Effects of Soil Moisture on Control of *Heterodera schachtii* with Aldicarb[1]

G. D. GRIFFIN[2]

Abstract: Soil moisture and the nematode population density in aldicarb-treated soil influenced control of the sugarbeet nematode, *Heterodera schachtii.* Greater numbers of nematode larvae infected 14-day-old sugarbeet seedlings growing in aldicarb-treated soil at 20-30% than at 80-100% field capacity (F. C.), and plant growth was inversely related to nematode infection and the nematode population density. Compared with that of control plants, plant growth increase also was greater at 80-100% F. C. when the nematode population was above 1.8 larvae/gm soil. A nematode population of 1.8 larvae/gm soil did not significantly affect sugarbeet yields. Aldicarb gave less control when soil moisture levels dropped to 20 and 50% F. C. at nematode populations of 3.5 and 6.2 larvae/gm soil. More effective control was obtained wth soil moisture levels at or above 80% F. C. This difference was attributed to continued activity of the toxicant in the rhizosphere at the high moisture level. *Key Words:* sugarbeet, sugarbeet cyst nematode, oxime carbamates, nematicide.

Nematicidal activity of aldicarb, a carbomoxyloxime, was first reported by Spurr and Sousa in 1966 (8). Since then it has been used successfully to control plant-parasitic nematodes on several important crops (1, 2, 3). In the intermountain area of the western United States, aldicarb is used successfully to control the sugarbeet cyst nematode, *Heterodera schachtii.* However, effective control and maximum sugarbeet yields are obtained only when optimum soil moisture is maintained. Preliminary studies have shown that, with a great nematode population density, soil moisture must be closely controlled to obtain adequate crop protection.

Nonfumigant nematicides may not control nematodes by killing them. Rather, control may result from indirect effects such as inhibition of vital body functions of the nematode. Nonfumigant nematicides have been reported to control cyst nematodes by several mechanisms: *(i)* inhibition of hatching, *(ii)* nematistasis of larvae, i.e. impairment of the mechanism of larvae to migrate to invasion sites, and *(iii)* disorientation of males that prevents fertilization (5, 6, 7, 9, 10). However, any or all of these control mechanisms are influenced by the amount of active material in contact with nematode eggs, larvae, or males and this quantity is limited by the amount of aldicarb in solution and its hydrolytic degradation to sulfoxide and sulfone.

This study was made to determine the relationships of soil moisture population densities and activity of aldicarb for control of *H. schachtii* on sugarbeet.

MATERIALS AND METHODS

Greenhouse Study: Heterodera schachtii-infested sandy loam soil (19% moisture-holding capacity) was thoroughly mixed and added to redwood flats (15 x 30 x 30 cm). Eight flats were treated with 3.37 kg (a.i.)/ha aldicarb. Treatment was made to simulate commercial applications of the nematicides; granules were distributed onto the soil in 100-mm bands, 2 bands per box, and immediately covered with 20 mm of soil. Sugarbeet seeds (Amalgamated Sugar Company, Lot 603) were planted immediately over the treated band and covered with 10 mm of soil. Eight nontreated redwood flats were similarly planted with sugarbeet seeds.

All flats were placed into galvanized steel pans (50 mm deep) and watered from the bottom. Moisture-sensing blocks buried 3 and 8 cm deep were used to monitor soil moisture. Soil moisture in four nontreated and four aldicarb-treated flats was maintained at 80-100% field capacity (F. C.). Soil moisture in the eight remaining flats, four nontreated and four aldicarb-treated, was maintained at 20-30% F.C.

After 15 days, roots of 20 plants from each treatment were stained and nematode infection was determined. The remaining plants were thinned to 10/flat, harvested

Received for publication 8 November 1976.
[1]Cooperative investigation, Agricultural Research Service, United States Department of Agriculture, and Utah State Agricultural Experiment Station.
[2]Nematologist, Agricultural Research Service, United States Department of Agriculture, Crops Research Laboratory, Utah State University, Logan, Utah 84322.

at 55 days, and yield and nematode numbers (females and cysts) per plant were determined.

