The efficacy of carbofuran against the potato cyst nematode *Globodera rostochiensis*

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Summary

Carbofuran is effective against the potato cyst nematode, *G. rostochiensis* in the soil phase of the life cycle ; it also affects the number of eggs per cyst in the post-cropping cyst population. Regression analysis is a useful method of measuring the effects of non-volatile nematicides on hatching. Variations in the developmental population structure in the host plant is a simple way of illustrating the nematicidal effects on juveniles in the roots. A simple pot test in different soil types would quickly eliminate unsuitable nematicides.

Résumé

Efficacité du carbofuran contre le nématode à kyste de la pomme de terre Globodera rostochiensis

Le carbofuran est actif contre le nématode à kyste de la pomme de terre, *G. rostochiensis*, au cours de la phase sol de son cycle biologique; il affecte aussi le nombre d'œufs par kyste et la population de kystes observée après la récolte. L'analyse de régression s'est révélée être une bonne méthode pour mesurer les effets des nématicides non volatiles. Les variations dans le développement de la population dans la plante hôte sont un bon moyen de mettre en évidence les effets nématicides sur les juvéniles se trouvant dans les racines. Un simple test en pot avec différents types de sol devrait éliminer rapidement les nématicides inefficaces.

Carbofuran is a wide spectrum carbamate insecticide and nematicide. Work by Disanzo (1973) has shown that it was effective against *Meloidogyne incognita*, *Pratylenchus penetrans* and *Tylenchorhynchus claytoni* by preventing nematodes from invading host roots. Non-volatile nematicides have been shown to be effective against the potato cyst nematode, *G. rostochiensis* (Whitehead, 1973) and the major action of aldicarb (Hague & Pain, 1973) and oxamyl (Boparai & Hague, 1974) has been shown to be against the soil phase of the life cycle of the nematode. The present paper investigates the "mode of action" of carbofuran against *G. rostochiensis*, the effectiveness of carbofuran in different soil types and also illustrates new techniques for evaluating non-volatile nematicides.

Materials and methods

In the first experiment batches of 200 cysts of *G. rostochiensis* with a mean of 163 eggs per cyst extracted from heavily infested soil were mixed into 1 kg of sandy-loam soil to give an initial population of 32 eggs/g soil. At the same time 5% carbofuran granules were mixed into the soil to give concentrations of 0, 1, 2, & 4 mg/kg : a 2 mg/kg treatment with 10% aldicarb granules was used as a standard.

Each soil mixture was placed in a 12.5 cm plastic pot into which was planted a two-week old seedling of the cultivar Red Craigs Royal grown from a potato sprout : pots were kept in a cool glasshouse where temperature varied from 15°-25° and pots were watered when necessary.

For each treatment duplicate samples were

taken six times at 7, 12, 17, 25, 33 and 70 days after treatment and planting, so that each treatment was effectively replicated twelve times.

Assessments

On each sampling date the shoots from two pots per treatment were cut off and the roots carefully separated from the soil : the soil in each pot was divided into equal portions, one of which was air-dried and the other kept moist.

150 g of the air-dried portion was extracted on the Fenwick can and the number of eggs per cyst determined. The moist soil was placed on the Whitehead tray (Whitehead & Hemming, 1965) and the number of second stage juveniles extracted after 48 h counted.

The roots were stained in acid fuchsin in lactophenol and the different stages of the nematode determined (Southey, 1970).

In the second experiment batches of 300 cysts with a mean of 100 eggs per cyst were mixed into 1 kg of loamy sand, silty loam, silty clay and a peat mixture to give an initial population of 30 eggs per gram of soil : 5% carbofuran granules were incorporated into each soil to give dosages of 0, 2, 4 & 8 mg/kg in 12.5 cm plastic pots into which a two-week old potato seedling of the cultivar Home Guard was planted.

Eight weeks after the application of carbofuran the tops of the plants were cut off and the pots left to dry. Cysts were extracted from 100 g air-dried soil and the number of cysts and number of eggs per cyst estimated by standard techniques.

Results

The effect of carbofuran on the emergence of second stage juveniles was determined by estimating the decrease in the number of eggs per cyst with time in the presence of the host plant (Tab. 1). From this data, knowing the initial cyst content, the number of hatched juveniles can be estimated, the percentage emergence calculated and transformed to the angular scale and plotted against time after application of carbofuran (Fig. 1). 50% of the second stage juveniles emerged after 18 days in the untreated pots, but it took 26, 31 and 35 days for 50% of the juveniles to emerge at 2 and 4 mg/kg of carbofuran and 2 mg/kg aldicarb respectively.

