Essondale. At Vancouver the average number of seedlings per 20 row-feet at 0, 7, 14, and 28 g of Zinophos was 227, 152, 118, and 61 respectively.

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EXPERIMENTS AGAINST CARROT RUST FLY (*Psila rosae* (F.)) RESISTANT TO CYCLODIENE ORGANOCHLORINE INSECTICIDES[1]

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In July, 1961 reports from the Provincial Government's Colony Farm at Essondale, near Vancouver, to the effect that aldrin was no longer protecting carrots from damage by carrot maggots (*Psila rosae* [F.]), led to an investigation to determine: if strains of flies resistant to cyclodiene insecticides were present, and if suitable control measures could be developed.

The first spring seeding of carrots at Essondale was destroyed because the damage was so severe. Although recommended chemicals had been applied it soon became evident that the second crop also was heavily infested. Random samples in mid-August showed that at least 50% of the carrots were damaged. Collections of pupae were made at this time by sifting the soil for three inches on each side of the row to a depth of about six inches. Forty-five feet of row yielded more than 750 puparia plus an additional 1,200 from the maggots in the infested carrots. Samples of these puparia were shipped to the Entomological Laboratory at Chatham, Ont., for screening against various insecticides. The results of these tests (Niemczyk and Harris, 1962) showed that the flies were highly resistant to aldrin but very susceptible to diazinon. The toxicity of malathion was about mid-way between the other two.

Based on results obtained during investigations to find effective insecticides against resistant strains of onion maggots (Finlayson, 1959 and Howitt, 1958); cabbage maggots (Finlayson and Noble, 1964a and b and Howitt and Cole, 1962); and carrot maggots (Howitt and Cole, 1959); experiments were designed to test the effective insecticides against the second generation of carrot rust fly at Essondale. This paper reports on the experiments in 1961, 1962, and 1963. A temporary method was developed for preventing damage and the effects are shown of several dosages of chemicals on seedling emergence in various soil types. In the lower Fraser Valley commercial carrots are usually grown in muck soil.

Materials and Methods

The pesticides used in the investigation are listed in Table 1 and are identified chemically in accordance with Billings (1963) and Kenaga

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TABLE 1.—Chemical definitions of pesticides applied against carrot maggots.

Aldrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,8-dimethanonaphthalene
B.25141	0,0-diethyl 0-p-(methylsulfinyl) phenyl phosphorothioate
B.37289	0-ethyl 0-2,4,5,-trichlorophenyl ethylphosphonothioate
B.39007	0-isopropoxyphenyl methylcarbamate
Captan	N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide
Carbophenothion (Trithion)	S-[(p-chlorophenylthio)methyl] 0,0-diethyl phosphorodithioate
Diazinon	0,0-diethyl 0-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate
E.I.43064*	2-(diethoxyphosphinothioylimino)-1,3-dithiolane
Ethion	0,0,0′,0′-tetraethyl S,S′-methylenebisphosphoro dithioate
G.C.4072	2-chloro-1-(2,4-dichlorophenyl)vinyl diethyl phosphate
Guthion	0,0-dimethyl S-(4-oxo-1,2,3-benzotriazin-3(4H)-ylmethyl) phosphorodithioate
N.2790*	0-ethyl S-phenylethylphosphonodithioate
Nemacide (V-C 13)	0-(2,4-dichlorophenyl) 0,0-diethyl phosphorothioate
Zinophos	0,0-diethyl 0-2-pyrazinyl phosphorothioate

* Chemical name obtained from company brochure.

(1963). Formulations and rates of application are given in Table 2.

The carrot variety Scarlet Nantes Half-long was used, except at Essondale in 1963 when variety Gold Pak was grown. One g of seed (approximately 400), plus the insecticide, was sown in 20 ft of row with a V-belt seeder.

In 1961 the experiment was planted in mid-July on a plot immediately adjacent to the destroyed field of carrots. The design was a split-plot randomized block of 14 treatments,

TABLE 2.—Rate of furrow applications of insecticides against carrot maggot at several locations in British Columbia in 1961, 1962, and 1963.