Field Studies: In an initial field experiment similar to the greenhouse study, *H. schachtii*-infested microplots (3.05 x 4.27 m) of a sandy loam soil (22% moisture holding capacity) were rototilled and the nematode population was determined (2-3 larvae/gm soil).

Moisture-sensing blocks were buried 15 cm deep and 91 cm apart. Two alternate rows of each plot were treated with 4.49 kg (a.i.)/ha aldicarb, and two alternate rows were left as nontreated controls. The four rows were planted on 76-cm row centers with sugarbeet seed (Amalgamated Sugar Company, AH-10). Chemical application was similar to that described in the greenhouse study, except granules were applied in 12.5-cm bands with a row-banding applicator. Each plot was irrigated with a sprinkler to bring soil moisture to or near field capacity immediately after planting. Plots were allowed to dry to 20, 40, 60, and 80% F. C. (4 plots per moisture level), and then sprinkler irrigated to bring moisture levels to 100% F. C. at the 15-cm depth. Forty days after planting, 20 plants were carefully harvested from each row of each plot, and the numbers of *H. schachtii* females and cysts per plant were determined. The remaining plants were thinned to a 20-cm spacing. After 100 days of growth, all plants were harvested and root weights determined.

A second microplot study was made to investigate the effects of soil moisture and *H. schachtii* population densities on sugarbeet yields. Sufficient amounts of methyl bromide-fumigated soil were incorporated into microplots with a rototiller to give a nematode density of 6.2 $\pm$ 0.67, 3.5 $\pm$ 0.38, and 1.8 $\pm$ 0.23 larvae/gm of soil. Noninfested microplots were used as controls. Treatments were replicated 4 times.

Two alternate rows of each microplot were treated with 4.49 kg (a.i.)/ha aldicarb, and the remaining two rows were left as nontreated controls. Granules were applied in 12.5-cm bands with a row-banding applicator. The four rows were planted with sugarbeet seed (Amalgamated Sugar Company, AH-10) on 76-cm row centers. All plots were sprinkler irrigated immediately after chemical treatment and planting to bring soil moisture to 100% field capacity at the 15-cm depth. Initially, soil moisture levels were allowed to drop to 20, 50, and 80% F. C. before subsequent irrigations. Plots maintained at 80% F. C. were irrigated 8 days after planting. To obtain 50% F. C., plots were first watered 13 days after planting and then at 9-day intervals for 4 irrigations. Plots held at 20% F. C. received their first irrigation 44 days after planting and the second 21 days later. All subsequent irrigations for all plots were made at 6-day intervals.

One-hundred-twenty days after planting, all plots were harvested and sugarbeet yields determined.

RESULTS AND DISCUSSION

Greenhouse Study: Differences in soil moisture levels in aldicarb-treated soil resulted in significant differences in infection of sugarbeet seedlings by *H. schachtii* larvae. Larval infection was less in treated soil and greatest in nontreated soil at 80-100% F. C. After 14 days, there were 0.3 and 35.8 larvae/seedling in the treated soil and nontreated wet soil. A similar effect was found in the dry soil (20-30% F. C.); there were 9.1 and 25.3 larvae per seedling in the treated and nontreated soil (LSD = 6.2 @ $P = 0.05$). The greater infection of sugarbeet seedlings in treated soil at 20-30 % F. C. than at 80-100% F. C. was evidence of a higher aldicarb concentration of oxime carbamates in solution in soil kept at higher moisture levels. The greater infection of seedlings in nontreated soil at 80-100% F. C. than at 20-30% F. C. can be attributed to more optimum growing conditions (larger root area resulting in a greater chance for nematode-root proximity) and a more favorable environment for migration of nematodes.

Significant differences in plant weight between treated and nontreated soil at 80-100% F. C. and not at 20-30% F. C. after 40 days (Table 1) would indicate greater nematicidal activity of the chemicals at 80-100% F. C.

