Phytotoxicity of some organophosphate insecticides to onions and carrots during germination and emergence

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Summary

The phytotoxicity of some commonly used insecticides to onions (*Allium cepa*) and carrots (*Daucus carota*) during establishment was assessed in pot trials. Terbufos, ethoprophos, phoxim and carbofuran (all 10% a.i. granular formulations) and chlorpyrifos (25% a.i. wettable powder) were applied at three rates in the soil used to cover the seed (37.5, 75 and 150 mg a.i. L^{-1} soil 20 mm deep). No treatment significantly ($P>0.01$) reduced percentage emergence in onions, whereas terbufos, ethoprophos and chlorpyrifos reduced emergence in carrots. Seedling size 22 and 37 days after sowing of onions was significantly reduced by terbufos, ethoprophos and chlorpyrifos and in carrots by ethoprophos, carbofuran and chlorpyrifos. The same treatments also caused delays in emergence of both crops. Visible symptoms in cotyledons were also observed with phoxim in onions and carbofuran in carrots.

Introduction

Soil application of insecticides in close proximity to the seed row can control various pests of carrots (*Daucus carota*) and onions (*Allium cepa*) during germination and early growth (e.g., Sparrow *et al.* 1973, Stevenson 1976, Goodyer *et al.* 1989). However, phytotoxicity can be a problem with some chemicals, either by direct physiological effects (Dalvi and Salunkhe 1975) or by interaction with pathogens (Rawlins 1965). For example, the organochlorines lindane and aldrin are known to be phytotoxic when applied as a seed dressing to onions (Finlayson 1957). Diazinon has been found to reduce establishment of carrots, but its phytotoxic effects can be counteracted by seed treatment with the fungicide thiram (Stevenson 1976).

There is little published information regarding the phytotoxicity of other carbamate or organophosphate insecticides to carrots and onions. Stevenson (1976) provided conflicting evidence on the phytotoxicity of carbofuran to carrots, but Thompson *et al.* (1981) reported carrot numbers were not reduced by rates up to 66.7 mg a.i. m^{-1} row. Getzin (1973) found indications that carbofuran at 45.9 mg a.i. m^{-1} row in onions had increased plant vigour, but Jodko (1988) encountered some phytotoxicity from carbofuran applied to onions as a seed dressing. Chlorpyrifos is generally non-phytotoxic at recommended rates and methods of application, but some crops are especially sensitive to it during the seedling stage or if the chemical is applied close to the seed (Sparrow *et al.* 1973). Stapleton *et al.* (1987) found ethoprophos (10% a.i. granular) did not cause significant phytotoxicity to carrots when used as a nematicide, however the rate in the vicinity of seed was small (1.35 kg a.i. ha^{-1} spread and incorporated) and a delay of several weeks occurred before planting.

Some chemicals currently considered to have potential for soil use include carbofuran, chlorpyrifos, ethoprophos, phoxim and terbufos. This study reports the results of pot trials conducted to determine the phytotoxicity to carrots and onions of those chemicals applied to soil at sowing.

Materials and methods

Two experiments were conducted concurrently in a glasshouse (temperature 12–32°C) at Yanco (Lat. 34°33', Long. 146°25') in New South Wales, one with carrots (cv. Western Red) and one with onions (cv. Brown Spanish). Three rates of terbufos, ethoprophos, phoxim, carbofuran (all 10% a.i. granules) and chlorpyrifos (25% a.i. wettable powder) and an untreated control were evaluated using completely randomized designs, with three replicates for the insecticide treatments and nine for the controls. Greater replication of the control was used to improve comparisons between treatments and the control. The placement of pots was re-randomized several times during the experiments to reduce any effects of position in the glasshouse.