Granular insecticide		Toxicant in grams per 1,000 row-feet 1961	1962	1963	Granular insecticide		Toxicant in grams per 1,000 row-feet 1961	1962	1963
Aldrin	5%	—	7	—	E.I.43064	10%	—	—	7
		14	14	—			—	—	14
		28	28	28			—	—	28
B.25141	10%	—	—	7	G.C.4072	10%	—	—	7
		—	—	14			—	—	14
		—	—	28			—	—	28
B.37289	10%	—	—	7	Guthion**	10%	—	7	—
		—	—	14			14	14	—
		—	—	28			28	28	—
B.39007	10%	—	—	7	N.2790	10%	—	—	7
		—	—	14			—	—	14
		—	—	28			—	—	28
Carbophenothion	10%	—	—	—	Nemacide	5%	—	7	—
		14	—	—			14	14	—
		28	—	—			28	28	—
Diazinon*	5%	—	7	7	Zinophos	10%	—	7	7
		14	14	14			14	14	14
		28	28	28			28	28	28
Ethion	5%	—	—	—					
		14	—	—					
		28	—	—	Untreated		—	—	—

* 10% granular was used in 1961.
** 3% dust was used in 1961.

comprising two rates with each of seven insecticides, and one untreated check, replicated five times. Each plot consisted of two 20-foot rows: one treated at 14 g of toxicant per 1,000 row-feet, the other at 28 g.

In 1962 the investigation was conducted at three sites: at Essondale in muck soil; at Victoria in peat soil; and at the University farm in Vancouver in sandy soil. The design was a split-plot latin square of five insecticides, applied at four rates, replicated five times. The insecticide granules were applied at 0, 7, 14, and 28 g of toxicant per 1,000 row-feet. Each plot contained four rows 20 feet long, one row at each rate.

In 1963 in muck soils at Essondale and Colebrook in the lower Fraser Valley, experiments compared eight granular insecticides applied to the furrow at 7, 14, and 28 g of toxicant per 1,000 row-feet with aldrin granules at 14 g and an untreated check. At each site were 25 furrow treatments, an untreated check and two captan seed treatments each replicated four times. Four captan plots received 14 g of diazinon to determine if captan would reduce the deleterious effects of diazinon on seedling emergence. For the captan seed treatment the carrot seed was dipped in 5% Methocel[2] sticker solution, and stirred with a glass rod in a beaker while captan was added at 1 oz per 2 lb of seed. Continuous stirring during the addition of the captan powder ensured a uniform coating on the seeds.

In 1961 efficacy of the treatments was measured by two appraisals of carrot samples for maggot damage; for the first, 50 carrots were pulled at random from each plot 100 days after seeding; for the second, the remaining carrots were pulled 30 days later.

In 1962 and 1963 emergent seedlings were counted 30 days after seeding and the foliage was examined periodically to determine any phytotoxic effects from the treatments. In addition two appraisals for damage were made. In 1962 they were made 100 days after seeding and at harvest 50 days later; in 1963 at 75 and 150 days after seeding.

Damage was assessed by washing the carrots thoroughly and examining them individually for signs of feeding on the main root. A single tunnel constituted a damaged carrot.

2 Dow Chemical Co., Midland, Michigan.

TABLE 3.—Average percentage damage by carrot maggots after various treatments at Essondale, B.C., 1961.*

Treatment	Toxicant per 1,000 row-feet (g)	Damage after 100 days	Treatment	Toxicant per 1,000 row-feet (g)	Damage after 130 days
Diazinon	14	4	Zinophos	28	5
Diazinon	28	8	Diazinon	14	5
Zinophos	14	10	Zinophos	14	6
Zinophos	28	10	Diazinon	28	9
Guthion	28	35	Guthion	28	61
Nemacide	28	49	Nemacide	14	61
Guthion	14	52	Ethion	28	61
Ethion	14	54	Guthion	14	64
Ethion	28	64	Nemacide	28	67
Nemacide	14	67	Ethion	28	70
Carbophenothion	28	68	Carbophenothion	28	71
Carbophenothion	14	72	Carbophenothion	14	84
Aldrin	14	86	Aldrin	14	94
Aldrin	28	93	Aldrin	28	95
Untreated	—	94	Untreated	—	98

*Values within the same bracket are not significantly different (Duncan, 1955).

Results

1961 Experiment (Table 3).—Furrow applications with granular diazinon and Zinophos at 14 and 28 g per 1,000 row-feet significantly reduced the amount of damage caused by resistant carrot maggots. Damage was less than 10%, whereas in aldrin-treated and untreated plots it was more than 90%. No phytotoxic symptoms were seen nor was there any apparent reduction in the number of seedlings.

