# Penetration of 1,2-Dibromo-3-Chloropropane in a Florida Soil

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*Abstract:* Gas-liquid chromatography was used to detect movement of the nematicide, 1,2-dibromo-3-chloropropane (DBCP), in soil columns containing top- and subsoil of Astatula fine sand. Topsoil contained 1.4-1.6% organic matter and subsoil 0.20-0.25%. DBCP was applied at various rates as aqueous drenches. Depth of penetration was controlled by organic matter in topsoil and varied with the amount of water applied. Maximum DBCP penetration after 14 days was 28 cm; maximum water infiltration, 115 cm. Maximum depth of penetration was obtained with a water emulsion of 30 $\mu$g/ml of DBCP applied in 15 cm of water. DBCP applied in 5 cm of water to soils containing 2.0% and 0.125% organic matter penetrated 6 cm and 60 cm, respectively. *Key Words:* DBCP penetration, nematicide.

DBCP, 1,2-dibromo-3-chloropropane, is presently the only nematicide registered for use on established citrus trees in Florida. Many experiments conducted in citrus groves have shown that DBCP is very effective for control of *Tylenchulus semipenetrans* Cobb, the major nematode parasite of citrus (1, 3, 8, 9). DBCP is applied mainly in irrigation water or by chisel injection. Soil and root assays of nematode populations in treated areas have indicated variation in the pattern of diffusion and penetration of the chemical. With the techniques described by Johnson and Lear (5), a more precise method is now available for detecting distribution of DBCP in soils. Subsequent studies (4, 6, 7) by this technique have added greatly to knowledge on efficacy and movement of DBCP in soils.

This paper reports results of laboratory studies on penetration and distribution of DBCP as influenced by time, chemical concentration, quantity of water applied, and organic matter content in a soil type extensively planted to citrus in Florida.

## MATERIALS AND METHODS

The soil type used in these studies was an Astatula fine sand, which is widespread in Florida, particularly in the central ridge section. Physical characteristics were 94-96% sand, 3-6% silt and clay and pH 6.2. Two soil horizons occur differing mainly in organic matter content: the A horizon (topsoil) 1.4-1.6% organic matter (OM), 5-6% moisture holding capacity (MHC); and the B horizon (subsoil), 0.20-0.25% OM, 3.5% MHC.

Received for publication 6 September 1974.

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In the field, topsoils vary from 8-30 cm in depth. The columns used in these studies were packed to represent an Astatula fine sand profile, with topsoil standardized at approximately 22 cm deep and subsoil below. Plexiglass columns 7.5-cm diam were made of rings 7.5 cm high and joined with masking tape to give any desired length. Columns were packed with moist soil and stored for several days to equilibrate. To preclude the formation of an interface between topsoil and subsoil, the entire column was loosely filled and tamped for continuity.

Emulsions of DBCP were made from a commercially available formulation, diluted with distilled water to series concentrations ($\mu$g active ingredient per ml), and applied to columns at selected rates ranging 5-160 $\mu$g/ml as aqueous drenches in 5-15 cm of water. After the fumigant emulsions were applied, the tops of the columns were covered with petri dishes to restrict evaporation and chemical loss. To determine the effect of organic matter on DBCP penetration in soil, dried organic debris from beneath trees and the upper cm of soil were composited, blended, and passed through sieves. Organic-matter particles, $< 44 \mu m$ and $105\text{-}250 \mu m$ in size, (classified as fine and coarse) were mixed with a washed Astatula subsoil virtually free of organic matter (OM $< 0.05\%$) to attain OM percentages of 0.125, 0.25, 0.5, 1.0, and 2.0%, respectively. To obtain a uniform OM-soil content, a 2% OM-soil mix was prepared, and lesser percentages were made from this by doubling the subsoil content (w).

