

Evaluation of the Protective and Therapeutic Properties of DBCP for Control of Root-Knot Nematode on Tomato

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Abstract: Twelve soil drenches over a period of 30 days with DBCP concentrations of 40 $\mu\text{g/ml}$ did not completely prevent infection of tomato plants by root-knot nematode juveniles. Repeated DBCP drenches of 40 $\mu\text{g/ml}$ halted gall development during the drenches, but 10 days after drenching was discontinued galls were apparent. DBCP drenches at 200 $\mu\text{g/ml}$ prevented tomato root development, and 40 $\mu\text{g/ml}$ slowed it. Ten $\mu\text{g/ml}$ increased the height of root-knot-infected plants, but not their top weights. Treated plants were lanky. Protective drenches of 2.5 to 40 $\mu\text{g/ml}$ of DBCP decreased nematode populations and increased fruitfulness. DBCP as a therapeutant reduced the incidence of galling on new roots and halted increases in gall size on previously infected roots but did not improve fruitfulness or plant size significantly.

This research was done to improve understanding of the unique combination of high nematotoxicity and low phytotoxicity associated with DBCP (1,2-dibromo-3-chloropropane). Although this contact nematicide is toxic to certain plants (8) it is known that large undecomposed roots and nematodes within them are not completely killed by high application rates (6). A quantitative study of the merits of DBCP as a therapeutant and protectant from endoparasitic nematodes is timely in view of recent public decisions on DBCP (1), and such data may also provide information needed for best use of this material.

Two related experiments are reported herein. The first experiment was designed to determine the concentration of DBCP necessary to protect the roots of young tomato plants from root-knot nematode juveniles, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949. The second was conducted to determine the concentration of DBCP needed for therapy of root-knot nematode on infected tomato root systems.

MATERIALS AND METHODS

General: Stock solutions of DBCP made from Fumazone 86EC (Dow Chemical Co., Midland, Mich.) were diluted just prior to application with water containing a one-half-strength Hoagland's solution. Each 15-cm clay pot received 400 ml of the solu-

tion during each irrigation. Irrigations were made every 2 to 6 days depending on evapotranspiration rates and plant size. Moisture tension in the pots did not exceed -0.8 bar. Two days after the final DBCP application, repeated irrigations with water were made to leach the DBCP.

A population of *M. incognita* was obtained from field soil around fig, *Ficus carica* L., and then multiplied on tomatoes in a greenhouse.

Tomato plants (cv. Red Cherry) were grown in a pasteurized loamy sand in 15-cm clay pots at 22 to 28 C. Each pot was nested within a second clay pot which was surrounded by wood shavings. The sawdust bin overlay a sand and gravel bed and was capped with a sheet of plywood (2-cm thick x 2.5-m long and 1.6-m wide) with holes provided for pot insertion. A 7.5-cm glass petri-plate was placed under each pot to facilitate weekly collection and counting of second-stage root-knot nematode juveniles in drainage from three pots in each treatment. These counts were used as the criterion of nematode mobility within soil.

A coiled stainless-steel tube (0.35-cm diam) placed near the center of the soil of several pots of each treatment was used to remove vapor samples. These were taken at various intervals following each irrigation with DBCP and analyzed directly by gas-liquid chromatography (7). DBCP concentrations in the soil water were calculated on a Henry's Constant value of 165 (2), and data are reported as the calculated concentration of DBCP present in soil water as well as the initial concentration in the drench.

Plant height was assessed periodically and at the termination of the experiment, when shoots and roots were weighed, fruits counted, and root galling rated. Counts of galls/gram of root were made where relevant. Gall size was determined as well as the location of galls on the root system. Root systems were given a gall rating from 1 (one gall to 25% of root system galled) to 4 (75–100% of root system galled).

Protection: DBCP was applied around tomato plants 12 times during 30 days. The first DBCP treatment was made one day before adding the nematode inoculum. This inoculum consisted of tomato roots containing a minimum of 100 small galls. It was

placed just beneath the soil surface of each pot. Similar inoculum was added every 2–6 days, usually the day after the DBCP drench. Eleven such inoculations were made.

Therapy: Plants were inoculated 21 days before the first DBCP drenches. At time of DBCP treatment, seedlings were 5 weeks old and supported several hundred galls per root system. Eleven drenches were made during a 21-day period.

