In-Vitro and In-Vivo Effects of Aldicarb on Survival and Development of Heterodera schachtii

ARNOLD E. STEELE and LARRY R. HODGES[1]

Abstract: Aqueous solutions of 5-500 μg/ml aldicarb inhibited hatching of *Heterodera schachtii.* Addition of hatching agents, zinc chloride, or sugarbeet root diffusate, to the aldicarb solutions did not decrease the inhibition of hatching. When cysts were removed from the aldicarb solutions and then treated for 4 wk in sugarbeet root diffusate, larvae hatched and emerged. Treatments of newly hatched larvae of *H. schachtii* with 5-100 μg/ml aldicarb depressed later development of larvae on sugarbeet (*Beta vulgaris*). Similar treatments with aldicarb sulfoxide had less effect on larval development, and aldicarb sulfone had no effect. Numbers of treated larvae that survived and developed were inversely proportional to concentration (0.1-5.0 μg/ml) and duration (0-14 days) of aldicarb treatments. Development of *H. schachtii* on sugarbeet grown in aldicarb-treated soil was inversely proportional to the concentration of aldicarb in the tested range of 0.75 - 3.0 μg aldicarb/g of soil. Transfer of nematode-infected plants to soil with aldicarb retarded nematode development, whereas transfer of plants first grownin treated soil to nematode-infested soil only slightly suppressed nematode development. Development of *H. schachtii* was inhibited in slices of storage roots of table beet (*B. vulgaris*), sugarbeet and turnip, (*Brassica rapa*), that had grown in soil treated with aldicarb. *Key Words:* sugarbeet nematode, culture, diffusate.

A number of nematode species are effectively controlled with aldicarb [2-methyl-2-(methylthio)propionaldehyde-*O*-(methylcarbamoyl) oxime] (1, 2, 15, 18, 24). Its known systemic insecticidal action suggests that it may act in a similar manner against nematodes. Results of one study indicated that aldicarb may control cyst-forming nematodes after they have entered the roots (16). Treatment of infected potato plants in solutions of aldicarb for 1 day caused second-stage larvae (L2) to emigrate from roots when plants were later transferred to nutrient solution.

Other studies suggest that aldicarb acts directly on nematodes in soil and not indirectly through the host (9, 10), Soil treatments with aldicarb prevented invasion of potato roots by *Heterodera rostochiensis* Wollenweber, resulting in accumulation of L2 in the soil (17). Drenches of 5 μg/ml aldicarb on potted infested soil inhibited hatching of *H. rostochiensis* for 1-2 wk. After that, nematodes rapidly emerged up to 5 wk (8). Aldicarb in potato root diffusate suppressed hatching of *H. rostochiensis.* Later, hatching was initiated by treatment of cysts with diffusate alone. Almost no nematodes hatched from cysts treated with diffusate alone after 12 wk in aldicarb (14). However, aldicarb in soil rapidly oxidizes to aldicarb sulfoxide [2-methyl-2-(methylsulfinyl)propionaldehyde-*O*-(methylcarbamoyl)oxime], which is partially oxidized to aldicarb sulfone [2-methyl-2-(methylsulfonyl) propionaldehyde-*O*-(methylcarbamoyl)oxime]. The sulfoxide is the main active material with a half-life of about 2 wk in soil (3) and 1 wk in plants (4).

Solutions of 1 μg/ml aldicarb partially reduced hatching of *Heterodera schachtii* Schmidt, but 5 μg/ml completely suppressed hatching, and L2 exposed to 10 μg/ml could no longer move normally (22). In this study, the residual effects on hatching were not tested, and it was not determined if treated larvae could enter host plant roots.

Information on the modes of action of aldicarb on *H. schachtii* is needed. In addition, the question of whether or not aldicarb may act systemically to control nematodes within roots of host plants has not been satisfactorily answered. For these reasons, a study was undertaken to determine (i) how aldicarb immediately and residually affects hatching of *H. schachtii,* (ii) how concentration and duration of exposure of hatched L2 to aldicarb affect their penetration and development in sugarbeet *Beta vulgaris* L., and (iii) whether or not development of *H. schachtii* within roots of sugarbeet can be influenced by systemic action of aldicarb.

MATERIALS AND METHODS

Effects of aqueous solutions of aldicarb on hatching and emergence of larvae from cysts: Two tests investigated the effects of aldicarb

Received for publication 24 February 1975.