1962 Experiment (Table 4).—Maggot infestations were negligible at Vancouver and Victoria so that no damage was sustained even in the untreated plots. At Essondale the infestation was nearly as low. In September more than 100 days after seeding, no damage was evident. At harvest, 150 days after seeding, the damage was still very light. In the untreated plots it averaged 32.2% (range 6 to 50%). In the treated plots the damage was similar, indicating that the residual effective period of the organophosphates tested was shorter than that of the cyclodiene organochlorines. Granular formulations in general, regardless of soil type, caused a decrease in the number of emergent seedlings which became more significant as the rate of application increased. In the light soils Zinophos and diazinon caused greater decreases than Guthion and Nemacide. No other symptoms of phytotoxicity were seen.

1963 Experiment (Table 5).—There was no damage by first generation maggots at either site, nor at Essondale by the second generation. At Colebrook only B.25141 gave satisfactory protection from both generations of maggots, allowing 10, 29, and 44% damage for the three rates applied. Untreated and aldrin-treated plots had 77 and 76% damage respectively. The numbers of emergent seedlings were significantly reduced by several treatments: at Colebrook, B.39007 and Zinophos at the three rates, diazinon at 28 and 14, and E.I.43064 at 28 g; whereas at Essondale only B.25141 and diazinon at 28 g caused a reduction.

TABLE 4.—Average number of emergent seedlings and percentage damage by carrot maggots after various treatments in several soil types in British Columbia, 1962.

Treatment	Toxicant per 1,000 row-feet (g)	Emergent seedlings per 20 row-feet			Percentage damage at Essondale
		Essondale muck	Victoria peat	Vancouver sandy	
Aldrin	0	172	259	273	18
	7	147	275	237	38
	14	165	279	213	37
	28	172	285	222	38
Diazinon	0	153	274	271	30
	7	131	266	113	34
	14	102	235	83	28
	28	83	198	74	30
Guthion	0	167	302	249	26
	7	162	301	237	28
	14	167	284	219	28
	28	167	249	198	30
Nemacide	0	160	283	251	45
	7	156	279	235	34
	14	152	279	204	27
	28	140	262	193	29
Zinophos	0	165	254	257	42
	7	138	241	147	34
	14	127	241	134	41
	28	120	205	105	26
Difference necessary for significance P=.05		30	36	32	14

TABLE 5.—Average number of emergent seedlings and percentage damage by carrot maggots after various treatments at two sites in British Columbia, 1963.

Granular insecticides	Toxicant per 1,000 row-feet (g)	Emergent seedlings per 20 row-feet		Percentage damage (150 days)	
		Colebrook	Essondale	Colebrook	Essondale
B.25141	28	263	186	10	0
	14	302	214	29	0
	7	293	230	44	0
B.39007	28	82	208	73	0
	14	121	282	91	0
	7	146	277	83	0
Zinophos	28	196	200	49	0
	14	216	199	80	0
	7	241	196	77	0
Aldrin	28	337	231	76	0
G.C.4072	28	342	244	53	0
	14	348	286	64	0
	7	303	244	71	0
N.2790	28	266	221	24	0
	14	324	186	22	0
	7	319	219	31	0
B.37289	28	349	287	53	0
	14	370	313	64	0
	7	351	277	53	0
E.I.43064	28	246	217	61	0
	14	286	270	78	0
	7	346	208	75	0
Diazinon	28	144	144	67	0
	14	222	193	70	0
	7	282	204	73	0
Untreated	—	340	266	77	8
Captan	—	336	207	90	0
Cap.+diaz.	14	280	217	83	0
Difference necessary for significance P=.05		84	78	27	—

When the carrot seeds were coated with captan and sown with 14 g of diazinon there was little reduction.

Discussion

From experiments conducted in the lower Fraser Valley and at Armstrong from 1950 to 1954, recommendations were made for control of the carrot maggot in British Columbia (Fulton and Handford, 1955). These included several methods of application of aldrin, heptachlor, chlordane, and lindane, all of which gave outstanding results.

In the state of Washington (Howitt and Cole, 1959) and at Essondale, no indication of resistant carrot rust fly was observed during late carrot cropping of the previous year. The severe damage inflicted by carrot maggots in the first planting in 1961 and the large number of pupae collected exemplify the rapid rise in population when resistance develops. In 1961 the normal insecticidal application for crop protection was made to both early and late plantings, which probably contributed further to the selection for resistance.