RESULTS

General: Concentrations of DBCP in the soil vapor varied with the closeness to application time. Concentrations of DBCP vapor in the soil did not increase with repeated drenches of DBCP. In general, concentrations of DBCP in the soil were slightly lower where tomato roots or nematode inoculum was present in the soil (Table 1).

Infected tomato roots, and roots exposed to infective juveniles, produced significantly less aboveground growth than the uninfected plants. Weight of belowground portions was not reduced by nematodes, presumably because of the weight of the galled tissue.

Treatment of plants with 40 $\mu\text{g}/\text{ml}$ or more of DBCP resulted in reduced plant growth above- and belowground. At 200 $\mu\text{g}/\text{ml}$ DBCP basal leaves of tomatoes were chlorotic, and marginal necrosis developed within 10 days after first exposure; basal leaves were eventually completely necrosed. These same plants recovered after the DBCP exposure period, but supports were required to hold the plants erect. Young leaves on plants treated with 40 or 200 $\mu\text{g}/\text{ml}$ DBCP were bluish rather than green.

Tomato plants drenched with 5.0, 40.0, and especially 10.0 $\mu\text{g}/\text{ml}$ developed lengthy internodes. Slight necroses of root tips occurred at the higher concentrations of DBCP in both experiments. Roots were abundant in all DBCP treatments except 200 $\mu\text{g}/\text{ml}$, where few roots occurred and root decay was common. Flowering and fruit set were not delayed except that no flowering occurred following protective drenches of 200 $\mu\text{g}/\text{ml}$.

Numbers of infective root-knot juveniles were largest in soils where plant roots or DBCP were not present. At 40 to 200 $\mu\text{g}/\text{ml}$

TABLE 1. Effect of DBCP drenches on tomato plants infected with *Meloidogyne incognita*, or uninfected.

Plant	Root-knot	Concn. of DBCP drench ($\mu\text{g/ml}$)	Plant ht. (cm)	Shoot wt. (g)	Root wt. (g)	No. fruit/plant	No. galls/gram root	Root-gall rating ^y	Nematodes exiting (pot)	Av. DBCP concn. ($\mu\text{g/ml}$)
Protective effects of DBCP in inoculated soil										
+	-	0	67 e	224 c	42 ^a bc	7.5 e	0 a	0 a	—	—
-	+	0	—	—	—	—	—	—	241 b	—
+	+	0	49 c	109 b	63 d	1.5 ab	262 e	4.0 e	61 a	—
+	+	2.5	54 cd	86 b	57 cd	2.8 bc	228 d	3.3 d	27 a	0.57 a
+	+	5	54 cd	78 b	65 d	3.8 cd	171 c	2.5 c	11 a	0.93 a
+	+	10	61 de	95 b	67 d	5.2 d	103 b	1.2 b	17 a	1.22 a
-	+	10	—	—	—	—	—	—	77 a	2.91 b
+	-	10	58 cde	94 b	53 cd	4.2 cd	0 a	0 a	—	1.73 ab
+	+	40	39 ab	39 b	30 b	0.8 ab	0.4 a	0 a	11 a	7.05 c
+	+	200	5 a	0.6 a	0.4 a	0.0 a	0 a	0 a	7 a	41.2 d
Therapeutic effects of DBCP on infected plants										
+	-	0	92 e	128 e	48 d	5.4 b	0 a	0 a	—	—
-	+	0	—	—	—	—	—	—	0 a	—
+	+	0	74 cd	70 c	43 cd	1.2 a	96 a	4.0 a	0 a	—
+	+	2.5	67 bc	62 c	39 cd	1.9 a	93 a	2.1 c	1 a	0.72 a
+	+	5	68 bc	62 c	37 c	1.7 a	87 a	1.7 c	0 a	1.15 ab
+	+	10	62 b	42 b	27 b	1.7 a	83 a	1.3 b	2 a	2.45 c
-	+	10	—	—	—	—	—	—	2 a	3.05 c
+	-	10	81 d	98 d	46 d	5.4 b	0 a	0 a	—	1.57 b
+	+	40	61 b	38 b	28 b	1.1 a	83 a	0.8 b	0	11.1 d
+	+	200	46 a	17 a	13 a	0.1 a	20 a	0.3 a	0 a	48.4 e

Numbers followed by the same letter do not differ significantly according to Duncan's multiple-range test ($P = 0.05$).