[1]Nematologists, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 5098; and Union Carbide Corporation, P.O. Box 1906; both at Salinas, California 93901.

The authors thank Madeline Guernsey for her technical assistance. Mention of a proprietary product does not constitute a guarantee or warranty of that product by the U.S. Department of Agriculture, and it does not imply approval of it to the exclusion of other products that may also be suitable.

with and without synthetic or natural hatching agents on hatching and emergence of L2. Hatching agents used were 4mM zinc chloride (5) or sugarbeet root diffusate. Newly formed cysts of *H. schachtii* were separated from soil and root debris and stored 10 days at 8 C by methods previously described (19). Groups of 20 intact cysts were incubated in 5 ml of treatment solution in small sieves (collection cups, Hykro Pet Industries, Esbjerg, Denmark) enclosed by plastic portion cups (Thunderbird Container Corp., El Paso, Texas 79912).

In one test, concentrations of 0.01, 0.05, 0.10, 0.50, 1.0, and 5.0 μg/ml aldicarb were evaluated (analytical grade chemicals supplied by Union Carbide Corporation, Salinas, California 93901). Cysts were treated 2 wk in aldicarb solutions with or without sugarbeet root diffusate, transferred through three changes of tap water, and again incubated 2 wk in solutions without aldicarb. The test was replicated six times. In a second test, cysts were treated 4 days with 10, 50, 250, or 500 μg/ml aldicarb with or without hatching agents, transferred through three changes of tap water during a period of 4 days and then incubated 4 wk in sugarbeet root diffusate. This test was replicated four times; each replicate was comprised of 20 cysts. Data of both tests were subjected to analysis of variance, and Duncan's multiple range test.

Effects of aldicarb and its oxides on survival and subsequent development of hatched L2: Newly hatched larvae were treated for 24 h with water solutions of 0, 5, 25, 50, or 100 μg/ml aldicarb, aldicarb sulfoxide, or aldicarb sulfone and thoroughly washed with several liters of tap water. Treated and nontreated L2 were inoculated on roots of sugarbeet transplanted to a steam-sterilized sand-soil mixture 10 days after germination. Thirty-two days after inoculation, sugarbeet plants were harvested, and roots and soil were examined for adult female *H. schachtii.*

Another test evaluated how treating L2 with water solutions of 0.1, 1.0, 2.0, and 5.0 μg/ml aldicarb for 4, 8, and 14 days affected development of adult *H. schachtii* females on sugarbeet roots. Both tests were replicated five times.

Effects of soil treatments of aldicarb on penetration and development of H. schachtii on sugarbeet: Temik®, 10% granular aldicarb pesticide, was incorporated into a steam-sterilized sand-soil mixture with a twin shell laboratory blender. In one test, we studied how growing sugarbeet in potting medium with 6 μg/g aldicarb affected penetration and development of *H. schachtii.* Ten-day-old sugarbeet seedlings germinated in sterilized sand were transplanted to individual 20-cm clay pots which contained 5.2 kg treated or nontreated potting medium. Brown cysts with eggs and L2 were broken open, and the cyst walls and contents were placed 2.5 cm below the soil surface at the time of transplanting. Treatments were replicated eight times. Each pot received at first 1,500 ml of water, and thereafter only enough was added to maintain proper plant growth without leaching aldicarb or its oxides from the pots. Fifteen and 45 days after inoculation, plant roots were examined for L2-L4 and adults. Males emerged from roots were counted from plants harvested 16 days after transplanting and incubated 8 days with roots submerged in water as described previously (21).

A second test evaluated rates of 0.75, 1.50, and 3.0 μg/g aldicarb in soil on production of adult female *H. schachtii.* Each treatment was replicated seven times, and each replication included two plants. Forty-five days after inoculation, the plants were harvested, and the roots and soil were examined for adult female nematodes.

A third test was made to determine if aldicarb acts systemically in sugarbeet roots. Sugarbeets were grown for 14 or 21 days in a sand-soil mixture with 6 μg/g aldicarb (incorporated as 10% granular formulation), transplanted to nontreated soil, and inoculated with 30 viable cysts per plant. In this test, sugarbeets were also transplanted to a sand-soil mixture with 6 μg/g aldicarb, 5, 10, and 15 days after being inoculated with 30 cysts per plant. Sugarbeets were also inoculated with nematode cysts and grown 30 days in soil with or without 6 μg/g aldicarb. The 14 treatments were replicated eight times. All plants were harvested 30 days after the last transplanting, and the roots and soil were examined for larvae or adults of *H. schachtii,* or both. Larvae were counted from roots stained in boiling lactophenol-acid fuchsin and macerated in a Waring Blendor. Except as noted, the methods used in the tests of aldicarb in soil were the same.

