degree.

TABLE 1—Materials, methods and dosage used to assess organophosphorus insecticides at Kamloops, North Kamloops and Kelowna, B.C., 1959.

Treatment[3]			Application[4]	Formulation rate[1] oz Per lb seed Insecticide	Per lb seed Captan[2]	Per 1000 row-feet Insecticide	Per 1000 row-feet Captan[2]
Carbo-phenothion	25	WP	S	4.0	—	—	—
	25	WP	S	4.0	4.0	—	—
	5	G	F	—	—	10.0	—
	5	G	F	—	—	10.0	2.0
	5	G	F	—	—	20.0	—
	5	G	F	—	—	20.0	2.0
Diazinon	25	WP	S	4.0	—	—	—
	25	WP	S	4.0	4.0	—	—
	2.5	G	F	—	—	19.5	—
	2.5	G	F	—	—	19.5	2.0
	2.5	G	F	—	—	39.0	—
	2.5	G	F	—	—	39.0	2.0
Endrin	25	WP	S	4.0	—	—	—
	25	WP	S	4.0	4.0	—	—
	2	G	F	—	—	24.5	—
	2	G	F	—	—	24.5	2.0
	2	G	F	—	—	49.0	—
	2	G	F	—	—	49.0	2.0
Ethion	50	WP	S	2.0	—	—	—
	50	WP	S	2.0	4.0	—	—
	5	G	F	—	—	10.0	—
	5	G	F	—	—	10.0	2.0
	5	G	F	—	—	20.0	—
	5	G	F	—	—	20.0	2.0
Captan	50	WP	S	—	4.0	—	—
	50	WP	F	—	—	—	2.0
Untreated			—	—	—	—	—

[1] Based on 16-inch rows.
[2] Captan applied at 2.0 oz/lb with seed, or 2.0 lb/acre in the furrow.
[3] Figures=percent toxicant; WP=wettable powder; G=granules.
[4] S=seed treatment; F=furrow treatment.

per acre with the fungicide captan, resulted in much better seedling emergence than that in the checks. In general, seed treatments reduced the number of seedlings.

Effect on damage— The rounded averages of percentage damage where no chemicals were applied show that the populations were heavy. These were as follows: Kelowna (clay loam), 67; Kelowna (peat), 79; Kamloops (sandy clay loam), 88; and North Kamloops (clay loam), 98 per cent. These contrast with reductions to very low levels with OP chemicals (Table 3).

Although the insecticdal treatments at all the sites allowed significantly less damage than the untreated checks, there were still considerable variations between treatments. The relative ineffectiveness of endrin is marked.

The average percentage damage allowed by the various treatments at all sites, regardless of method and rate of application was as follows: diazinon, 1.2; ethion, 3.2; carbophenothion, 3.7; endrin, 20.8; captan alone on the seed, 56.3; captan alone in the furrow, 61.7; and the untreated checks, 83.2.

TABLE 2.—Average number of emergent seedlings in 20 row-feet of onions from seed after various treatments against the onion maggot, **Hylemya antiqua** (Meig.), at several locations in British Columbia, 1959.

Treatment oz tox./lb seed or lb tox./A	Application[1]	Average emergent seedlings North Kamloops (loam)	Kamloops (loam)	Kelowna (loam)	Kelowna (peat)
Carbophenothion					
1	S	154	163	157	189
1	S & C	145	167	143	315
1	F	230	212	265	299
1	F & C	243	299	321	315
2	F	204	212	285	320
2	F & C	269	277	311	329
Diazinon					
1	S	147	121	57	217
1	S & C	117	79	87	198
1	F	110	119	76	292
1	F & C	141	161	98	318
2	F	100	44	38	254
2	F & C	83	78	63	270
Endrin					
1	S	150	165	188	232
1	S & C	176	146	199	247
1	F	178	182	147	308
1	F & C	184	170	186	333
2	F	139	149	110	295
2	F & C	158	166	141	315
Ethion					
1	S	151	196	129	260
1	S & C	145	170	122	260
1	F	212	227	252	303
1	F & C	222	296	255	323
2	F	179	184	170	315
2	F & C	213	240	221	309
Captan	S	160	211	247	257
Captan	F	233	246	326	317
Untreated		212	235	288	301
Diff. necessary for significance at 5%		62	59	54	63

[1] S = seed treatment; F = furrow treatment; C = captan, at 2 oz/lb seed or 2 lb/A in furrow.

