Chemical Control of Nematodes

soil type important limiting factor in control of certain plant parasitic nematodes with volatile soil fumigants

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Root-knot nematode can frequently be controlled successfully by treating infested fields with a soil fumigant.

In California the materials most generally used for root-knot nematode control in field and truck crop areas are D-D mixtures at the rate of 20 gallons per acre or ethylene dibromide mixtures applied at the rate of four to six gallons of actual ethylene dibromide per acre.

These chemicals are applied between crops at a time when the soil is in good tilth. The temperature of the soil at a six-inch depth should be between 50° F and 75° F and the soil moisture should be within the range of 50% and 75% of the moisture equivalent at the time of treatment.

Following treatment, the soil should be allowed to remain undisturbed for a period of about two weeks. At the end of this period the planting operation may go ahead in a normal manner. In general the treatment is effective for only the growing of one crop that is susceptible to root-knot nematode attack.

Sugar-beet nematode control with volatile soil fumigants has not been proven to be practical in most of the infested areas in California. Although good results have been obtained in Utah and Idaho using D-D mixtures at the rate of 25 gallons per acre, the poor control obtained in most California tests and demonstrations has made it impracticable to recommend the treatments in California. A number of possibilities have been investigated to obtain an explanation for the obvious differences between the effectiveness of D-D mixture in the Utah-Idaho area and in California.

Toxicity tests were carried out to determine the relative susceptibility of root-knot nematode and sugar-beet nematode to D-D mixtures. Soil fumigants as applied in the field are directed against the free-living infective larvae of root-knot nematode. Chemical control of sugar-beet nematode must by necessity be concerned with killing of the eggs that are contained in the dead female bodies—cysts—since this is the stage present in the field at the time of treatment.

The most commonly accepted explanation for the failure of soil fumigants to control sugar-beet nematode has been that the eggs contained in the sugar-beet nematode cysts are protected from the action of the fumigant.

Controlled laboratory tests have shown that root-knot nematode larvae and the eggs—in cysts—of the sugar-beet nematode are about equally susceptible to D-D mixtures. Also it was found that ethylene dibromide mixtures which are effective against root-knot nematode larvae did not have any effect on the eggs—in cysts—of sugar-beet nematode. Additional tests have shown that D-D mixtures have a high toxicity to root-knot nematode eggs while ethylene dibromide has low toxicity to eggs of this nematode. It has also been found that D-D mixtures are more effective than ethylene dibromide mixtures when applied to soil containing unrotted nematode galls.

It was concluded from these laboratory tests that factors other than differences in the susceptibility of the nematode species concerned were involved in the failure of D-D mixtures to control sugar-beet nematode in California.

Field observations of fumigation treatments to control root-knot and sugar-beet nematode have indicated that the most effective root-knot nematode controls are usually obtained in relatively light sandy soils. On the other hand, practically all of the fumigation treatments to control

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Nematode infested cotton field. The picture on the left was taken in 1940 showing serious infestation. The same area in August 1945 *(right)* after the upper center strip, to the right of the canal, had been treated with various rates of D-D in January of the same year. Results can be seen by the darker shade of the strip.

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sugar-beet nematode have been made in soils of the clay loam or clay series.

Investigations were undertaken to ascertain the effect of soil type upon the root-knot and sugar-beet nematode kills obtained in various soils with volatile soil fumigants.

Several soil types having moisture equivalents ranging from seven to more than 150% were collected in the field. These soils were placed in 32-gallon metal cans. Duplicate samples of root-knot nematode inoculum contained in cheesecloth bags were placed two, four, six, and eight inches from the center of the can at three, six, 12 and 18 inches below the soil surface. A measured amount of D-D mixture—2.15 ml.—was injected in the center of the soil contained in the can to a depth of six inches below the surface.

Total Number of Root-knot Nematode Larvae Surviving a Single Injection of 2.15 ml. of D-D Mixture in Six California Soils

Soil type	Moisture equivalent	Moisture percentage at treatment	Root-knot larvae surviving
Fresno sandy loam	**7.0**	**5.1**	**20**
Yolo fine sandy loam	**10.4**	**9.2**	**88**
Yolo silt loam	**18.6**	**15.5**	**1,507**
Yolo clay loam	**30.1**	**23.9**	**1,155**
Bowers clay	**30.7**	**23.2**	**2,417**
Organic loam (Delta peat)	**150 (plus)**	**112.5**	**2,247**

After seven days exposure the samples were removed and the number of root-knot larvae per sample surviving the treatment was recorded for each soil type. During fumigation the soil temperature was maintained at 68° F. An attempt was made to fumigate all soils at a moisture content of about 75% of the moisture equivalent. The relative effectiveness of the fumigant in several soil types is indicated by the total number of root-knot larvae surviving the treatment in 32 samples exposed in each soil type.