Table 1

The effect of carbofuran and aldicarb on the number of eggs per cyst in cysts extracted from treated soil at different times after application

Sampling time *Days after application*	*Untreated*	*Milligrammes per kilogram*			
		Carbofuran			*Aldicarb*
		1	*2*	*4*	*2*
7	104	120	151	172	149
12	98	123	136	146	148
17	47	104	147	151	151
25	36	31	80	78	104
33	12	20	41	64	91

Mean Initial Cyst Content = 163 eggs per cyst.

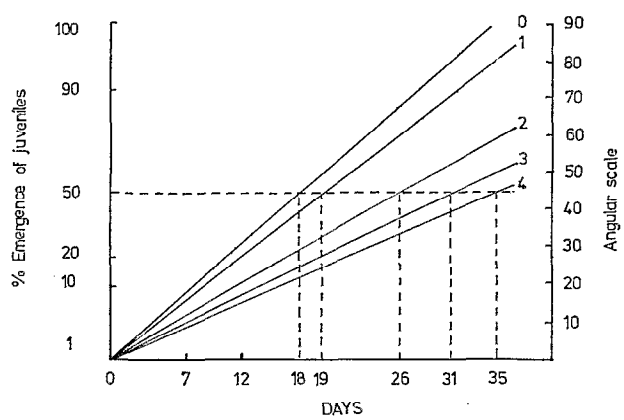

Fig. 1. The regression lines for the percentage of second stage juveniles of *G. rostochiensis* emerging after treatment with carbofuran and aldicarb.

O = untreated : y = 2.604 ; 1 = 1ppm carbofuran : y = 2.331 x (n.s.) ; 2 = 2ppm carbofuran : y = 1.722 x (***) ; 3 = 4ppm carbofuran : y = 1.466 x (***) ; 4 = 2ppm aldicarb : y = 1.291 x (***). S.E. of regression coefficients : 0.168. Residual s.s. = 5625.56 ; residual d.f. = 45 ; residual m.s. = 125.01.
*** significantly different from untreated, P = 0.001.

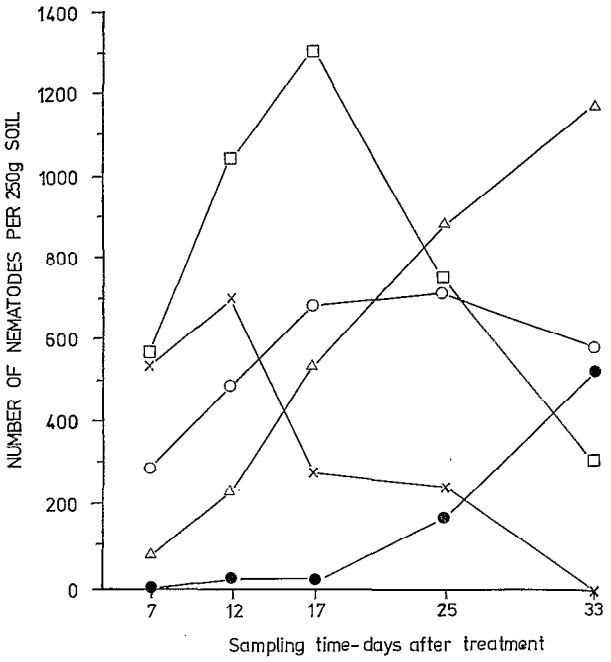

Fig. 2. The numbers of second stage juveniles of *G. rostochiensis* recovered from 250 g moist soil at different time intervals after application of nematicides.
Squares : 1ppm carbofuran ; white circles : 2ppm carbofuran ; triangles : 4ppm carbofuran ; black circles : 2ppm aldicarb ; crosses : untreated.

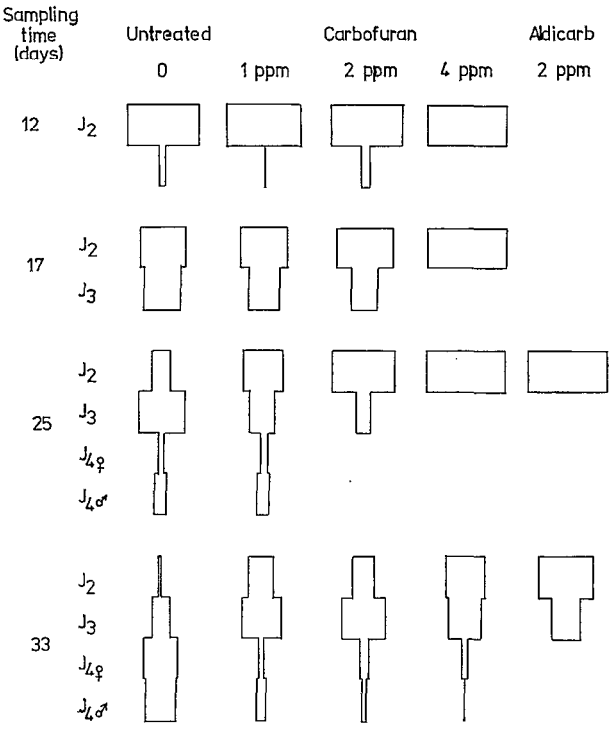

Fig. 3. The population structure of different juvenile stages of *G. rostochiensis* in potato roots grown in soil treated with carbofuran and aldicarb.

