Control of Sugar Beet Nematode With 1,3-Dichloropropenes in Irrigation Water

L. E. Warren[1]

Received for publication March 5, 1962

Introduction

Sugar beet nematode *(Heterodera schachtii Schmidt)* has been observed in all the important sugar beet producing areas of the United States and Europe (10)[2]. Because of the protective cysts that enable this pest to survive long periods of adversity, economic controls are difficult. Rotation and early planting are recommended in California as reported by Hart (4). Thorne and Jensen (9), Oftedal (6), Altman and Fitzgerald (1), Turner (11) and others have reported effective controls of sugar beet nematode using preplant injection fumigations with 1,3-dichloropropenes at the rate of 200-250 lb per acre made in the fall or spring before planting. This work, along with other research, resulted in recommendations as reported by Bischoff (2) in the Mountain States to combine soil fumigation with crop rotations.

Soil fumigation for sugar beet nematode control is practiced generally where there is emphasis on sugar beets as a cash crop or where the climate does not permit fall and winter plantings. In California, even with rotations and early plantings, widespread damage often occurs; these may range from nearly a complete loss to a slightly reduced yield.

With chisel injections, distribution through the soil mass depends upon gaseous diffusion. If the soil is too wet, such as after winter rains, dispersion will be limited to a few inches around the line of injection. Organic matter above 3% also may limit gaseous diffusion (3).

Experiments with 1,2-dibromo-3-chloropropane in irrigation water reported by Morton (5) and Warren (12) have given good control of root knot *(Meloidogyne* spp.), root lesion *(Pratylenchus* spp.) and other nematodes. It was decided that water applications might be more efficacious than the chisel injections in distributing toxicants to control sugar beet nematode through the soil mass, particularly in the heavier soils. This paper presents the results of experiments designed to determine the response of sugar beets to the control of sugar beet nematode with the application of 1,3-dichloropropenes as Telone® in water using different

[1] Research Agriculturist, The Dow Chemical Company, Agricultural Research Laboratory, Seal Beach, California.

[2] Numbers in parentheses refer to references.

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methods of irrigation. Since the high ratio of 1,3-dichloropropenes to other constituents is unique to Telone, the trade name will be used hereafter in this report.

Methods

In two of the experiments reported chisel and water applications were compared. Injections were made with conventional chisels in lines 12 in apart and 8 to 9 in deep followed by cultipacking to "seal" the surface. In one experiment, the chemical was deposited in a "sheet" 4 to 5 in deep using 12-in "duckfoot" sweeps 12 in apart modified as shown in Figures 1 and 1a by attaching an outlet at the lower back of the shank to direct a flat fan nozzle horizontally.

Figure 1.—Side view (left) and bottom view (right) of 12-in duckfoot sweep with flat fan nozzle attached to back of shank and directed backward under a shield over wings.

For irrigation applications, the chemical was metered into the water stream at the suction side of a centrifugal pump with a known output and dispensed into a ditch or pipe (Figure 2) to be carried to the individual plots. Initially the amount of water in acre-inches was selected to penetrate somewhat beyond the depth to which control was desired, about 24 in. A Spraying Systems Flow Regulator with an appropriate orifice was used to regulate the flow of chemical into the water stream. An emulsifier, at 5 percent of the Telone, was added to insure adequate dispersion in the first experiment. Physical data sheets (8) indicate that Telone is soluble in water at over 1000 ppm. Simple agitation tests determined that Telone at 200 ppm would dissolve readily in water if vigorously agitated. As a true solution it would not settle out. Therefore, unformulated Telone was used in the other experiments reported.