Systemic action of aldicarb in storage roots of host plants: Two other tests were designed to determine if systemic nematicidal activity

of aldicarb could be detected in the storage roots of 'Detroit Dark Red' table beet (*Beta vulgaris* L.), 'U.S. 75' sugarbeet (*B. vulgaris* L.), and 'Purple Top White Globe' turnip (*Brassica rapa* L.). In the first test, we used red table beets with storage roots varying from 4- to 6-cm in diameter. The beets were washed, and lateral roots were removed. The beets were then transplanted to 15-cm diameter clay pots which contained steam-sterilized nontreated soil or soil with 6 μg/g aldicarb incorporated as previously described. After the plants had grown for 14 days in a greenhouse, green peach aphids (*Myzus persicae* Sulzer) were placed on the leaves. The aphids were contained in small nylon-screened feeding cages that were clipped to leaves. After 24 h, the cages were removed, and the aphids were examined to determine mortality rates.

After this bioassay confirmed the presence of aldicarb in leaf tissues, the leaves, petioles, and lateral roots were removed from storage roots of each of six plants. To obtain two root-

TABLE 1. Effects of aldicarb on hatching of *Heterodera schachtii*.[a]

Conc aldicarb (μg/ml)	1-14 days in aqueous soln's of aldicarb	15-28 days in water	Total Hatch	1-14 days in diffusate containing aldicarb	15-28 days in diffusate alone	Total Hatch
0	152 vw	42 z	193 tu	1,044 xy	133 z	1,177 xy
0.01	400 wx	101 z	501 uv	1,631 z	131 z	1,762 z
0.05	567 x	167 z	733 vw	1,255 yz	147 z	1,403 y
0.10	436 wx	53 z	488 uv	870 x	155 z	1,025 wx
0.50	207 vw	241 yz	448 tuv	500 w	544 y	1,044 wx
1.00	91 v	226 z	317 tu	326 vw	960 x	1,286 xy
5.00	3 v	166 z	169 t	11 v	1,017 x	1,028 wx

[a]Mean numbers of larvae emerged from six replications of 20 cysts. Common small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly, $P = 0.05$. Only means within the same treatment period are compared.

TABLE 2. Influence of pretreatment of *Heterodera schachtii* cysts with solutions containing aldicarb and/or hatching agents on later emergence of larvae from cysts in sugarbeet root diffusate.[a]

Pretreatment medium	Conc aldicarb (μg/ml)	Mean no. larvae/treatment[b] Pretreatment solution	Water	Diffusate	Mean larval emergence[c]
Distilled water	0	363 x	73 x	1,679 twx	2,114 wx
	10	6 w	22 x	2,157 wxyz	2,186 wxy
	50	1 w	0	2,655 xyz	2,656 wxyz
	250	2 w	0	2,399 wxyz	2,400 wxyz
	500	1 w	0	2,367 wxyz	2,368 wxyz
Zinc chloride solution	0	938 y	399 xy	1,064 stw	2,401 wxyz
	10	0 w	1,508 z	986 st	2,494 wxyz
	50	0 w	258 x	1,796 twx	2,054 wx
	250	0 w	0 x	2,590 wxyz	2,590 wxyz
	500	0 w	0 x	1,898 wxy	1,898 w
Sugarbeet-root diffusate	0	2,330 z	295 x	559 s	3,183 xyz
	10	0 w	125 x	2,280 wxyz	2,405 wxyz
	50	0 w	16 x	2,828 yz	2,844 xyz
	250	0 w	0 x	2,930 z	2,930 xyz
	500	0 w	0 x	3,014 z	3,014 xyz

[a]Cysts were incubated for 4 days in distilled water, 4 mM zinc chloride, or sugarbeet-root diffusate containing the indicated concentrations of aldicarb. Then they were incubated 1 wk in distilled water, followed by 4 wk in sugarbeet-root diffusate.
[b]Different letters indicate Duncan's multiple groupings of treatments that differ significantly, $P = 0.05$.
[c]Value is the mean number of larvae emerged from four replications of 20 cysts in pretreatment solution, water, and sugarbeet-root diffusate.