The delay observed in hatching was also reflected in the numbers of second stage juveniles recovered from the soil (Fig. 2) particularly during the first two weeks after treatment. It was also apparent that the number of juveniles extracted was increasing with time at 4 mg/kg of carbofuran and 2 mg/kg of aldicarb indicating that juveniles were not entering roots but were accumulating in the soil. The delay in hatching and the prevention of invasion was also reflected in the numbers of different juvenile stages found in the roots (Fig. 3); 31 days after the application of the nematicides there were more second and third stage juveniles in the treated roots than in the untreated ; very few fourth stage nematodes were recovered from the treated roots.

Ten weeks after treatment the final population was determined (Tab. 2). Carbofuran at 4 mg/kg markedly reduced the population and decreased the number of eggs per cyst, but aldicarb at 2 mg/kg was more effective.

The results of the second experiment are shown in Table 3. Carbofuran is most effective in the sandy soil but at 8 mg/kg control was excellent in three soil types ; the nematodes did not multiply in the clay soil.

Discussion

Hague (1979) discussed techniques for evaluating the efficacy of non-volatile nematicides against *G. rostochiensis*. In this paper two additional methods of assessing the performance of a nematicide are presented. The main activity of non-volatile nematicides has been shown to be against the soil phase of the life cycle of plant parasitic nematodes (Whitehead, 1973) and thus techniques which evaluated effects on the hatching process in potato cyst nematodes are necessary to understand the mode of action of the nematicide. Regression analysis (Fig. 1) is a useful way of assessing both the effectiveness of the treatment and also illustrating the delay in emergence due to the nematicidal treatment.

Table 2

The effect of carbofuran and aldicarb on the final population of *G. rostochiensis*

Treatments	*Untreated*		*Carbofuran*		*Aldicarb*	*Initial Population*
Concentrations mg/kg	0	1	2	4	2	
No. of cysts in 100 g soil	1029	469	169	59	28	20
No. of eggs/cyst	199.5	176	135.5	85.5	86.5	163
No. of eggs/g soil	2052	825.4	229	50.4	24.2	32
Multiplication rate in terms of eggs/g	63.13	24.8	6.16	9.58	0	—
% reduction in population estimated as eggs/g		59.8	88.9	97.5	98.8	—

Table 3

The final population of *G. rostochiensis* (eggs per g soil) after application of carbofuran to 4 soil types

Carbofuran Concentration (mg/kg^{-1} of soil)	*Number of eggs per g of soil* *Loamy Sand*	*Silty Loam*	*Peat*	*Silty Clay*
2	9.9 ***	58.8 *	277.9 *	44.7
4	5.7 ***	34.1 **	79.5 **	19.5
8	6.7 ***	66.4 *	34.7 ***	21.6
Untreated	904.7	320.5	976	28.1

Initial population = 30 eggs per g of soil.
*, **, *** significantly less than untreated at P = 0.05, 0.01 & 0.001 respectively ; vertical comparison only.

Non-volatile nematicides may also affect the development of nematodes in the root system and thus the population structure illustrated in Fig. 3 is a simple way of understanding how the chemical is affecting the nematode.

Disanzo (1973) working with *Meloidogyne incognita* and *Pratylenchus penetrans* reported that more nematodes were recovered from treated soil after ten and fifteen days than from untreated soil : similar effects were observed in the present work with *G. rostochiensis*. The second stage juveniles which accumulated in the treated soil at 4 mg/kg (Fig. 2) do not all finally enter the roots and thus, as suggested by Disanzo, the reduction in the nematode population may be attributed to starvation or to a combination of starvation caused by disorientation of the nematode in its search for the root system and possibly sublethal toxicity.

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The nematicidal activity of carbofuran as a soil application seems to be similar to that of oxamyl (Boparai & Hague, 1974) and aldicarb (Hague & Pain, 1973), but aldicarb is a more effective nematicide.

Carbofuran gave reasonable control of potato cyst nematode in loamy sand, silty loam and peat soils but clearly was most effective in the sandy soil. A simple pot test in different soil types would quickly eliminate nematicides likely to be unsuitable under field conditions.

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