DISTRIBUTION OF NEMATICIDES IN SOIL AND ITS INFLUENCE ON THE CONTROL OF SUGARBEET CYST NEMATODE *HETERODERA SCHACHTII* AND ROOT-KNOT NEMATODE *MELOIDOGYNE INCOGNITA*

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ABSTRACT

Garabedian, S., and N. Hague. 1982. Distribution of nematicides in soil and its influence on the control of sugarbeet cyst nematode *Heterodera schachtii* and root-knot nematode *Meloidogyne incognita.* Nematropica 12:313-318.

The effect of distribution of nonvolatile nematicides on the control of root-knot rematode, *Meloidogyne incognita* (Kofoid & White) Chitwood on tomato, and the sugarbeet cyst nematode, *Heterodera schachtii* Schmidt on sugarbeet, was tested in the greenhouse using 20 cm diam plastic pots. Variation of distribution patterns is unlikely to limit the efficacy of aldicarb and oxamyl, but can limit the efficacy of carbofuran and terbufos. These differences can be attributed to the greater mobility of aldicarb and oxamyl in soil. However, it was clearly demonstrated that all four nematicides effectively prevented nematode invasion of the roots, when the nematodes were in contact with the nematicides.
Additional key words: nematode control, application methods, aldicarb, oxamyl, carbofuran, terbufos.

RESUMEN

Garabedian, S., y N. Hague. 1982. La distribución de nematicidas en el suelo y su influencia sobre el grado de combate del nematodo enquistador *Heterodera shachtii* y el de las agallas *Meloidogyne incognita.* Nematrópica 12:313-318.

Se estudió a nivel de invernadero con macetas plásticas de 20-cm de diámetro el efecto de la distribución de nematicidas no volatiles sobre el combate del nematodo nodulador *Meloidogyne incognita* (Kofoid & White) Chitwood en tomate y sobre el del enquistador *Heterodera shachtii* Schmidt en remolacha azucarera. Las variaciones en las formas de distribución de los nematicidas no parecieron afectar las eficacias de aldicarb o oxamil, pero si las de carbofurán y de terbufos. Estas diferencias se pueden atribuir a una mayor mobilidad de aldicarb y oxamil en el suelo. Aún asi, se demostró conclusivamente que los cuatro nematicidas pueden impedir la invasión de las raíces por los nematodos cuando éstos

entraron en contacto con los nematicidas.
Palabras claves adicionales: combate de nematodos, métodos de aplicación, Temik, Vydate, Furadan, Counter.

INTRODUCTION

Organophosphate and carbamate compounds, although systemic, are known to exert their major effect on nematodes in the soil (4) by preventing them from successfully locating and invading the roots. Nematode control is greatly affected by the choice and dosage of nematicides and application method. No single nematicide is suitable for controlling all nematode species and application strategy will depend upon the species to be controlled. Uniformity of granule distribution in the soil affects the efficacy of oxamyl and phenamiphos differently (3). Whitehead *et al* (8), observed that row treatments with aldicarb failed to control potato cyst nematode, *Globodera rostochiensis* Weber. Aldicarb and oxamyl prevented early invasion and damage to sugarbeet seedlings by *Heterodera schachtii* Schmidt, when amounts of these chemicals were mixed with the top 15 cm of the soil rather than placed around the roots of young plants (9). The ability of aldicarb and carbofuran to control root-knot nematode on tomato below the depth of incorporation was varied. Spot applications however were more effective than row treatments (1,5). The purpose of this study was to compare different patterns in distribution of non-volatile nematicides on the control of root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood, and the sugarbeet cyst nematode, *H. schachtii.*

MATERIALS AND METHODS

Plastic pots of 20 cm diameter were filled to a depth of 18 cm with 2500 gm of sandy loam soil (40% sand + 60% loam). To minimize leaching of the chemicals, the bottom 2 cm of each pot was filled with loam. Heavy infestations of both nematode species were used in this experiment with relatively low concentrations of nematicides. Each pot was either inoculated with 32 egg masses of *M. incognita* (average 356 eggs/egg mass) to give a population approximately equivalent to 4.6 eggs/gm soil or 220 cysts of *H. schachtii* containing an average of 185 eggs/cyst to give a population of 16 eggs/gm soil.