The data obtained indicate that a given dosage of D-D mixture is about 100 times more effective in killing root-knot nematode larvae in Fresno sandy loam than in Bowers clay or organic loam.

Sugar-beet nematode kills in the various soils were found to follow the same trend as those indicated for root-knot nematode.

The diffusion patterns of the fumigant were also obtained in these tests. They indicate that the reason for the lowered effectiveness of D-D mixture in heavy soils is due to the reduced diffusion of the nematicide in the heavier type soils. In Fresno sandy loam the fumigant was toxic eight inches laterally and 12 inches vertically from the point of injection. In Bowers clay the fumigant failed to kill larvae in samples located four inches laterally and six inches downward from the point of injection. Typical diffusion patterns obtained against sugar-beet nematode in Yolo fine sandy loam and Egbert organic loam when 2.15 ml. of D-D mixture was applied in a single injection point are shown in the table in columns two and three.

Lateral and Vertical Diffusion of 2.15 ml. of D-D Mixture in Yolo Fine Sandy Loam and Egbert Organic Loam as Indicated by Sugar-Beet Nematodes Surviving in 100 ml. Sample of Inoculum Located Varying Distances from the Point of Injection

Depth (inches)	Yolo fine sandy loam: Lateral distance (inches)								Egbert organic loam: Lateral distance (inches)							
	8	6	4	2	2	4	6	8	8	6	4	2	2	4	6	8
3	0	0	0	0	0	0	0	0	100	100	43	10	6	26	20	100
6	0	1	0	0*	0	0	0	0	89	38	21	0*	0	2	100	100
12	0	0	0	0	0	0	0	0	100	100	41	18	68	100	42	63
18	3	11	8	1	2	7	1	3	21	100	41	100	100	10	15	100

* Injection point of fumigant.

These laboratory toxicity and diffusion experiments as well as field observations indicate that soil type may directly influence the success or failure of applications of volatile soil fumigants applied for sugar-beet nematode control. Also, it is suggested that root-knot nematode control might be influenced by soil type. Ethylene dibromide mixtures should not be used against sugar-beet nematode but can be used successfully against root-knot nematode larvae. Also since larvae of the root-knot nematode are among the most susceptible of the plant parasitic species to the action of soil fumigants, it appears probable that the soil type may frequently prove to be the most important limiting factor in securing satisfactory nematode control with volatile soil fumigants.

The effectiveness of D-D mixture in controlling sugar-beet nematode in the Utah-Idaho area is probably correlated with soil type. Beet soils in that area are in general lighter and have lower moisture equivalents than the average California beet soils.

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considered extremely toxic to most plants unless in exceptionally high concentrations.

The analyses for these are important in determining the type of salt occurring in the water. The sulfate anion is generally considered about half as toxic as the chloride; therefore, plants tolerate about twice the concentration of sulfates as chlorides. If the total salts occur largely in the form of calcium sulfate—gypsum—the total salt value can be raised about 50%.

Most well waters in California contain appreciable quantities of salts. An estimate of the salt content in parts per million, or tons per acre-foot of water from conductance—K × 10^5—is given in the accompanying table.

Salt Content of Irrigation Waters

Water class	Conductance K x 10^5 at 25° C	Salt content: Total	Salt content: Per acre-ft. of water
		Ppm	Tons
Class I (Excellent to Good)	100	700	1
Class II (Good to Injurious)	100–300	700–2,100	1–3
Class III (Injurious to Unsatisfactory)	300	2,100	3

A water may be in Class I and still contain approximately a ton of salts per acre-foot of water. If three acre-feet are used per season, about three tons of salt will be added to the soil. Many of the well waters of the state have a conductance in the neighborhood of 50 to 100. This is equal to about one half to one ton of salt per acre-foot of water.

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A second article on this subject by Dr. L. D. Doneen will report analyses of six river and nine well waters of California.