TABLE 3. Number of adult female *Heterodera schachtii* per plant 32 days after inoculation of second-stage larvae treated 24 h with oxime carbamates.

Conc (μg/ml)	Aldicarb	Aldicarb sulfoxide	Aldicarb sulfone
0	42[a] z	...	...
5	17 twx	26 xyz	40 z
10	3 t	17 twx	32 xyz
25	8 tw	16 twx	38 z
50	3 t	23 w	36 yz
100	9 tw	20 wxy	30 xyz

[a]Values given are means of five plants. Different letters indicate Duncan's multiple groupings of treatments that differ significantly, $P = 0.05$.

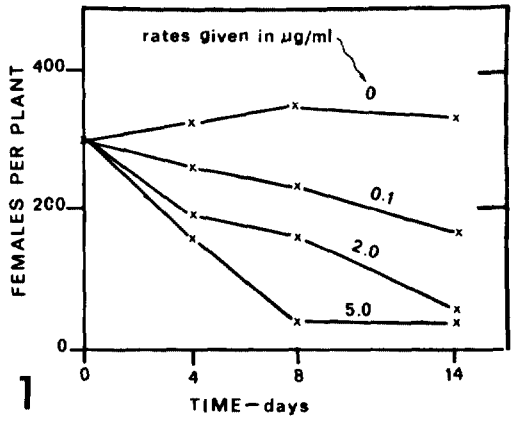
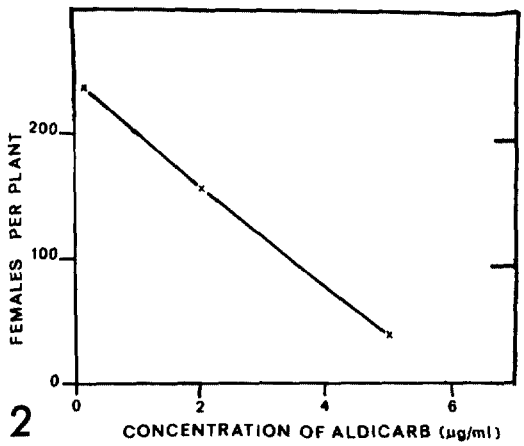


FIG. 1. Influence of duration of exposure of second-stage larvae of *Heterodera schachtii* to selected concentrations of aldicarb on later development of females on sugarbeet.

halves, the storage root of each of six plants grown in treated or nontreated soil was cut transversely midway between the crown and root tip. The sliced surface of each root fragment was inoculated with eggs and larvae of 30 broken cysts with a hatch potential of about 250 larvae per cyst, placed in loosely-capped sterile crystallizing dishes, and incubated in a chamber kept at 100% relative humidity and 24 C (20). After 25 days, the slices were examined for nematode developmental stages. This test was repeated with table beet, sugarbeet, and turnip, but the preliminary bioassay with aphids was omitted.

RESULTS

Effects of aqueous solutions of aldicarb on hatching and emergence of larvae from cysts: Treatments of 0.01 and 0.05 μg/ml aldicarb stimulated hatching and emergence of larvae from cysts of *H. schachtii* (Table 1).



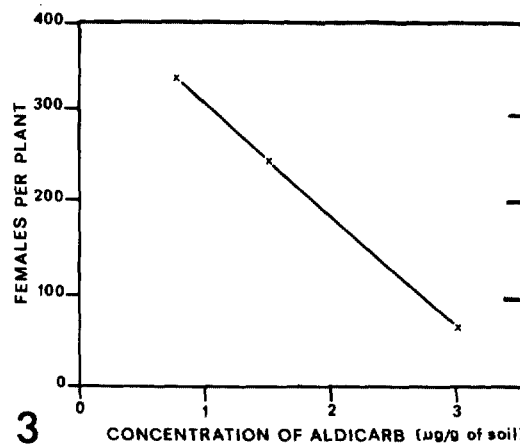


FIG. 2-3. 2) Influence of exposure of second-stage larvae of *Heterodera schachtii* to selected concentrations of aldicarb for 8 days on later development of females on sugarbeet. 3) Influence of concentration of aldicarb in soil mix on development of *Heterodera schachtii* females on sugarbeet.