Four nonvolatile nematicides, aldicarb 15 G (2-methyl-2-(methylthio)propionaldehyde-0-methylcarbamoyloxime), oxamyl 24L (N,N-dimethyl-2-methylcarbamoyloxyimino-2-(methylthio)acetamide), carbofuran (2,3-dihydro-2,2-dimethylbenzofuran-7-yl methylcarbamate) and terbufos 20 G (S-tert-butylthiomethyl 0,0-diethyl phosphorodithioate), were used at the rate of 15 mg granules per pot. Soil for the individual pots was treated separately, granular nematicides being added to the soil according to the following 5 distribution patterns:

A. *Surface application:* cysts or egg masses were mixed with the soil, then the granules were distributed over the soil surface and incorporated to a depth of 1-2 cm.
B. *Uniform distribution:* cysts or egg masses were mixed with soil in which granules had previously been incorporated manually into the volume of the soil.
C. *Uniform distribution:* cysts or egg masses were added around the root system by injection into 3 holes; granule distribution same as in B.
D. *Spot application:* both granules and cysts or egg masses were placed manually around the root system of sugarbeet or tomato seedlings.
E. *Spot application:* cysts or egg masses were mixed with the soil; granules were placed manually around the root system.

Untreated pots inoculated with *M. incognita* and *H. schachtii* and planted with tomatoes and sugarbeets served as controls.

Two-week-old seedlings of tomato, cv "Money Maker," and sugarbeet, cv "Amono," were transplanted into pots either before adding the granules to the soil (treatments A, D and E) or immediately after the granules were thoroughly mixed with the soil manually as in treatments B and C.

Pots were placed in a growth room at a temperature of 23 ± 2° C. Each pot received 300 ml of Hoagland's solution once a week; pots were watered approximately every 48 hrs with 500 ml of water.

Thirty-two days after treatment, the plants were removed with the roots washed, stained in 0.1% hot acid fuschin, and cleared in lactophenol 4:1 (6). Stained roots were macerated in a Silverson® blender for 45 sec at high speed to release fourth stage females.

RESULTS

All four nematicides reduced larval invasion into tomato and sugarbeet seedlings (Table 1). Aldicarb and oxamyl were the most effective of the four nematicides against both species. The pattern of granule distribution had an effect on all of the 4 nematicides; carbofuran and terbufos were the most affected.

The best aldicarb treatment (D) reduced the number of females by 90% with *M. incognita* and 89% with *H. schachtii.* In all 5 distribution patterns there were fewer females of both species in the roots compared with the controls (Table 1).

Oxamyl reduced the number of females in roots of both tomato and sugarbeet and was affected more by the different patterns of distribution than aldicarb. The best oxamyl treatment (D) reduced *M. incognita* females by 90% and *H. schachtii* females by 89% (Table 1). Generally, oxamyl in treatments A, B and C was more effective against cysts than against egg masses.

Carbofuran in all treatments, except A, was more effective against cysts than against egg masses. The most effective treatment to control both *M. incognita* and *H. schachtii* was (D); it reduced the number of females by 85% and 91%, respectively (Table 1).

Table 1. Number of females of *Meloidogyne incognita*[x] and *Heterodera schachtii*[y] on tomato and sugarbeet roots (percentage of control of the nematodes).

Distribution Patterns	Aldicarb M.I.	Aldicarb H.S.	Oxamyl M.I.	Oxamyl H.S.	Carbofuran M.I.	Carbofuran H.S.	Terbufos M.I.	Terbufos H.S.
A-Surface Application	35*	46*	42*	54**	27	17	23	22
B-Uniform Distribution	51**	88***	49**	80***	38*	86***	22	51**
C-Uniform Distribution	46**	54***	86*	52***	28	45**	19	38*
D-Spot Application	89***	90***	90***	89***	85***	91***	50**	84***
E-Spot Application	55**	84***	45*	55*	51**	85***	21	50*

M.I. = *Meloidogyne incognita*
H.S. = *Heterodera schachtii*
*,**,*** = Significantly less than untreated plants at $p<0.05$, 0.01 and 0.001 respectively (horizontal comparison only).
[x]Mean of 622 females in untreated plants inoculated with *M. incognita.*
[y]Mean of 4,570 females in untreated plants inoculated with *H. schachtii.*

Terbufos needed actual contact with the nematodes in order to perform against both cysts and egg masses. In all 5 distribution patterns, it was more effective against *H. schachtii* than against *M. incognita.* In treatment D, terbufos reduced females of *H. schachtii* by 84%, but did not reduce the number of *M. incognita* females below 50%.

