# RATES, METHODS, AND PERSISTENCE OF INSECTICIDES USED FOR PREVENTING CARROT MAGGOT DAMAGE[1]

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ABSTRACT

Fourteen carbamate and organophosphorus insecticides for preventing damage by carrot maggot, **Psila rosae** (Fab.), were applied as granules in the seed furrow at 2 locations in muck soil, and supplemented with 2, 3, 4, or 8 sprays of the same materials during the season. The spray applications were made at 40 and 70 days after seeding; 30, 50, and 70 days; 30, 50. 70, and 90 days; 40, 70, and 100 days. Diazinon, the currently recommended treatment, was applied 8 times at 10-day intervals from 30 to 100 days. All the granules except chlorfenvinfos and ethion reduced the number of emergent seedlings. The reduction was 40% in plots treated with diazinon, thionazin, Chemagro 7375, Nemacur, pirimiphos-methyl, and TD-8550. Maggot damage was negligible until 100 days after seeding, but by 160 days only plots treated with carbofuran, fensulfothion, ethion and 3 of the numbered compounds had less than 20% damage. Residues of pesticides in the carrots ranged from 0.12 ppm of ethion 30 days after the final application, to 1.28 ppm of thionazin 10 days after. Residues in carrots held in storage at 5°C for 30, 60, and 90 days, increased with the period of storage, except those from plots treated with chlorfenvinphos.

## INTRODUCTION

When strains of carrot rust fly, *Psila rosae* (Fab.), became resistant to organochlorine insecticides, experiments were conducted after 1961 to determine methods and rates or applications of insecticides which would prevent damage by the rust fly maggot yet produce carrots free of residues. From 1961 to 1963 promising carbamate and organophosphorus insecticides were applied at various rates in the seed furrow. None was persistent enough to prevent damage for more than a single generation (Finlayson *et al.*, 1964). Further experiments (Finlayson *et al.*, 1966) showed that damage could be reduced below 5% if furrow applications were supplemented by drenches, but the method usually resulted in residues in the carrots at harvest (Finlayson *et al.*, 1970). The only insecticide which protected the carrots from damage without leaving residues in excess of established tolerance was diazinon (Finlayson *et al.*, 1968). However, the need to spray every 10 days from 30 days after seeding to 10 days before harvest made the cost almost prohibitive. Experiments were continued with the most promising compounds to determine effective methods at reduced rates which would lower costs and residues. This paper reports on an experiment designed to investigate the use of fewer sprays at various periods after seeding.

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## MATERIALS AND METHODS

The insecticides used in the primary and secondary experiments are listed alphabetically and identified chemically in Table 1. Common names are used except where these have not yet been assigned. (Kenaga and Allison, 1969).

At two locations in muck soil, granular insecticides at 1 oz toxicant per 1000 row-feet were applied in the furrow with the seed. Carrots, var. Hi Pak, were sown at 0.5 g per 20 feet of row with a V-belt rod-row seeder. The seed and the insecticide were separated in the belt by a fine layer of soil over the seed. In-furrow applications in the primary experiment were supplemented with 2, 3, or 4 sprays (Table 3) at staggered intervals after seeding, at 1 lb toxicant per acre per application in 100 gal water. The schedules were: 40 and 70 days; 30, 50, and 70; 40, 70, 100; and 30, 50, 70 and 90. In-furrow applications of the secondary experiment were supplemented 30, 50, and 70 days after seeding. Diazinon, the currently recommended treatment, was applied in the furrow at 1 oz toxicant per 1000 feet and sprayed 8 times at 10-day intervals starting 30 days after seeding, at 10 oz toxicant per acre in 100 gal water.