^yBased on roots developed subsequent to initiation of DBCP drenches.

*Root weights only include those roots within the pots. Three plants from this treatment developed large tap roots extending through the hole in the bottom of the pot.

few mobile nematodes occurred in the leachates except during the two weeks following the leaching of DBCP from the soil.

Protection: Each incremental increase in DBCP concentration resulted in increased protection of tomatoes from nematode infection. Tomato yield improved as DBCP concentrations increased except at 40 and 200 $\mu\text{g/ml}$ DBCP, where plant height and root weight were lower than in the inoculated untreated plants. Significant phytotoxicity occurred upon exposure to a 40 $\mu\text{g/ml}$ drench of DBCP. At this concentration, galling was not apparent on most roots, although some small galls were present on various older and shallower roots.

Therapy: None of the DBCP therapy experiments yielded gall-free root systems. Applications of DBCP did not significantly improve growth of nematode-infected plants. Nematode-free plants drenched with 10 $\mu\text{g/ml}$ DBCP were significantly reduced

in plant height and shoot weight when compared with untreated plants; however, root weights and fruit yield were not significantly changed.

Ratings of gall size revealed that size of individual galls decreased as concentrations of DBCP were increased. Drenches of 0, 2.5, 5.0, 10.0, 40, and 200 $\mu\text{g/ml}$ respectively resulted in galls which were large, medium-large, medium, small-medium, small and small-decayed. Existing galls exposed to 10 $\mu\text{g/ml}$ did not increase in size during the drench period.

DISCUSSION

A unique property of DBCP which allows its use adjacent to established plants is that it moves through soil at low concentrations for long exposure periods. We were not able to maintain constant concentrations of DBCP in these pot experiments without repeated DBCP application, how-

ever, because of the small volume of soil used. Concentrations in the soil pore spaces decreased with time, presumably because of volatilization, absorption by roots, and adsorption to soil particles. In the field, persistence of DBCP in pore spaces is better (3).

Lethal-dose values of DBCP with various exposure techniques have been reported. Johnson and Lear (4, 5) reported that a minimum concentration of 20 to 25 $\mu\text{g/g}$ in the soil water with a minimum exposure of 21 days was necessary for eradication of *Meloidogyne* spp. Youngson *et al.* (10) reported that concentrations above 1.25 ppm for seven days gave good control of *Meloidogyne* when drenched into small pots containing root-knot nematode. Walla (9) reported that 1.0 ppm for 96-hr exposure was sufficient to control second-stage juveniles of *M. incognita*. Our data indicate that infective root-knot juveniles can survive relatively high doses, depending upon their juxtaposition to a root tip and the time required to enter. Uninfected tomato roots exposed to 40 $\mu\text{g/ml}$ DBCP were protected from root-knot infection for the duration of the exposure. Pots drenched with lower concentrations had less protection. Drenches in excess of 2.5 $\mu\text{g/ml}$ deter the nematodes' ability to infect a root tip successfully. It appears, however, that a young root system in the vicinity of the nematode can protect the nematode by providing refuge as well as providing a sorptive site that lowers concentrations in soil water. It is significant, then, that concentrations from repeated drenches of 40 $\mu\text{g/ml}$ will not be sufficient to completely relieve an herbaceous plant from infection. It is interesting that although previously infected plants were not therapeutically relieved of infection, gall growth was halted. This effect was presumably due to a halting of gall reinfection by adjacent offspring and indicates that all stages of root-knot nematode outside the root can be affected by DBCP. Highest concentrations of DBCP reduced galling by destruction of the root itself.

In making water applications of DBCP on California tree and vine crops, concentrations of 30 to 50 $\mu\text{g/ml}$ DBCP in the

drench are applied. Concentrations in soil, however, are much lower, depending upon soil texture, presence of organic matter, method of application, topography of land, temperature, soil moisture level, and other factors (McKenry, M. V., unpublished). DBCP differs from other alkyl-halide fumigants in that concentrations toxic to large roots are seldom attained in soil. Thus, there is a margin of safety between nematotoxicity and phytotoxicity.

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