Effect on yield— Onion seed is normally sown at 4 lb per acre. In these experiments the seed was sown at 6 lb because diazinon had already been shown to reduce germination. The distance between rows remained 16 inches. The increased numbers of seedlings which emerged made it necessary to thin the rows. Thus, although diazinon may have reduced the emergent seedlings by 25 to 50 per cent, the stands remaining had heavy yields of marketable onions.

The untreated checks produced very low yields. There was little difference in yield between the various organophosphorous treatments. In the peat soil at Kelowna 14 out of 18 treatments resulted in significantly higher yields of onions than the untreated checks. There were no significant differences in yield between any of the treatments at this site.

Discussion

The OP insecticide diazinon reduced the number of emergent onion seedlings significantly and more than any other insecticide used. On peat soil, however, the difference was not great. Howitt (1958) reported that the stand was reduced only when diazinon was applied in the furrow at rates in excess of 1 lb per acre. Although the numbers of emergent seedlings were clearly reduced in our experiments, the severe phytotoxic symptoms with lindane reported previously (Finlayson, 1952, 1957) were never observed. Greenhouse experiments and petri-dish tests with diazinon have since shown that germination is not reduced directly by seed treatment. It may be, therefore, that under the field conditions prevailing in the mineral soils, there was some reaction that inhibited germination.

The field experiments with OP insecticides took place in a season of great and continuing abundance of *H. antiqua*. The first generation produced at least 2 additional destructive generations despite being reduced in June by a fungus disease (probably *Empusa muscae* Cohn; Miller and McClanahan, 1959; Perron and Crete, 1960). Nevertheless, the 3 organophosphorus insecticides, carbophenothion, diazinon, and ethion, gave economic control of the onion maggot regardless of method and rate of application.

Compensating for the reduction in stand known to occur with diazinon by sowing more seed made it necessary to thin large numbers of seedlings to allow proper sizing of the bulbs, but treatments having many

TABLE 3.—Average percentage damage in 20 row-foot of onions from seed after various treatments against the onion maggot, **Hylemya antiqua** (Meig.), at several locations in British Columbia, 1959.

Treatment oz tox./lb seed or lb tox./A	Application[1]	Percentage damage			
		North Kamloops (loam)	Kamloops (loam)	Kelowna (loam)	Kelowna (peat)
Carbophenothion					
1	S	6.4	1.0	0.1	1.9
1	S & C	5.8	2.6	0.0	6.6
1	F	6.9	1.4	0.7	9.3
1	F & C	14.0	1.2	0.7	6.7
2	F	6.0	1.0	0.3	3.2
2	F & C	5.5	1.2	0.6	3.6
Diazinon					
1	S	2.2	0.7	0.9	0.8
1	S & C	5.0	1.4	2.2	1.0
1	F	3.1	0.4	0.0	0.8
1	F & C	0.5	0.1	0.0	0.5
2	F	1.1	1.9	1.8	0.5
2	F & C	0.8	0.7	1.0	1.2
Endrin					
1	S	78.5	62.5	34.0	38.6
1	S & C	62.7	43.7	14.4	35.0
1	F	41.2	29.6	4.9	11.1
1	F & C	37.6	23.8	4.8	9.1
2	F	24.0	14.2	3.6	7.2
2	F & C	33.1	20.6	1.7	7.9
Ethion					
1	S	5.8	1.0	1.3	3.2
1	S & C	6.8	2.6	1.3	11.9
1	F	5.1	1.3	1.0	2.3
1	F & C	7.1	1.0	2.7	4.2
2	F	2.9	0.8	0.8	1.9
2	F & C	2.1	1.0	0.4	2.3
Captan	S	83.7	65.9	25.9	49.8
Captan	F	95.4	62.4	29.3	69.9
Untreated		98.3	87.7	67.2	79.0
Diff. necessary for significance at 5%		11.0	17.3	5.1	15.7

[1] S=seed treatment; F=furrow treatment; C=captan at 2 oz/lb seed or 2 lb/A in furrow.

TABLE 4.—Average marketable yield of 20 row-feet of onions from seed after various treatments against the onion maggot, **Hylemya antiqua** (Meig.), at several locations in British Columbia, 1959.