Treatments in the primary experiment were randomized and replicated four times at each location. Each plot consisted of four 20-foot rows. Treatments in the secondary or trial experiment were randomized and replicated only twice. The effectiveness of the insecticides

TABLE 1. Chemical definitions of insecticides used for preventing damage by carrot maggots.

| | |
|---|---|
| Bux | 1:4 mixture m-(1-ethylpropyl)phenyl methylcarbamate m-(1-methylbutyl)phenyl methylcarbamate |
| carbofuran | 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate |
| Chemagro 7375 | Unknown |
| chlorfenvinphos | 2-chloro-1-(2,4-dichlorophenyl)vinyl diethyl phosphate |
| diazinon | O,O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothioate |
| ethion | O,O,O',O'-tetraethyl S,S'-methylenebisphosphorodithioate |
| fensulfothion | O,O-diethyl O-p-[(methylsulfinyl)phenyl] phosphorothioate |
| N-2596 | S-(p-chlorophenyl) O-ethyl ethanephosphonodithioate |
| Nemacur | ethyl 4-(methylthio)-m-tolyl isopropylphosphoramidate |
| pirimiphos-ethyl[1] | 2-diethylamino-4-methylpyrimidin-6-yl diethyl phosphorothionate |
| pirimiphos-methyl[1] | 2-diethylamino-4-methylpyrimidin-6-yl dimethyl phosphorothionate |
| TD-8550[1] | S-(N-methoxycarbonyl-N-methylcarbamoyl-methyl) dimethylphosphonothiolothionate |
| thionazin | O,O-diethyl O-2- pyrazinyl phosphorothioate |
| trichloronate | O-ethyl O-2,4,5-trichlorophenyl ethylphosphonothioate |

[1]Chemical definitions from Pesticide Research Report 1970 315-332. Compiled by Can. Comm. Pesticide Use Agriculture, Ottawa.

was assessed by counting the number of emergent seedlings in 2 meters of row and by examining scrubbed carrots, harvested 160 days after seeding, for maggot tunnels; one or more tunnels per root constituted a damaged carrot.

At intervals of 10, 30, and 50 days after the final application five carrots were taken from each replicate treated with carbofuran, chlorfenvinphos, ethion, fensulfothion and thionazin. The carrots were washed and placed in frozen storage for analysis. Large samples were also taken 50 days after the final application from the plots treated at 40, 70, and 100-days, then placed in open bags in refrigeration at 5° C. Sub-samples of these were taken after 30, 60, and 90 days refrigeration, washed and put into frozen storage prior to analysis to determine the effect of refrigerated storage on residues.

The frozen samples of treated and untreated carrots were shredded on a Braun Multimix, thoroughly intermixed and 50 g subsamples were analysed as follows:

*Chlorfenvinphos, ethion and thionazin* were extracted with ethyl acetate following the procedure of Storherr and Watts (1965). Cleanup was by sweep co-distillation (Watts and Storherr (1965)) and analysis was by gas chromatography on a 6 ft column of 4% OV 101 and 6% OV 210 using a flame photometric detector in the phosphorus mode. Recoveries from fortified carrots were as follows: chlorfenvinphos, 1.0 ppm, 97%; ethion, 0.1 ppm, 111%; and thionazin, 1.0 ppm, 82%.

*Fensulfothion* residues were determined by the method of Williams *et al.* (1971) using flame photometric detection.

*Carbofuran* analyses were made by modifying the method described by Cook *et al.* (1969) for corn. The modifications included substitution of alumina for Nuchar-Attaclay and silica gel in the cleanup column, and the use of a Coulson conductivity detector (Coulson, 1966) instead of a microcoulometric detector. Recoveries from fortified carrots at 0.5 ppm were: carbofuran, 101% and 3-hydoxy-carbofuran, 108%.

The percentage solid matter in the frozen shredded carrots after refrigeration at 5 C for 0, 30, 60, and 90 days was determined by two methods. In the first, 100 g samples were oven-dried at 100°C, air cooled and brought to constant weight at room temperature in a desiccator over calcium chloride. In the second, 5 g samples were boiled in xylene and the water collected in a Bidwell and Sterling distilling receiver (1925).