Addition of 1.0-500 μg/ml aldicarb to solutions containing 4 mM zinc chloride, or to sugarbeet-root diffusate inhibited hatching and emergence of L2 (Tables 1 and 2). Replacement of these solutions with water or sugarbeet-root diffusate without aldicarb added resulted in a return to normal levels of hatching. These tests show that whereas low concentrations of aldicarb may stimulate hatch, high concentrations may temporarily inhibit hatch, even in the presence of hatch-promoting substances. However, in a similar test, treatments of up to 1,000 μg/ml aldicarb, aldicarb sulfoxide, or aldicarb sulfone for 1 wk failed to kill nonhatched larvae within cysts (Steele and Hodges, *unpublished*).

Effects of aldicarb and its oxides on survival and subsequent development of hatched L2: Treatment with 5-100 μg/ml aldicarb or aldicarb sulfoxide subsequently suppressed development of adult females on sugarbeet (Table 3). Aldicarb sulfone had no measurable effect on larval development. Effects of aldicarb on L2 were proportional to the duration of exposure (Fig. 1) and to concentration (Fig. 2).

Effects of soil treatments of aldicarb on penetration and development of H. schachtii on sugarbeet: Soil treatments of aldicarb greatly depressed penetration of *H. schachtii* larvae. The mean numbers of nematodes recovered from plants grown in aldicarb-treated soil were 1.6 larvae, 0.4 adult males, and 0.5 adult females. In contrast, 176.1 larvae, 94.6 adult males, and 158.5 adult females were found on plants grown in nontreated soil. Only three males in the fourth stage of larval development were found in the roots of two of seven plants examined after growing 15 days in soil with 6 μg/g aldicarb. Two of eight plants grown 18 days in aldicarb-treated soil had three L4 females.

Examination of sugarbeet plants inoculated with *H. schachtii* and grown 30 days in nontreated soil after an initial growth of 14 or 21 days in soil with 6 μg/g aldicarb or nontreated soil revealed that the aldicarb treatments only slightly, but significantly, reduced the numbers of nematodes (Table 4). However, penetration of L2 may have been delayed in plants grown 14 days in aldicarb-treated soil. Transfer of plants infected for 5, 10, or 15 days with *H. schachtii* to soil with aldicarb greatly reduced the numbers of all larval stages and adults parasitizing sugarbeet as compared to controls.

Systemic action of aldicarb in storage roots of host plants: Only 9% of the aphids were alive 24 h after they were allowed to feed on leaves of table beet grown 21 days in soil that at first had 6 μg/g aldicarb. In contrast, 90% of the aphids survived after feeding 24 h on

TABLE 4. Influences of aldicarb and/or its oxides within roots of sugarbeet on continued development of *Heterodera schachtii* larvae in situ, and on penetration and development of migrating larvae.

Treatment no.[a]	Initial treatment		Subsequent chemical treatment	Mean numbers of nematodes[b]				
	Chemical	Duration (days)		L2	L3	L4	Adults	All nematodes
1	nontreated	30	...	0	0	0	0	0
2	nontreated	30	...	3.2	17.3	67.7	99.0	187.3 S
3	aldicarb	30	...	6.3	6.6	6.6	2.4	21.9 sT
4	aldicarb	45	...	18.4	4.8	7.9	45.6	76.6 st
5	nontreated	14	nontreated	65.0	1.9	13.8	743.8	824.5 U
6	aldicarb	14	nontreated	53.4	4.8	14.0	585.1	657.4 u
7	nontreated	21	nontreated	170.1	36.0	57.4	731.4	995.0 V
8	aldicarb	21	nontreated	101.8	16.8	32.1	718.9	869.5 v
9	nontreated	5	nontreated	0.3	2.4	9.1	8.9	21.1 WZ
10	nontreated	5	aldicarb	0	0	0	0.1	0.1 w
11	nontreated	10	nontreated	1.8	6.6	11.8	18.0	38.2 XZ
12	nontreated	10	aldicarb	0.1	1.1	0.8	0.4	2.4 x
13	nontreated	15	nontreated	19.0	62.0	202.5	23.6	307.1 Yz
14	nontreated	15	aldicarb	0.1	0.8	0.1	4.6	5.6 y

[a]Treatment 1 was not inoculated on either transplanting date. Treatments 5-8 were inoculated on the second transplanting date. All other treatments were inoculated on the first transplanting date. Inoculated plants received 30 cysts/plant. Plants were grown in nontreated soil or soil with 6 μg aldicarb/g soil as indicated. Plants of treatments 1-4 harvested at end of first treatment period.