Treatment oz tox./lb seed or lb tox./A	Application[1]	Yield, lb North Kamloops (loam)	Kamloops (loam)	Kelowna (loam)	Kelowna (peat)
Carbophenothion					
1	S	19.9	11.3	10.8	12.9
1	S & C	20.5	12.3	10.8	13.9
1	F	18.7	13.8	10.5	14.5
1	F & C	18.3	15.8	11.0	11.3
2	F	18.8	11.6	11.3	15.5
2	F & C	21.9	14.9	10.6	15.9
Diazinon					
1	S	24.0	14.5	6.4	14.3
1	S & C	20.9	9.2	7.8	16.9
1	F	25.0	16.1	9.6	15.0
1	F & C	24.2	17.6	10.4	15.7
2	F	20.3	6.7	5.5	13.3
2	F & C	19.0	9.6	6.5	14.4
Endrin					
1	S	8.9	4.2	11.5	10.5
1	S & C	12.9	6.1	13.6	11.7
1	F	20.0	10.9	11.4	13.7
1	F & C	21.5	8.8	9.8	15.0
2	F	21.5	12.1	9.8	16.2
2	F & C	20.7	12.3	10.8	14.3
Ethion					
1	S	19.0	13.9	11.3	13.5
1	S & C	20.9	14.2	10.6	14.6
1	F	19.6	14.2	12.3	15.3
1	F & C	20.5	12.7	12.6	13.0
2	F	17.4	14.7	11.7	12.4
2	F & C	18.6	12.6	12.9	14.0
Captan	S	6.0	3.8	12.0	8.2
Captan	F	2.2	5.4	11.0	7.1
Untreated		1.1	2.1	3.7	3.8
Diff. necessary for significance at 5%		5.7	6.9	4.3	9.4

[1] S = seed treatment; F = furrow treatment; C = captan at 2 oz/lb seed or 2 lb/A in furrow.

emergent seedlings produced no greater yields than those with fewer. Inhibition of germination and emergence is still a factor to be reckoned with in using diazinon.

Endrin was comparatively ineffective allowing damage as high as 73.5 per cent at 1 oz per lb of seed. This was the calendar recommendation in British Columbia and the treatment had reduced damage to less than 1 per cent in experiments only 3 years previously (Finlayson *et al.*, 1959). The maggots have been shown to be resistant to all the cyclodiene insecticides.

The degree of resistance shown by strains from British Columbia corresponds closely to that from Washington, Oregon and Idaho (personal communications), Michigan (Elmosa *et al.*, 1959), and Ontario (McClanahan *et al.*, 1959). Strains resistant to these insecticides are reported from all onion-growing areas of North America. Each strain appears to have developed independently.

Summary

In the interior of British Columbia, carbophenothion, diazinon, endrin, and ethion were tested for control of onion maggot, *Hylemya antiqua* (Meig.). They were applied as granular formulations to the furrow at 1 or 2 lb toxicant per acre or as wettable powder to the seed at 1 oz per lb of seed. Captan was added to half of each plot for smut control. The three organophosphate insecticides gave good to excellent control in mineral and peat soil. Endrin, to which resistance had arisen, allowed various amounts of damage up to 78.5 per cent. Diazinon caused considerable reduction in the number of emergent seedlings, especially in sandy loam. The other treatments had little or no effect on emergence, nor were other phytotoxic symptoms noted. Average yield in lb of marketable onions from 20 row-feet were: ethion, 14.7; carbophenothion, 14.5; diazinon, 14.4; endrin, 12.9; and untreated, 2.7.

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CONTROL OF MOUNTAIN PINE BEETLE, *Dendroctonus ponderosae* HOPK. BROOD IN LOGS WITH LINDANE EMULSION

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Introduction

In the southwestern United States, lindane in oil, to a great extent has replaced other chemicals in the control of *Dendroctonus* spp. in logs and slash. In British Columbia, Kinghorn (1955) demonstrated that ethylene dibromide or lindane in oil-in-water emulsion was effective against the mountain pine beetle in lodgepole pine. Nevertheless, ethylene dibromide, without exception, has been recommended and used as the bark beetle control insecticide in the interior of British Columbia. Ethylene dibromide in oil-in-water emulsion has proved inconvenient to handle and recently the insecticide has become difficult to obtain. Therefore, the following test was carried out in order to assess the effectiveness of lindane emulsion against mountain pine beetle, *Dendroctonus ponderosae* Hopk., in white pine, *Pinus monticola* Dougl., under conditions in the interior of British Columbia.

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