TABLE 2. Average number of emergent carrot seedlings in 2 meters of row after treatments to prevent damage by carrot maggots.

| Treatment | Number of seedlings | Treatment | Number of seedlings |
|---|---|---|---|
| Bux | 45.0 | Nemacur | 27.0 |
| carbofuran | 51.0 | pirimiphos-ethyl | 55.0 |
| Chemagro 7375 | 22.5 | pirimiphos-methyl | 29.5 |
| chlorfenvinphos | 63.5 | TD-8550 | 23.0 |
| diazinon | 34.0 | thionazin | 34.8 |
| ethion | 67.3 | trichloronate | 56.8 |
| fensulfothion | 47.0 | Untreated | 63.0 |
| N-2596 | 48.5 | | |

## RESULTS AND DISCUSSION

Seedling emergence was unsatisfactory for determining the effects of the insecticides on the seeds at the Kennedy location because a layer of blue clay which extended over several plots resulted in very restricted germination. Counts were taken only at the Spranger location. Some effects are recorded in Table 2. Only chlorfenvinphos and ethion treatments produced as many seedlings per unit length of row as untreated plots. Chemagro 7375, Nemacur, pirmiphos-methyl, and TD-8550, all exploratory compounds, had less than half the number of seedlings found in untreated plots. Seedling numbers in the diazinon-treated plots were about half those in untreated plots, a disadvantage to its use since it was first recommended. Thionazin caused similar reductions.

Damage from first and second generation maggots was almost negligible 100 days after seeding. By 130 days damage was evident in untreated and diazinon-treated carrots and at 160 days losses in yield were evident (Table 3). Of the insecticides in the primary experiment only carbofuran, fensulfothion and thionazin were consistently effective in preventing damage. Three sprays at 40, 70, and 100 days appeared to be the best schedule for preventing damage. In the secondary experiment (Table 4) all except N-2596 and pirimiphos-methyl averaged less than 20% damage. Chemagro 7375 and Nemacur had less than 10% damage but their reduction of seedling emergence offset their usefulness.

Residue analysis was restricted to the five most effective insecticides. The results from samples taken 10, 30, and 50 days after final

TABLE 3. Percentage damage by maggots to carrots at 160 days after seeding, using various methods and rates of insecticides in the primary experiment.

| Insecticide | Untreated | 4 lb (40, 70) | 5 lb (30, 50, 70) | 5 lb (40, 70, 100) | 6 lb (30, 50, 70, 90) | 7 lb (30, 40, ...100)[2] | Average |
|---|---|---|---|---|---|---|---|
| | Rate in lb/acre, and days after seeding sprays were applied ( ) | | | | | | |
| **Kennedy Farms** | | | | | | | |
| Bux | - | 38.6 | 26.2 | - | - | - | 32.4 |
| carbofuran 5G | - | - | 9.3 | - | - | - | 9.3 |
| carbofuran 10G | - | 14.1 | 11.0 | 14.1 | 10.0 | - | 12.3 |
| chlorfenvinphos | - | 16.5 | 30.4 | 21.3 | 31.4 | - | 24.9 |
| diazinon | - | - | - | - | - | 34.7 | 34.7 |
| ethion | - | 18.7 | 14.9 | - | - | - | 16.8 |
| fensulfothion | - | 8.0 | 4.0 | 9.8 | 7.1 | - | 7.2 |
| thionazin | - | 22.6 | 10.7 | 15.5 | 12.5 | - | 15.3 |
| trichloronate | - | - | 25.0 | - | - | - | 25.0 |
| Untreated | 45.6 | - | - | - | - | - | 45.6 |
| **Spranger Farm** | | | | | | | |
| Bux | - | 27.7 | 35.2 | - | - | - | 31.4 |
| carbofuran 5G | - | - | 11.8 | - | - | - | 11.8 |
| carbofuran 10G | - | 4.7 | 15.5 | 0.0 | 12.4 | - | 8.1 |
| chlorfenvinphos | - | 13.6 | 34.9 | 5.9 | 34.3 | - | 22.2 |
| diazinon | - | - | - | - | - | 28.1 | 28.1 |
| ethion | - | 9.7 | 19.4 | - | - | - | 14.5 |
| fensulfothion | - | 3.9 | 6.9 | 3.9 | 1.0 | - | 3.9 |
| thionazin | - | 4.6 | 7.5 | 4.0 | 1.0 | - | 4.3 |
| trichloronate | - | - | 28.0 | - | - | - | 28.0 |
| Untreated | 34.8 | - | - | - | - | - | 34.8 |

[1] In-furrow granular application plus 2, 3, 4 or 8 sprays.
[2] Eight spray applications.