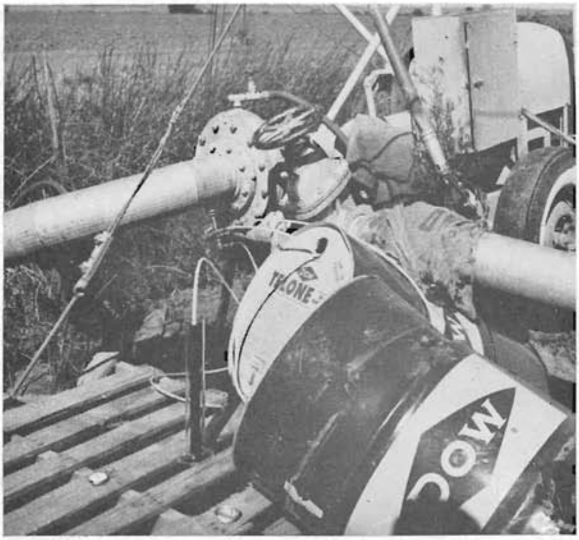

Figure 2.—Telone being added to water at suction of centrifugal pump.

Treatments were applied in October, December and May; previous results with chisel injections have shown that these differences in time of treatment should not affect the control. The sugar beets were planted by the cooperating growers from February to June and were grown under normal culture. They were harvested by weighing several 20 ft to 96 ft lengths of the center 3 to 8 rows in each plot. Samples for tare and sucrose percent were analyzed by the sugar companies concerned. Pounds of sucrose per acre were calculated from individual plot weights and sugar sample percentages.

Treatments were replicated in randomized blocks or strips. The data were analyzed using analysis of variance techniques according to Snedecor (7) and lowest significant difference values are indicated with the tables of results.

The soils in these experiments were clay-loams with 2 to 15 percent organic matter. Details are presented with each experiment.

Treatment Data and Results

In December, 1959, Telone at 15 to 25 gallons per acre was applied as chisel and irrigation treatments to an Egbert muck soil on the Gardiner Ranch near Isleton, California with 10 to 15 percent organic matter at 6- to 17-in depths. The mineral fraction was 20 percent clay, 60 percent silt and 20 percent sand. Moisture was 15 to 19 percent, which was somewhat above the wilting point; air space was 17 percent at 7 in and 49 percent at 17 in. Temperature at 6 in was 48°F. The plots were 20 ft wide by 100 ft long, quadruplicated. The chemical to which an emulsifier was added at 5 percent by volume was dispersed in 7 acre-inches of water by flooding for the irrigation treatments. Chisel injections were made by the Harvey Lyman Chemical Company. Spreckels variety 601 beets were planted on April 12.

Eight center rows were harvested from each plot on September 12. Differences in growth were obvious from the time of emergence through the season. The percent sucrose and tare and yields of roots and sucrose are presented in Table 1.

Table 1.—Comparison of chisel and basin irrigation methods of applying fumigants in organic soil to control sugar beet nematode.

Telone per acre	Application method	Percent tare	Tons beets per acre	Percent sucrose	Pounds sucrose per acre
0 gal	Basin irrigation	10.4	7.4	12.7	1864
15 gal	7 acre-in water	8.7	15.8	16.3	5160
20 gal	7 acre-in water	5.1	19.1	16.7	6392
25 gal	7 acre-in water	8.1	15.4	14.6	4512
0 gal	injection	21.9	5.9	10.4	1280
15 gal	12 in spac.	14.5	8.6	13.1	2220
20 gal	12 in spac.	11.2	10.4	13.0	2700
25 gal	12 in spac.	12.0	10.6	12.9	2736
LSD 5%		4.2	2.9	1.6	1028
1%		5.8	4.0	2.2	1402

Note that the tare has been reduced commensurate to the nematode control. It is noteworthy that, in addition to the increase in tonnage of roots, the sucrose percentage is higher in the irrigation treatments than in the untreated or injection plots where control was poor. The return to the grower amounted to over a threefold increase in actual sucrose with 15 to 20 gallons of Telone in water per acre. The short growing period probably prevented attainment of the maximum yield that could be derived from this treatment.