From the experiments conducted in 1961 it appeared at first that both diazinon and Zinophos would protect carrots (Fig. 1) and would not reduce the number of seedlings. Since these tests confirmed work by Howitt and Cole (1959) methods and rates were determined for field applications. Although large numbers of pupae were present at Essondale in 1961, few flies were found and light damage only was recorded in the experimental plots in 1962 and again in 1963. These reductions were attributed in part to the control practices of the farm management. In both years the furrow treatment with diazinon was supplemented with sev-

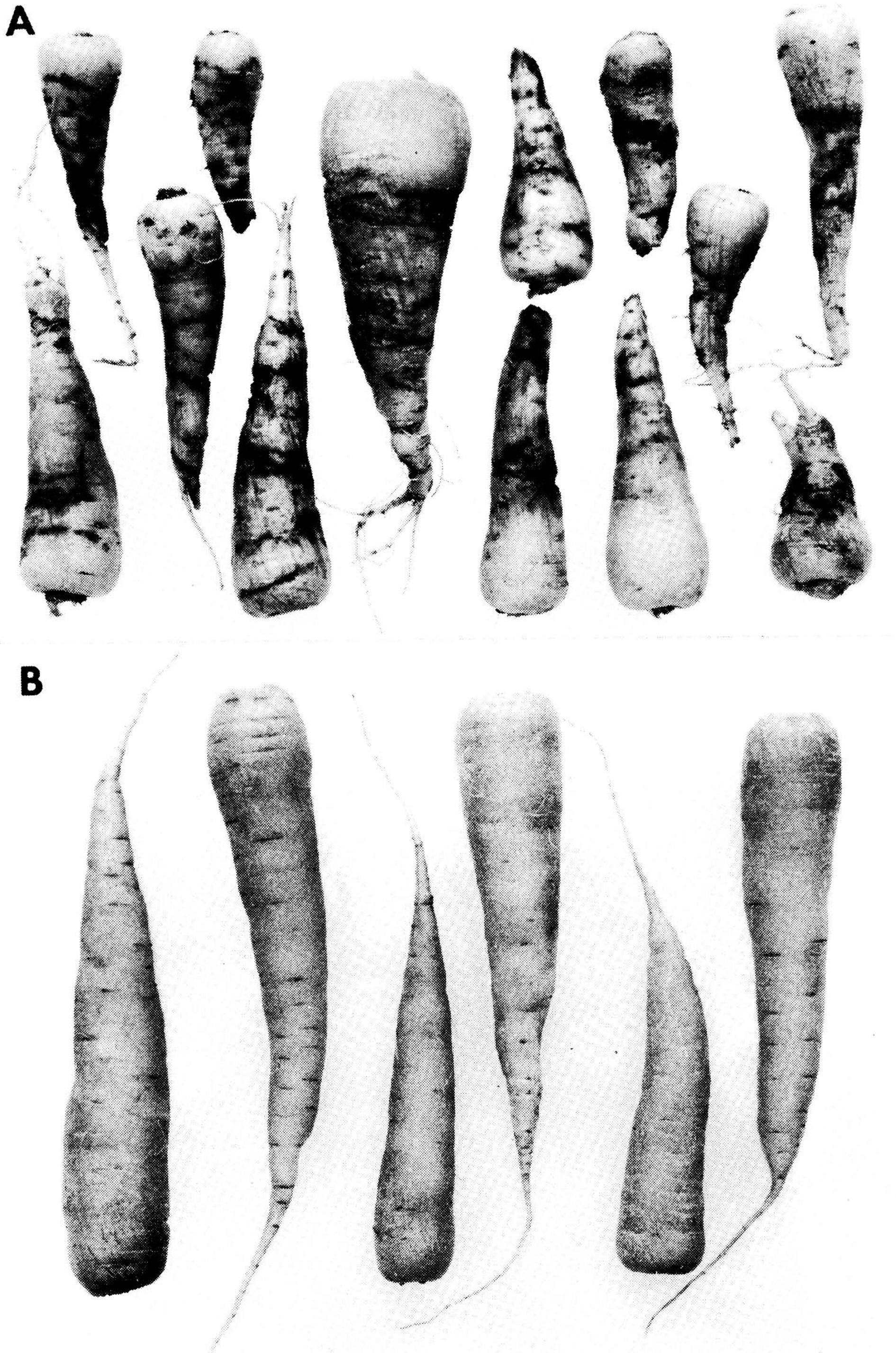

Fig. 1. A.—Carrots, from aldrin-treated and untreated plots, damaged by resistant carrot maggots. B.—Carrots from diazinon- and Zinophos-treated plots.

eral total spray treatments which coincided with the emergence of flies so that the population was effectively reduced.