[b]Means of eight replications. L2 = second-stage larvae; L3 = third-stage; L4 = fourth-stage; obtained from roots 30 days after initial or subsequent treatments. Adults include males, females, and brown cysts. Only means tagged with the same letter compared. Means tagged with unlike case letters differ significantly, $P = 0.05$.

TABLE 5. Numbers of third- and fourth-stage (L3 and L4) *Heterodera schachtii* on root slices of various host plants grown in nontreated soil or soil treated with 6 μg/g aldicarb.[a]

Test plant	Treatment	L3 and L4[b]	Adults	Total[c]
Table beet	Aldicarb	0	0	0 x
	Nontreated	54	227	281 z
Sugarbeet	Aldicarb	0	0	0 x
	Nontreated	2	67	69 y
Turnip	Aldicarb	0	0	0 x
	Nontreated	37	179	216 z

[a]Plants were grown for 21 days in soil, their roots were sliced and inoculated with cysts and incubated for 25days at 24 C.
[b]Means of six root slices from three plants.
[c]Means tagged with unlike letters differ significantly, $P = 0.05$.

plants grown in nontreated soil. Thus, aldicarb, its oxides, or all three were taken into the plants and translocated to the leaves.

Although large numbers of hatching L2 *H. schachtii* were found on the surfaces of root slices of plants grown in aldicarb-treated soil, only a few larvae had penetrated the slices by the 25th day after inoculation. Similarly, only one developing larva and one adult were found on each of three of the eight root slices of plants treated with aldicarb, whereas means of 55 larvae and 328 adults were recovered from root slices of nontreated plants (Fig. 4, 5). In an additional test, enough aldicarb was taken up by roots of table beet, sugarbeet, and turnip to prevent penetration and development of *H. schachtii* (Table 5).

DISCUSSION

Aqueous solutions of organic and inorganic substances in excess of 10^{-2} M inhibit hatching of *H. rostochiensis* and *H. schachtii,* whereas concentrations in the order of 3-4 M are lethal to nonhatched larvae (7, 23). Inhibition of hatch by solutions with sublethal concentrations of osmotically active substances was reversed by transferring cysts to host root diffusates. Failure of L2 to hatch in the presence of hatching agents with aldicarb or its oxides cannot be accounted for by osmotic effects (5 μg/ml aldicarb is equivalent to a 2.65×10^{-5} M solution). Larvae within eggs of *H. rostochiensis* are stimulated to greater activity by hatching agents, and eventually emerge through an exit slit cut in the egg by repeated thrusts of the nematode stylet (6). Chemical (aldicarb) suppression of movement of hatched larvae with attendant aberrant stylet behavior (11, 12, 13) suggests similar effects on larvae within eggs. However, in this study, in-vitro treatments with aldicarb differentially affected hatching and development of larvae. Hatch inhibition by aldicarb or its oxides was reversible, regardless of concentration or duration of treatment. In contrast, both concentration and duration of treatment markedly influenced survival of hatched L2. Results of one test established that hatching of sugarbeet nematode is stimulated by 0.01-0.05 μg/ml aldicarb. Toxic materials often cause stimulation at relatively minute concentrations. These results suggest that