Gogeldrie clay topsoil (van Dijk 1961) was used for consistency with previous field trials (Goodyer *et al.* 1989), but was dried before use for 48 hours at 70°C to kill wireworms. Plastic pots 150 mm in diameter (1.3 L) were filled to 60 mm from the top with untreated soil, followed by a 20 mm layer of sieved untreated soil to provide a uniform seedbed. Fifty seeds were distributed over the surface and covered to a depth of 20 mm with insecticide treated soil (approximately 0.3 L). To prepare the treated soil, appropriate quantities of each pesticide were shaken thoroughly with air dry, sieved soil, to produce rates of 37.5, 75 and 150 mg a.i. L^{-1} soil. Each pot constituted one plot.

If it is assumed that in a field situation, band-in-furrow treatment would treat a strip 50 mm wide by 20 mm deep, the rates tested would correspond to 37.5, 75 and 150 mg a.i. m^{-1} row, or 0.5, 1.0 and 2.0 kg a.i. ha^{-1} at a row spacing of 75 cm. The low and medium rates are then comparable to rates used in the field by Getzin (1973), Thompson *et al.* (1981) and Goodyer *et al.* (1989).

Daily counts of emerged seedlings were made at 7 to 18 days and at 21 days after first watering. These data were used to determine the total number of seedlings which emerged ("maximum emergence") and number of surviving seedlings at the final count ("final emergence") as a percentage of seeds sown and to estimate the time in days between sowing and 50% of maximum emergence. Visual observations of phytotoxic effects were recorded and an area meter (*LI-COR* Model 3100) was used to measure the total size of ten seedlings sampled 22 days and 37 days after sowing. Seedling size was not determined in carrots at the medium and high rates of ethoprophos, as there were too few plants.

The data for each crop were analysed by analysis of variance. Square root transformation was required for seedling size data.

Results

Onions and carrots differed markedly in their response to insecticide treatment. In onions (Table 1), percentage emergence was not affected significantly ($P>0.01$) by any treatment, whereas in carrots (Table 2), both maximum and final percentage emergence were affected ($P<0.01$) by all rates of ethoprophos and high rates of chlorpyrifos and terbufos.

Seedling size of onions, but not carrots, was significantly ($P<0.01$) affected by terbufos at the high rate on both sampling occasions, whereas carbofuran at medium and high rates affected seedling size of carrots but not onions. Phoxim had no significant ($P>0.01$) effect on seedling size of either crop. Chlorpyrifos and ethoprophos affected seedling size of both crops, but carrots were more severely affected and did not grow between the two sampling occasions. Decreases in seedling size from insecticide treatment were associated with delays in emergence, which were most evident with chlorpyrifos in carrots.

Shrivelling of the cotyledon tips was observed in carrots treated with carbofuran. At all three rates of phoxim, onion plants exhibited a very distinctive bleaching at the top of the emerging cotyledon hook.

Table 1: Effects of various insecticide treatments on onions during seedling establishment.

Chemical, rate and formulation (mg a.i. /L of covering soil)		% emergence Maximum	Final	Days to 50% of maximum emergence	Seedling size (√[cm²/10plants]) at 22	37 days from sowing
Carbofuran	37.5	95	94	9.6	2.23	3.23
10G	75	94	93	9.2	2.35	3.21
	150	94	93	9.2	2.37	3.14
Chlorpyrifos	37.5	95	93	9.7	2.16	3.30
25WP	75	95	93	10.3	1.81*	2.79*
	150	94	93	11.2*	1.36*	2.42*
Ethoprophos	37.5	90	89	10.5*	1.77*	2.78*
10G	75	94	93	10.7*	1.68*	2.77*
	150	89	89	11.8*	0.95*	2.36*
Phoxim	37.5	90	90	9.4	2.60	3.65
10G	75	94	93	9.5	2.42	3.26
	150	95	95	9.1	2.26	3.31
Terbufos	37.5	97	95	9.2	2.64	3.13
10G	75	88	87	10.3*	2.23	3.29
	150	82	82	11.0*	1.72*	2.90*
Control		94	90	9.3	2.55	3.55
sed						
vs control		3.03	4.31	0.400	0.163	0.191
vs other tmts.		3.71	5.28	0.490	0.199	0.234

* Means differing significantly from the control by an lsd test (P<0.01).