After harvest, samples of soil were collected in the irrigation treatments from 6 to 12 in and 18 to 24 in deep at 2 points per plot and potted into 1 gallon cans. Rape was planted and maintained in a greenhouse above 58°F. After about three months, the roots were examined for "pearls" with the results shown in Table 2.

The reduction in the number of cysts is correlated directly with the amount of Telone applied, but there is doubt that a second good crop of beets could have been grown without retreatment. The fact that the 25 gallons per acre treatment had the lowest cyst count, but not the best yield may indicate some

Table 2.—Populations of sugar beet nematode in soil after one sugar beet crop following treatment with telone in basin irrigation.

Telone per acre	Cysts per can[1] 6-12 in	18-24 in
0 gal	7.3	7.5
15 gal	5.5	4.1
20 gal	3.0	4.7
25 gal	2.5	2.8

[1] Rating scale : 0 - 10
where 10 = profuse "pearls"; 0 = none.

chemical phytotoxicity, despite the long period from December to planting in April.

In October, 1960, a strip plot experiment was established on the Hunn, Merwin & Merwin Ranch, 10 miles southwest of Clarksburg, having a Sacramento clay-loam soil with about 2 percent organic matter; moisture was in the low part of the available range; air space at 7 in was 28 percent, at 17 in 13 percent. The texture range was 49 percent clay, 45 percent silt and 6 percent sand. Duplicate strip areas 20 ft by 1250 ft were set up. The plot basins were 20 ft by 100 ft and 7 acre-inches of water was used for the flooded treatments. The chisel injections were made by the Harvey Lyman Chemical Company with straight chisels and the duckfoot sweeps. Rainbird sprinklers were set up following the sweep treatments in less than 2 hours to apply 4 acre-inches of rain at ⅓ acre-inch per hour. Temperature at 6 in was 62°F. American No. 5 sugar beets were planted on February 26, 1961, and harvested September 13, 1961. Sections 26 ft long were taken from 3 rows per plot, weighed, and analyzed for sucrose by the American Crystal Sugar Company. The percent sucrose and yields of roots and sucrose are compared in Table 3.

Table 3.—Control of sugar beet nematode using chisel and basin irrigation application of Telone on clay-loam soil.

Telone per acre	Application method	Tons beets per acre	Percent sucrose	Pounds sucrose per acre
0 gal	flood	9.5	13.9	2641
10 gal	7 acre-in	18.0	14.5	5183
15 gal	7 acre-in	15.2	14.3	4223
20 gal	7 acre-in	16.4	14.1	4588
0 gal	injection	10.4	14.4	2995
15 gal	chisels	15.9	14.3	4539
25 gal	12 in spacing	17.0	13.7	4658
0 gal	sweeps	12.4	13.2	3289
15 gal	4 acre-in rain	16.3	14.4	4680
25 gal	4 acre-in rain	15.8	14.0	4429
LSD 5%		2.3	0.64	866
1%		3.1	0.85	1158

As in Table 1, the treated plots all produced much better yields than the untreated, but there was no difference between treatments except that Telone at 10 gallons per acre in water gave the best yields. This may indicate that this low rate in water is adequate for a good response. Prior to harvest, a pronounced reduction in watergrass *(Echinochloa crusgalli)* and pigweed *(Amaranthus* spp.) was noted where the treatments had been applied; the cleanest plots were those with Telone at 15 and 20 gallons per acre in water.

The failure to show better yields with the flooding treatments compared to the injections probably was the result of very favorable soil conditions for gaseous diffusion of the fumigants. A serious infestation of virus yellows also undoubtedly caused some reduction in yield and sucrose percentage. The treated beets at harvest time had very few visible cysts compared to large numbers in the untreated plots.