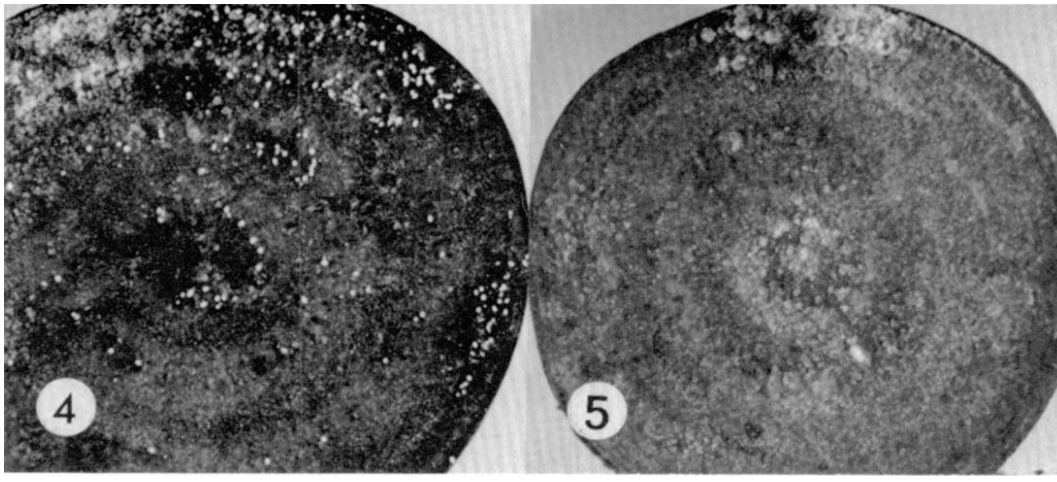


FIG. 4-5. Root slices of table beet grown 21 days in nontreated soil or soil treated with 6 μg/g aldicarb and inoculated with *Heterodera schachtii.* 4) Nontreated. 5) Treated.

sublethal treatments of aldicarb or degradation of treatment levels to concentrations that stimulate hatch may result in higher numbers of L2 invading host plant roots. On the other hand, concentrations of aldicarb that stimulate hatching may also disorient L2 sufficiently to interfere with invasion and development. Drench treatments of 0.05 μg/ml aldicarb failed to increase penetration and development of *H. schachtii* on sugarbeet (data not shown). Interestingly, 0.01 mg/g aldicarb sulfone was detected in tomato roots 16 days after roots were dipped in aldicarb solutions (13). Invasion of roots of treated plants by *M. incognita* was suppressed for more than 2 wk after treatment.

Extrapolation of data illustrated in Fig. 3 suggests that the minimum effective rate of aldicarb required for maximum control of *H. schachtii* in soil is about 3.5 μg/g. With methods used in this study, addition of 3.5 μg/g aldicarb to soil is equivalent to 11.5 μg/ml in the capillary water if all aldicarb were dissolved and removed from the granular carrier. However, this concentration is about twice that required for inhibition of hatching (Table 1) or control of L2 (Fig. 2), suggesting that only about half of the aldicarb in soil is immediately available for bioactivity. Aldicarb is released from its granular carrier within minutes of addition of sufficient soil moisture. However, aldicarb or its oxides may have been temporarily adsorbed on various components of the soil milieu. On the other hand, changes in the rates of conversion of aldicarb to the more soluble aldicarb sulfoxide or to the less toxic aldicarb sulfone may have precluded accumulation of optimum levels of effective toxicants.

Results of in-vitro tests on effects of aldicarb on cysts and L2 suggest that invasion of roots of plants grown in soil with 6 μg/g aldicarb was almost totally suppressed, mainly because hatching was inhibited and, to a lesser extent, because aldicarb acted directly on migrating L2. In-vitro tests established also that soil treatments with aldicarb arrest nematode development after the material is taken into the plant via the root system. Therefore, aldicarb acts both as a contact agent in soil and systemically in plants to prevent or delay the rate of hatching, penetration, and the development of *H. schachtii* in sugarbeet.

Only minimal control can be obtained if aldicarb or its toxic oxides are removed from the soil-root area. Losses of aldicarb carbamates in soil result from metabolic degradation and leaching. These materials are not "bound" in soils, and the direction of movement is determined by gradient moisture pressures. The concentrations of active carbamates in plants near the growing root tips are also reduced by upward translocation and degradation to relatively nontoxic materials. As a result, the materials should be continuously available to the root system for absorption to sustain systemic activity in the plant root. Although aldicarb controls nematodes within roots by systemic action, dynamic factors operating in the plant and soil suggest that the major effects of this material on cyst nematodes occur in the soil external to the plant.