TABLE 4. Percentage damage by maggots to carrots at 160 days after seeding, in the secondary experiment.[1]

| Treatment | Kennedy Farm | Spranger Farm |
|---|---|---|
| Chemagro 7375 | - | 8.9 |
| N-2596 | 42.0 | 26.9 |
| Nemacur | 12.0 | 5.7 |
| pirimiphos-ethyl | 19.6 | 14.3 |
| pirimiphos-methyl | 68.0 | 11.0 |
| TD-8550 | - | 12.3 |

[1] In-furrow applications followed by 3 sprays 30, 50, and 70 days after seeding.

treatment, are shown in Table 5. Some reduction of residue occurred in this period, probably as a result of dilution by growth, but in most treatments it did not diminish by as much as 50%.

Residues in samples from the 40-70-100 day schedule of treatments taken 50 days after the final application and held at 5°C for 30, 60, and 90 days, are given in Table 6. Except for those treated with chlorfenvinphos there was a general increase in the residues per unit weight over the storage period. We assumed that this resulted from a loss of water by the carrots in storage. Weights of the shredded samples, oven-dried at 100°C, or dehydrated by boiling in xylene, are shown (Table 6). It appears from the results that more than water is removed by the oven-drying method. These results are comparable to those of Bidwell and Sterling (1925) who discuss the advantages and disadvantages of each method. From the table it can be seen that the apparent increase in residue is associated with the change of water content of the carrots during storage. The extra solid matter per unit weight, as determined by the xylene method, ranged from 27.8% for chlorfenvinphos treated carrots to 33.9% for those treated with thionazin. These findings are different from those of Read (1971) who found that until approximately 80 days after planting rutabagas absorbed fensulfothion, which then decreased at a relatively constant rate; and that residues present at harvest decreased quickly to non-detectable levels in storage. Suett (1971) found that from a single application at seeding concentrations above 1 ppm could be present in marketable carrots 12-14 weeks after application at recommended rates. The rates of uptake declined as carrot growth slowed and subsequently the amounts of chlorfenvinphos, diazinon and fonofos residues in carrots changed very little.

In the U.K. Wheatley (1971) and in Canada Finlayson *et al.* (1966) have shown

TABLE 5. Residues in ppm in carrot samples taken 10, 30, and 50 days after the final application of insecticide.

| Schedule of drenches | | Kennedy | | | | | | | Sprunger | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after last application | carbofuran | 3-hydroxycarb. | chlorfenvinphos | ethion | fensulfothion | f. sulfone | thionazin | carbofuran | 3-hydroxycarb. | chlorfenvinphos | ethion | fensulfothion | f. sulfone | thionazin |
| 40-70 | 10 | ND | .10 | .44 | .38 | .26 | .04 | .80 | .09 | .37 | .50 | .24 | .29 | .06 | 1.28 |
| | 30 | .05 | .21 | .35 | .29 | .25 | .06 | .63 | .05 | .34 | .43 | .23 | .32 | .07 | 1.17 |
| | 50 | .06 | .06 | .30 | .20 | .26 | .10 | .57 | .04 | .22 | .24 | .20 | .18 | .07 | .73 |
| 30-50-70 | 10 | .05 | .26 | .60 | .34 | .31 | .05 | .93 | .05 | .10 | .41 | .16 | .31 | .05 | .95 |
| | 30 | .08 | .17 | .58 | .31 | .30 | .06 | .56 | ND | .18 | .36 | .12 | .31 | .05 | .63 |
| | 50 | .12 | .13 | .56 | .24 | .16 | .05 | .45 | ND | .14 | .27 | .22 | .24 | .06 | .72 |
| 40-70-100 | 10 | ND | .09 | .36 | - | .34 | .05 | .76 | - | - | - | - | - | - | - |
| | 30 | .05 | .08 | .42 | - | .25 | .06 | .65 | .07 | .14 | .32 | - | .45 | .14 | .56 |
| | 50 | .04 | .06 | .41 | - | .14 | .06 | .42 | .02 | .26 | .37 | - | .26 | .09 | .68 |
| 30-50-70-90 | 10 | .09 | .19 | .91 | - | .42 | .08 | 1.03 | .06 | .12 | .46 | - | .34 | .05 | 1.08 |
| | 30 | ND | .14 | .76 | - | .36 | .09 | .71 | .02 | .11 | .25 | - | .31 | .08 | .94 |
| | 50 | ND | .21 | .42 | - | .28 | .07 | .79 | ND | .22 | .38 | - | .46 | .14 | .51 |