Table 2: Effects of various insecticide treatments on carrots during seedling establishment.

Chemical, rate and formulation (mg a.i. /L of covering soil)		% emergence Maximum	Final	Days to 50% of maximum emergence	Seedling size (√[cm²/10plants]) at 22	37 days from sowing
Carbofuran	37.5	95	93	8.8	1.77	2.69
10G	75	80	73	8.5	1.52*	2.27*
	150	81	73	8.7	1.10*	1.60*
Chlorpyrifos	37.5	89	86	9.9*	0.77*	0.67*
25WP	75	85	83	10.6*	0.54*	0.28*
	150	61*	52*	11.8*	0.22*	0.18*
Ethoprophos	37.5	28*	27*	9.5*	1.63	1.55*
10G	75	13*	11*	–	–	–
	150	1*	1*	–	–	–
Phoxim	37.5	81	80	8.9	1.99	3.05
10G	75	81	79	8.7	1.63	3.24
	150	83	81	8.7	1.83	2.77
Terbufos	37.5	87	78	8.9	1.82	3.10
10G	75	82	81	8.0	1.80	3.17
	150	70*	67*	9.4*	1.67	3.23
Control		87	86	8.3	1.93	3.57
sed						
vs control		4.62	4.91	0.393	0.140	0.375
vs other tmts.		5.65	6.01	0.482	0.171	0.459

* Means differing significantly from the control by an lsd test (P<0.01).
– Not determined as too few plants emerged.

Discussion

Carbofuran at the rates tested had no significant effects on onions and the suggestion by Getzin (1973) that it might stimulate onion seedling growth was not supported. Carrot emergence percentage was not affected by carbofuran, but sensitivity to the chemical in this crop was indicated by reduced growth rate and visible symptoms: such damage could explain occasional reports of reduced emergence with the chemical in the field (Stevenson 1973).

Chlorpyrifos reduced growth, but did not affect percentage emergence of onion seedlings. This insecticide is currently used in onions in New South Wales as a seed dressing at a rate of 25 g a.i. kg^{-1} seed. At typical sowing rates of 2.5-4.5 kg seed ha^{-1}, the rate of chlorpyrifos resulting is 62.5-112.5 g a.i. ha^{-1}, well below the rates tested in these trials. Effects of chlorpyrifos on percentage emergence of carrots were only significant at the high rate, however the insecticide had severe, persistent effects on carrot seedling growth. Further evaluations of phytotoxicity of chlorpyrifos at low rates may be warranted to explain the reduction in emergence percentage of onions observed by Emmett and Savage (1980) and to determine its suitability as a seed dressing for carrots.

Ethoprophos delayed emergence of onions and reduced seedling size, without affecting emergence percentage. However, in carrots it severely reduced emergence at all three rates and reduced growth of the surviving seedlings. Phoxim did not affect emergence percentage or seedling size of onions, despite its bleaching effect in cotyledons. Terbufos caused no damage to either crop at the medium and low rates.

Greater phytotoxicity of ethoprophos and chlorpyrifos to carrots than to onions could have influenced the outcome of field experiments described by Goodyer *et al.* (1989), where ethoprophos (10% a.i. granular) and chlorpyrifos (25% a.i. wettable powder) were effective at 0.25, 0.50 and 0.75 kg a.i. ha^{-1} in onions, but at 0.25 and 0.50 kg a.i. ha^{-1} and not 0.75 kg a.i. ha^{-1} in carrots.

The interactions between treatment and species, low mortality of emerged seedlings and visible symptoms with some treatments indicate that treatment effects on percentage emergence resulted predominantly from insecticide phytotoxicity, rather than indirectly through increased incidence of damping-off. Comparisons of maximum and final emergence suggest that mortality of plants occurred very early in growth, with little subsequent loss in the period of the trial. The implications for a field situation of reductions in seedling growth rate without reductions in percentage final emergence are uncertain, as compensatory growth may alleviate yield effects, but delays in establishment could increase weed competition, reduce crop uniformity and increase the risk of seedbed diseases.

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