DISCUSSION

The distribution of nonvolatile nematicides in the soil is an important factor affecting nematode control. It is clearly indicated in this study that all 4 nematicides prevented invasion effectively when the nematode was in actual contact with the nematicide granules (D). This indicates that nonvolatile nematicides exert their effect by contact in the soil rather than by systemic action through the plant, a suggestion which is in accordance with previous findings (9). Therefore, information as to the position of the target organism in the soil relative to the plant root is critical to selection of the nematicides to be used and the method of application (7).

The distribution of granules in pots used in this study was more regular than normally found in field experiments. In order to provide greater sensitivity and avoid differences caused by uneven distribution of excessive amounts of chemical, only moderate dosages were used (1.5 mg a.i./pot). Despite the limitation of such pot experiments and the uniformity of granule distribution, the efficacy of aldicarb and oxamyl differed from that of carbofuran and terbufos.

In the field, it is necessary to have the nematicide properly distributed in the rooting zone when infective juveniles are moving toward the roots. This may be achieved by mixing the chemical thoroughly with the soil, or if the chemical is sufficiently mobile through redistribution by diffusion or leaching in the interval between application and nematode invasion of the plant. Thus, the effective control of aldicarb and oxamyl against both *M. incognita* and *H. schachtii* in all distribution patterns, except surface treatment, can be mainly attributed to their high solubility in soil water. Movement of nonvolatile nematicides depends on their Q-value (partition coefficient) and not on their water solubility *per se*. The smaller the Q-value, the greater potential mobility of the chemical in soil (2). Aldicarb and oxamyl have small Q-values ($\cong$10, respectively), so that a greater proportion of the chemical is in the soil solution, thus the potential mobility of the chemical is greater. The poor performance of carbofuran in some treatments may be attributed partly to its high Q-value, which was predicted as 31 (2); also, the applications of carbofuran and terbufos with distribution pattern (A) were ineffective against *M. incognita* juveniles. This could be because these juveniles were rapidly released from the egg mass and were able to invade roots of tomato before carbofuran or terbufos became available in soil water.

The differences in behavior of the 4 chemicals may be attributed to the differences in their mobility in the soil. In the sandy loam soil used in this study, aldicarb and oxamyl were probably weakly adsorbed, therefore potentially very mobile, whereas carbofuran and terbufos were possibly more strongly adsorbed and, thus, less mobile.

LITERATURE CITED

1. BRODIE, B.B. 1971. Differential vertical movement of nonvolatile nematicides in soil. J. Nematol. 3:292-295.
2. BROMILOW, R.H. 1980. Behavior of nematicides in soils and plants. Nematicide workshop manual. Rothamsted Exp. Sta. pp 87-116.
3. BROMILOW, R.H. and K.A. LORD. 1979. Distribution of nematicides and its influence on control of cyst nematode (*Globodera* and *Heterodera* spp.). Ann. Appl. Biol. 92:93-104.
4. HAGUE, N.G.M. and B.F. PAIN. 1973. The effect of organophosphorus compounds and oxime carbamates on the potato cyst nematode

Heterodera rostochiensis Woll. Pest Sci. 4:459-465.
5. SIVAKUMAR, C.V., P. RAJAGOPLAN, and M. MEERZAINUEEN. 1974. Control of tomato root-knot by spot application of granular systemic nematicides. So. India Hort. 22:5-7.
6. SOUTHEY, J.F. 1970. Laboratory Methods for Work with Plant and Soil Nematodes. Tech. Bull. No. 2. Min. of Agric. Fish & Food, London, H.M.S.O. 148 pp.
7. VAN GUNDY, S.D. and M.V. MCKENRY. 1977. Action of nematides. pp 263-282. In Plant Disease Advanced Treatise, Vol. I. How disease is managed. J.G. Horsfall and E.B. Cowling, eds. Acad. Press, New York.
8. WHITEHEAD, A.G., R.H. BROMILOW, K.A. LORD, S.R. MOSS, and J. SMITH. 1975. Incorporating granular nematicides in soil. Proc. 8th Brit. Insect and Fungi Conf. pp 133-144.
9. WHITEHEAD, A.G., D.J. TITE, P.H. FINCH, J.E. FRASER and M.E. FRENCH. 1979. Chemical control of beet cyst-nematode, *Heterodera schachtii* in some peaty loam soils. Ann. Appl. Biol. 92:73-79.

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