Another experiment was established on a McClusky clay-loam in the Spreckels sugar beet nematode nursery at Salinas, California to determine the efficacy of Telone in a furrow irrigation. In May, 1961, the beds were formed on 40 in centers as for normal planting. After these beds had dried out so the treated water could "sub" into them, the treatments were applied on May 23 in 4 acre-inches of water. The plots were 200 ft long and contained two full 2-row beds and a ½ bed border row on

Figure 3.—Growth of beets on treated versus untreated sides of a bed.

each side. Treatments were randomized in triplicated strips. The water was backed up to nearly the top of the ridge to soak the beds as rapidly as possible. Soil temperature at 6 in was 64°F. Soil moisture was 15 percent at 6 in and 19 percent at 16 in. Air space was 38 percent at 6 in and 26 percent at 16 in. Spreckels S-1 beets were planted June 1 and maintained in good growing condition through the season. Growth in the treated plots was much better than in the untreated plots from emergence on through the season. Figure 3 shows a 2-row bed with the treated and untreated rows. Although the treated beets obviously were not mature, on November 15, four 20-ft sections of row from the record beds were harvested from head, center and lower ends of each plot. They were weighed and analyzed for sucrose by the Spreckels Sugar Company. The sucrose percentages and yields of roots and sucrose are compared in Table 4.

Table 4.—Control of sugar beet nematode with Telone-treated water in furrow irrigation in clay-loam soil.

Chemical	Gallons per acre	Yield tons per acre	Percent sucrose	Pounds sucrose per acre
None	0	5.6	13.4	1500
Telone	15	12.0	12.9	3222
Telone	20	13.6	12.4	3300
Telone	25	13.7	11.8	3262
LSD 5%		1.4	1.4	453
1%		1.8	1.9	606

Although the Telone-treated beets responded dramatically to the treatment throughout the season and produced over twice as much sucrose as did the untreated beets, the yields obtained were too low to be acceptable commercially. The treated beets had a lush green color at the time of harvest and obviously had not exhausted the nitrogen. The reduced sugar percentages of the treated beets is evidence that they had not reached "maturity"; it is believed that, with additional growing time, these yields and sucrose percentages would have improved markedly. There were again very few cysts in the root zone at harvest time and there was no root proliferation in the treated plots; the stand was reduced and roots were extremely distorted by nematode action in the untreated plots.

In this experiment, the weed populations in the treated plots again were considerably less than in the untreated.

Discussion

These experiments demonstrate that 1,3-dichloropropenes applied in irrigation water will give control of sugar beet nematode in certain situations where control has been difficult with chisel injections. These are principally in the finer textured and organic soils.

Compounds dissolved in the water will move with the water over the surface and be carried into the soil a distance that depends on certain relationships between the soil fractions and the solute. Distribution over the surface can be accomplished by basin or furrow irrigation or sprinklers. The last method exposes the chemical to high losses by volatilization as the droplets fly through the air. Flooding offers the opportunity to achieve nearly 100 percent kill of the nematodes because the cysts in the top 2 to 3 in (as well as deeper) would be contacted readily by the chemical. Although the extent of control with the furrow method would be somewhat less than with the basin technique, growers may prefer the easier preparation. Local soil conditions will influence results considerably.

Although 1,3-dichloropropenes are not considered water soluble, as mentioned above, their solubility is over 2000 ppm. The amount required to control encysted sugar beet nematodes in the laboratory is *25 to 100 ppm* (3). Dilution by the soil moisture will require a somewhat higher concentration in irrigation water. There still is, however, an ample safety factor to effect solution of Telone in the applied water.

Since the Telone is heavier than water (sp gr = 1.21) and not readily water soluble, vigorous agitation is required to insure complete solution before settling out. This can be accomplished by introducing the chemical into the suction line of a centrifugal pump that provides all the irrigation water as shown in Figure 2. As an alternate method, a smaller pump can withdraw part of the water which is treated with enough material for all the flow and ejected back into the main stream. Other methods of adding Telone with sufficiently vigorous agitation to effect uniform dispersion in *all* the water also would be satisfactory.

Uniform horizontal distribution of treated water in the soil can result only from uniform dispersion on the surface. Sufficient treated water should be used to penetrate about 50 percent beyond the depth to which control is desired. This factor may vary with the amount of water in the soil and soil texture. Dilution by existing soil moisture and some adsorption of the toxicant by organic matter accounts for this requirement.