The experiments showed that the longevity of organophosphate insecticides was not enough to ensure undamaged carrots when these were subjected to attack by two generations of maggots. Indeed, only B.25141 appeared to have enough persistence in soil to afford protection to carrots sown in late spring and harvested in late fall, but at the rate necessary to prevent damage there was serious reduction in the numbers of emergent seedlings. Since the necessary period of protection extends from mid-May to late September an effective furrow dosage must be found which not only permits a normal stand of plants but also protects the young seedlings. A supplementary spray program must be initiated to reduce the numbers of adult flies and thus prevent oviposition.

Summary

Experiments were conducted in different soil types in 1961, 1962, and 1963, to determine the efficacy of organocarbamate, organochlorine, and organophosphate insecticides against carrot rust fy (*Psila rosae* [F.]) resistant to cyclodiene organochlorine insecticides. The granular insecticides were applied in the furrow at 7, 14, and 28 g per 1,000 row-feet. In 1961 diazinon and Zinophos allowed less than 10% damage by one generation of maggots; whereas the untreated and aldrin-treated plots had more than 90% carrots unmarketable. The treatments caused no apparent reduction in the numbers of emergent seedlings. In 1962 damage was recorded at harvest 150 days after seeding in the treated as well as the untreated plots indicating that the residual period of the organophosphates was not long enough to protect the carrots from attack by two generations of carrot maggot. The highest rate of application reduced the numbers of emergent seedlings. This was more evident in light mineral soil than in the organic soils. In 1963 no damage was inflicted by first generation maggots but only B.25141 was able to protect the crop from damage by second generation maggots. Several insecticides, B.39007, diazinon, Zinophos, and E.I.43064 causd significant reductions in numbers of emergent seedlings. A coating of captan on seeds sown with diazinon appeared to counteract the effect of diazinon on seedling emergence.

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FURTHER INSECTICIDE TESTS AGAINST THE DOUGLAS-FIR NEEDLE MIDGES, *Contarinia* SPP.[1]

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Introduction

In 1962, at Larkin, B.C., endosulfan (Thiodan) and DDT emulsible concentrates diluted to 0.3% and applied to run-off, when the buds had flushed, gave satisfactory control of *Contarinia* spp. (Ross and Arrand 1963).

In 1963, at Invermere, the effectiveness of lower concentrations of Thiodan and DDT wettable powders (WP), and Thiodan emulsible concentrate (E) was tested on single trees. Additional trials at Canal Flats to measure control in large blocks, and at Larkin to establish the optimum time for spraying, did not produce adequate data because of low numbers of *Contarinia* spp.

Methods and Results

At Invermere, 10 trees from 5 to 7 ft tall were used for each treatment and 10 were left unsprayed as checks. Insecticides were applied with a hand sprayer to run-off.

One Imperial gal of water was added to each of the following quantities of commercial concentrates to obtain the finished formulations:

1½ tablespoons Thiodan emulsible concentrate containing 2 lbs technical Thiodan per Imperial gal (0.1%); 1½ tablespoons of Thiodan 50% wettable powder (0.2%); 1½ tablespoons of DDT 50% wettable powder (0.2%).

Sprays were applied under warm (78 to 81° F.) calm conditions on May 22 and 23, when an average of 75% of the buds in the upper crown and 85% in the lower crown were open. At the time of spraying, midges were ovipositing on the buds.

Percentage infestation was determined in October from 10 terminal twigs picked at random at breast height from each tree (Table 1).

Wettable powders of Thiodan and DDT at 0.2% concentration, on the foliage of individual trees did not give adequate control, but an application of Thiodan emulsion at 0.1% concentration gave good control.

In October five twigs from each tree were examined for eggs of the spruce spider mite, *Oligonychus ununguis* (Jacot). Counts were limited to the basal inch of the underside of the terminal twig (Table 2).

There was no apparent difference between the check and the Thiodan treatments, but the DDT-treated samples had almost 100 times more

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