Field Studies: There was a direct relationship between sugarbeet yields and available soil moisture in soil treated with

TABLE 1. Effects of soil moisture on aldicarb control of *Heterodera schachtii* on sugarbeet in greenhouse flats.[a]

	Soil moisture level (% field capacity) 20-30[b]		80-100[b]	
Treatment	Plant wt (gm)	Females and cysts/root	Plant wt (gm)	Females and cysts/root
Aldicarb	1.96	20*	8*†[c,d]	2*†
Control	2.38	36	4††[e]	45††

[a]3.36 kg(a.i.)/ha aldicarb.
[b]Plant weights and nematode counts made 40 days after planting.
[c]Asterisk indicates significant difference from control ($P = 0.01$).
[d]Dagger (†) indicates significant difference from aldicarb-treated soil at 20-30% F. C. ($P = 0.01$).
[e]Double dagger (††) indicates significant difference from control at 20-30% F. C. ($P = 0.05$).

aldicarb. Good to excellent nematode control with increased plant growth was obtained when soil moisture was maintained at or above the 80% F. C. (Table 2). Although yields were much lower when soil moisture was reduced to 20% F. C., they were almost double those of the controls. Sugarbeet yields were inversely related to numbers of females and cysts per plant. In aldicarb-treated soil, the number of females and cysts per plant was highest on plants growing in the 20% F. C. plots, and lowest in the 80% F. C. plots. In the control plots, the numbers of females and cysts were highest on plants in the 80% F. C. plots because optimal conditions for plant growth favored nematode infection and development.

In the second microplot experiment, the level of control obtained was affected as much by soil moisture as it was by nematodes. Yields in both treated and nontreated soil were significantly less at 20% F. C. than at 50 and 80% F. C. (Table 3). The level of control was also less for the higher nematode densities. The lower nematode population (1.8 larvae/gm soil) had little or no effect on sugarbeet yields in aldicarb-treated and nontreated soil. These effects were not dependent on soil moisture. This response agrees with results obtained from field plots in northern Utah and southern Idaho sugarbeet-producing areas where fields with nematode densities below two larvae/gm of soil usually do not warrant a chemical control application. The only differences in yield at 1.8 larvae/gm soil were attributed to differences in soil moisture.

As the initial nematode population density was increased, the effects of soil moisture levels on yields, as they affected aldicarb control of nematodes, became more critical. There were no increases in sugarbeet yields in aldicarb-treated soil at 20% F. C. over those of nontreated plots at initial population densities of 3.5 and 6.2 larvae/gm of soil. Plants were stunted throughout the growing season, roots showing nematode damage were sprangled, and yields were low. At the 50% F. C. soil moisture level, there was an increase in sugarbeet yield in treated soil over that of

TABLE 2. Effects of soil moisture on aldicarb control of *Heterodera schachtii* on sugarbeet in field microplots.[a]

Soil moisture (% field capacity)	Yield (metric tons/hectare)[b] Aldicarb*	Nontreated	Females & cysts/plant[c] Aldicarb*	Nontreated
20	13	7	17	28
40	23	11	8	33
60	28	11	4	42
80	32	14	3	45
LSD ($P = 0.05$)	4	4	7	6

[a]4.49 kg(a.i.)/ha of aldicarb.
[b]Yield data collected 100 days after planting.
[c]Females and cyst data collected 40 days after planting.
*Sugarbeet yields from aldicarb-treated soil significantly different ($P = 0.01$) from yields from nontreated soil at same soil moisture levels.

TABLE 3. Effects of soil moisture and nematode population density on aldicarb control of *Heterodera schachtii* in field microplots.[a]

Initial nematode population (larvae/gm soil)	Sugarbeet yields (metric tons/hectare) 20% F.C.[b]		50% F.C.[b]		80% F.C.[b]	
	Aldicarb[c]	Nontreated	Aldicarb[c]	Nontreated	Aldicarb[c]	Nontreated
0.0	—	29	—	37*	—	37*
1.8	30	27	37*†[d,e]	35*	40*	37*
3.5	22	19	31*††#[f,g]	24*	39*††##[h]	25*
6.2	10	7	25*††	12*	38*††##	14*