LITERATURE CITED

1. BIRCHFIELD, W. 1971. Systemic nematicides control Rotylenchulus reniformis of cotton. Plant Dis. Rep. 55:362-365.
2. BRODIE, B. B. 1968. Systemic pesticides for control of sting and stubby-root nematodes on vegetables. Plant Dis. Rep. 52:19-23.
3. BROMILOW, R. H. 1973. Breakdown and fate of oxime carbamate nematicides in crops and soils. Ann. Appl. Biol. 75:473-479.
4. BULL, D. L. 1968. Metabolism of UC-21149 [2-methyl-2-(methylthio)propionaldehyde-*O*-(methylcarbamoyl)oxime] in cotton plants and soil in the field. J. Econ. Entomol. 61:1598-1602.
5. CLARK, A. J., and A. M. SHEPHERD. 1965. Zinc and other metallic ions as hatching agents for the beet cyst nematode, Heterodera schachtii Schm. Nature 208:502.
6. DONCASTER, C. L., and A. M. SHEPHERD. 1967. The behavior of second stage Heterodera rostochiensis larvae leading to their emergence from the egg. Nematologica 13:476-478.
7. DROPKIN, V., G. C. MARTIN, and R. W. JOHNSON. 1958. Effect of osmotic concentration on hatching of some plant parasitic nematodes. Nematologica 3:115-126.
8. HAGUE, N. G. M., and B. F. PAIN. 1970. Some observations on the effect of Temik on the potato cyst eelworm, Heterodera rostochiensis Woll. Plant Pathol. 19:69-71.
9. HAGUE, N. G. M., and B. F. PAIN. 1973. The effect of organo-phosphorus compounds and oxime carbamates on the potato cyst nematode Heterodera rostochiensis Woll. Pestic. Sci. 4:459-465.
10. MILLER, P. M. 1970. Failure of several non-volatile and contact nematicides to kill eggs in cysts of Heterodera tabacum. Plant Dis. Rep. 54:781-783.
11. NELMES, A. J. 1970. Behavioral responses of Heterodera rostochiensis larvae to aldicarb and its sulfoxide and sulfone. J. Nematol. 2:223-227.

12. NELMES, A. J., and S. KEERWEEWAN. 1970. The mechanism of aldicarb in controlling root knot nematodes, Meloidogyne incognita, on tomato. Pages 182-183 *in* Proc. 7th Int. Cong. Plant Protection, Paris.
13. NELMES, A. J., D. L. TRUDGILL, and D. C. M. CORBETT. 1973. Chemotherapy in the study of plant parasitic nematodes. Pages 95-112 *in* A. R. Taylor, and R. Muller, eds. Chemotherapeutic agents in the study of parasities. Vol. 2. Proc. Symp. Br. Soc. Parasitol., (Published in Oxford, England).
14. OSBORNE, P. 1973. Effect of aldicarb on the hatching of Heterodera rostochiensis larvae. Nematologica 19:7-14.
15. OUDEN, H. DEN. 1968. Bestrijding van het aardappelcystenaaltje met de systemische nematiciden Temik [2-methyl-2-(methylthio)propionaldehyde-*O*-(methylcarbamoyl)oxime] en Lannate [methyl-*O*-(methylcarbamoyl)thioacetohydroxamaat]. Meded. Fac. Landbouwwet. Rijksuniv., Gent. 33:719-728.
16. OUDEN, H. DEN. 1971. De ontwikkeling van Heterodera rostochiensis larven in aardappelwortels bij behandeling met systemische nematiciden in het bijzonder aldicarb. Meded. Fac. Landbouwwet. Rijksuniv., Gent. 36:889-903.
17. PAIN, B. F., and N. G. M. HAGUE. 1971. The effect of organo-phosphate and carbomyl-oxime nematicides against the potato cyst eelworm Heterodera rostochiensis Woll. Meded. Fac. Landbouwwet. Rijksuniv., Gent. 36:161-173.
18. SPURR, H. W., and A. A. SOUSA. 1966. Pathogenicidal activity of a new carbamoyloxime insecticide. Plant Dis. Rep. 50:424-425.
19. STEELE, A. E. 1972. Evaluation of cyst selection as a means of reducing variation in sugarbeet nematode inocula. J. Am. Soc. Sugar Beet Technol. 17:22-29.
20. STEELE, A. E. 1972. Development of Heterodera schachtii on large rooted crop plants and the significance of root debris as substratum for increasing field infestations. J. Nematol. 4:250-256.
21. STEELE, A. E. 1975. Population dynamics of Heterodera schachtii on tomato and sugarbeet. J. Nematol. 7:105-111.
22. STEUDEL, W. 1972. Versuche zum Einfluss von Aldicarb auf den Schüpfvorgang bei Zystem von Heterodera schachtii nach längerer Einwirkung. Nematologica 18:270-274.
23. WALLACE, H. R. 1956. The emergence of larvae from cysts of the beet eelworm, Heterodera schachtii Schmidt, in aqueous solutions of organic and inorganic substances. Ann. Appl. Biol. 44:274-282.
24. WHITEHEAD, A. G., and D. J. TITE. 1972. Control of stem nematode (Ditylenchus dipsaci) attacking onions by aldicarb and dazomet in sandy loam. Plant Pathol. 21:89-92.