ND = None detected

that damage from carrot maggots can be prevented by preseeding applications of pesticides to the soil, by post-emergence applications to the foliage, and by combinations of the two. Regardless of method the carrots have contained objectionable residues at harvest. The results of this experiment are no exception. As long as 50 days after final application, residues close to or above acceptable levels are still present in the carrots when treated at rates and with methods necessary for protection.

TABLE 6. Effect of refrigerated storage for various periods, on carrots harvested 50 days after the final application of insecticide.

| Insecticide | Days at 5°C | Percentage solids: Oven dried | Percentage solids: Xylene method | Residues[1]: P | Residues[1]: M | Residues[1]: Total |
|---|---|---|---|---|---|---|
| carbofuran | 0 | 10.56 | 12.8 | 0.02 | 0.26 | 0.28 |
| | 30 | 11.99 | 14.0 | 0.10 | 0.13 | 0.23 |
| | 60 | 12.01 | 14.6 | 0.06 | 0.25 | 0.31 |
| | 90 | 13.67 | 16.4 | ND | 0.33 | 0.33 |
| chlorfenvinphos | 0 | 11.71 | 13.0 | 0.37 | - | 0.37 |
| | 30 | 12.27 | 14.8 | 0.05 | - | 0.05 |
| | 60 | 12.35 | 15.0 | 0.10 | - | 0.10 |
| | 90 | 13.45 | 16.6 | 0.07 | - | 0.07 |
| fensulfothion | 0 | 11.02 | 12.0 | 0.26 | 0.09 | 0.35 |
| | 30 | 12.21 | 14.0 | 0.20 | 0.08 | 0.28 |
| | 60 | 12.21 | 14.6 | 0.35 | 0.10 | 0.45 |
| | 90 | 13.52 | 16.0 | 0.51 | 0.12 | 0.63 |
| thionazin | 0 | 10.88 | 12.4 | 0.68 | - | 0.68 |
| | 30 | 11.90 | 14.0 | 0.82 | - | 0.82 |
| | 60 | 12.35 | 14.4 | 0.60 | - | 0.60 |
| | 90 | 12.68 | 16.6 | 1.08 | - | 1.08 |

[1] P = Parent compound, M = Metabolite, ND = None Detected

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# THE FUNGI *BEAUVERIA BASSIANA* AND *METARRHIZIUM ANISOPLIAE* IN CULTURES OF THE ROOT WEEVIL *NEMOCESTES INCOMPTUS* HORN (COLEOPTERA: CURCULIONIDAE)

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The woods weevil, *Nemocestes incomptus* Horn, is a native root weevil which causes serious damage to strawberries in coastal British Columbia. Freshly emerged adults were collected in large numbers from a strawberry planting in early September 1971, and confined in screen-covered quart sealers in the laboratory at room temperature. About 200 adults were kept in each sealer and fed fresh wet strawberry foliage daily. By early October most of the adults had died. White fungus was seen at their leg joints and mouthparts. When apparently healthy, freshly collected adults were confined singly with a dead, fungus-covered adult they died within two to three days. The fungi on the dead weevils were identified as *Beauveria bassiana* (Fig. 1A) and *Metarrhizium anisopliae* (Fig. 1, A and B). These fungi are well known and have many insect hosts. The importance of these fungi in controlling root weevil adults or larvae in the field is not known but warrants further investigation.

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