[a]120 days' growth.
[b]Soil moisture levels (% field capacity). Soil moisture allowed to drop to specified soil moisture level before moisture level was brought back to 100% F. C. (Soil moisture holding capacity = 22%).
[c]4.49 kg(a.i.)/ha.
[d]Asterisk (*) indicates significant difference from aldicarb treated and nontreated soil at 20% F.C. (*P* = 0.05).
[e]Single dagger (†) indicates significant difference from aldicarb-treated and nontreated soil at 50% F. C. and 3.5 and 6.2 larvae/gm soil (*P* = 0.05).
[f]Double dagger (††) indicates significant difference from control (*P* = 0.01).
[g]Number symbol (#) indicates significant difference from aldicarb-treated soil at 50% F. C. and 6.2 larvae/gm soil (*P* = 0.05).
[h]Double number symbol (##) indicates significant difference from aldicarb-treated soil at 50% F. C. (*P* = 0.01).

the nontreated plots, but sugarbeet yields were less at a population density of 6.2 than at 3.5 larvae/gm soil.

Sugarbeet yields in soil treated with aldicarb at nematode populations of 3.5 and 6.2/larvae gm soil and maintained at 80% F. C. were greater (*P* = 0.01) than sugarbeet yields in similarly treated soil at 50% F. C. Yields in aldicarb-treated soil increased by 108% and 171% at 50% and 80% F. C., respectively, over those of nontreated plots in soil with nematode population levels of 6.2 larvae/gm of soil. Increases in yields at a population level of 3.5 larvae/gm soil were less spectacular, there being a 29 and a 56% increase in yields over those of the nontreated plots at 50 and 80% F. C. This result shows that at high nematode population densities, a longer period of chemical activation is required to achieve an adequate level of control, and this interaction becomes more apparent as the population density increases. There were no significant differences in sugarbeet yields from nontreated plots which had the same nematode density and were kept at 50% and 80% F. C. moisture levels. This fact would indicate a decrease in the importance of soil moisture as related to plant growth alone.

The infection and pathogenicity of *H. schachtii* to sugarbeet in both greenhouse and field studies were associated with soil moisture. However, the greater infection in nontreated soil can be attributed to more optimum plant growth conditions; root growth was greater and resulted in a greater chance for nematode-root proximity, and migration of the larvae to the area of root infection was favored by adequate soil moisture.

Thus, optimum use of aldicarb to control *H. schachtii* in sugarbeets requires proper placement and continued activation of the toxicant in the rhizosphere by appropriate moisture. This continued activity is obtained only when soil moisture is sufficient to release the material from granules and transport it to the rhizosphere where control is needed. The required period of control depends upon the initial nematode population density.

LITERATURE CITED

1. BIRCHFIELD, W. 1971. Systemic nematicides control Rotylenchulus reniformis of cotton. Plant Dis. Rep. 55:362-365.
2. BRODIE, B. B., and J. M. GOOD. 1973. Relative efficacy of selected volitile and nonvolitile nematicides for control of Meloidogyne hapla on tobacco. J. Nematol. 5:14-18.
3. CETOS, R. C. 1971. Evaluation of granular formulations of systemic nematicides for the control of Pratylenchus penetrans on potatoes. Phytopathology 61:887.

4. GRIFFIN, G. D., and T. G. GESSEL. 1973. Systemic nematicide control of Heterodera schachtii on sugarbeet. Plant Dis. Rep. 57: 942-945.
5. HOUGH, A., and I. J. THOMASON. 1975. Effect of aldicarb on the behavior of Heterodera schachtii and Meloidogyne javanica. J. Nematol. 7:221-229.
6. HOUGH, A., I. J. THOMASON, and W. J. FARMER. 1975. Behavior of aldicarb in soil relative to control of Heterodera schachtii. J. Nematol. 7:214-221.
7. OSBORNE, P. 1973. The effect of aldicarb on the hatching of Heterodera rostochiensis larvae. Nematologica 19:7-14.
8. SPURR, H. W., and A. A. SOUSA. 1966. Pathogenicidal activity of a new carbamoyloxime insecticide. Plant Dis. Rep. 50:424-425.
9. STEELE, A. E., and L. R. HODGES. 1975. In-vitro and in-vivo effects of aldicarb on survival and development of Heterodera schachtii. J. Nematol. 7:305-312.
10. STEELE, A. E. 1976. Effects of oxime carbomate nematicides on development of Heterodera schachtii on sugarbeet. J. Nematol. 8:137-141.