An optimum time to make the irrigation applications is in early fall in order to have the soil dried out somewhat and leave time to reshape the soil for over-wintering. There is no reason that a flooded field has to remain flat after the soil has dried out. The waiting period to plant beets after application of Telone at

20 gallons per acre would be satisfied by the time the soil dries out sufficiently to be worked.

The weed control displayed by Telone in water is probably the result of both some kill of weed seeds and the competition of better crop growth.

Experience indicates that soil moisture and air space in the heavier mineral soils are often sub-optimal. The narrow range for good gaseous dispersion of Telone between too dry and too moist is difficult to realize at practicable treatment times. Chisel injections, therefore, are undependable in these soils. They are of even less value in the organic soils (over 3 to 4 percent organic matter).

If good controls can be realized consistently with the sweep method of applying a "sheet" of chemical followed by sprinklers, this practice may prove to be more acceptable to some growers than the basin irrigation application. The optimum time to wait between injection and sprinkling will depend on the temperature, output of the sprinklers, the amount of moisture in the soil and the seal following injection. Probably 2 to 4 hours before sprinkling would be suitable.

Certain aspects of nematode control on soils with high organic matter remain to be determined. The moisture in the soil at treatment may influence results. It seems that here an appreciable amount of moisture may be desirable as contrasted to the mineral soils. The high moisture holding capacity and adsorption capacity for the 1,3-dichloropropene may prevent adequate dispersal of the treated water through sufficient soil volume if the soil is too dry before application. A grower could either pre-irrigate or await the first fall rains before treating.

Further research should be pursued to establish the value of water treatments of Telone in furrow irrigations and in higher organic soils. Also since sprinklers are used in some areas the "sweep" chisel technique should be investigated further.

Where careful control of irrigation water is possible, Telone at 15 to 20 gal. per acre in 4 to 7 acre-inches of water can be recommended using basin irrigation applications.

Acknowledgments

The assistance of the following in pursuing various facets of these experiments is gratefully acknowledged: John Bryan and George Wheatley of Spreckels Sugar Company; Norman Lawlor and Curzon Kay of American Crystal Sugar Company; Louis Kloor and A. Laiblan of Holly Sugar Corporation; other field, laboratory and managerial personnel of these companies; Harvey

Lyman Chemical Company and the growers who cooperated in these experiments.

Summary

Treatments of 1,3-dichloropropenes as Telone at 10 to 25 gallons per acre in fall basin applications of irrigation water were compared with chisel injections in clay-loam soils with 2 to 15 percent organic matter. One experiment included injections with a modified sweep chisel ("sheet") followed by 4 acre-inches of water through sprinklers. In another experiment, furrow applications of Telone in water were compared at dosages of 15 to 25 gallons per acre in spring. Results were as follows:

1. In the higher organic soils, the treatments with Telone in 7 acre-inches of water produced increases over chisel injections or untreated plots:
   A. Of several sucrose percentage points;
   B. In percent clean beets (reduced tare);
   C. In sucrose yields of 200 to 300 percent.
2. Soil samples from the above irrigation plots after harvest contained about 1/3 as many "pearls" in the Telone treatments as in the untreated soil.
3. In a clay-loam soil with optimum conditions for gaseous diffusion, comparisons of chisel injections, "sheet" injections followed by rain, and basin irrigation application indicated Telone at 10 to 25 gallons per acre produced similar increases with all treatments over the checks.
4. A furrow irrigation with Telone at 15 to 25 gallons per acre in 4 acre-inches of water produced excellent increases in yield.
5. Weeds always were less in the treated plots than in the checks or poor treatments—probably a combination of some seed kill by Telone and of competition from the more vigorous beets.
6. Further research on certain phases of the water application of Telone should be pursued to enable growers in all irrigated areas to take advantage of this activity.

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