Soil samples for DBCP analysis were taken as sections of the columns were dismantled at appropriate times after application. As plexiglass rings were removed, a $21 \times 43$ mm soil core was extracted from the center of each section, placed in 125-ml flasks containing 20 ml distilled water and 20 ml pesticide-grade hexane, and corked. Flasks were shaken 2 h on a reciprocating shaker, and then placed in a freezer. After water was frozen, the supernatant hexane and dissolved DBCP were decanted into glass-stoppered test tubes containing 1.0 g reagent-grade $Na_2SO_4$. These samples yielded 88-92% of the total DBCP content and were used for analysis similar to the method described by Johnson and Lear (6). For our analysis, a gas chromatograph equipped with a Ni-63, 10-millicurie electron-capture detector was used. Each DBCP-hexane sample was injected into an 18.3 × 0.42-cm stainless steel column, which was packed with 5% DEGS on 60/80 Chromosorb W-NAW. The flow rate of $N_2$, the carrier gas, was maintained at 60 ml/min through the detector by use of a scavenger column, and the signal output was recorded on a Servo/Riter II. Temperatures at injector port, manifold, column, and EC detector were 190, 170, 130, and 190 C, respectively. Technical (2.1 kg/liter) and emulsifiable (1.4 kg/liter) DBCP, ranging from 0.05 to 5.0 μg/ml active DBCP, were prepared with pesticide-grade hexane and used for internal reference standards.

Soil-moisture data were obtained from separate, but similar, samples. Moisture content was determined on a dry-weight basis. All treatments and extractions, unless otherwise indicated, were performed at room temperature (22-24 C).

Data were reported from soil samples with DBCP recovered in hexane, and concentrations were graphically determined. DBCP levels were expressed as μg/g of oven-dry soil, with 0.1 μg DBCP/g soil concentration equivalent to 2 μg DBCP/ml of soil water.

## RESULTS AND DISCUSSION

Studies in this laboratory have shown 2 μg DBCP/ml of soil water to be the minimal lethal concentration for control of free-living stages of *T. semipenetrans*. Similar and higher concentrations have been reported for control and eradication of *Meloidogyne* Goeldi (4, 5, 10).

To determine depth of penetration of DBCP and its water solvent, a time study from 1 h to 14 days was made. DBCP at a concentration of 10 μg/ml in 5 cm of water was applied to the soil surface. DBCP penetrated to a depth of 12 cm in the first h with an average concentration of 4.4 μg/g while water penetrated to 20 cm (Fig. 1). After 24 h, water infiltration had reached 67 cm, but DBCP had penetrated to only 15 cm. Maximum downward movement of DBCP after 14 days was 30 cm.

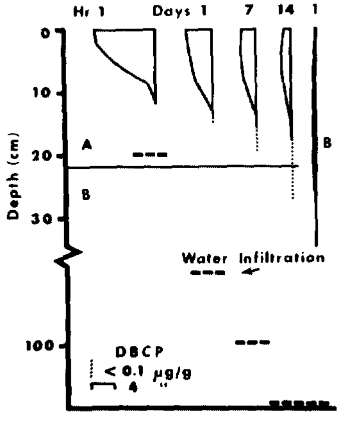


FIG. 1. Penetration of DBCP and water in columns of Astatula fine sand containing A and B horizons consisting of topsoil and subsoil, and columns containing only B horizon (subsoil) in relation to time. DBCP applied to the soil surface as a 10 μg/ml aqueous drench in 5 cm of water. Each time interval shows concentration and depth of penetration of DBCP, as represented, respectively, by the horizontal and vertical lines.

Greatest concentration of DBCP was in the upper 18 cm (Fig. 1). Highest retention was in the topsoil, but detection in the subsoil after 7 and 14 days indicated that downward movement in lesser concentrations occurred. Maximum depth of lethal concentrations of DBCP after 14 days was nearly double the first day's penetration. When comparative aqueous solutions of DBCP were applied to subsoil only (Fig. 1), downward movement of DBCP was less restricted, with maximum penetration of 41 cm in 1 day. Basically, initial distribution of DBCP in water in an Astatula soil occurred at time of application, and the pattern is similar to that reported for other soils (5, 10). However, there is a continuing, slight diffusion under the limiting influence of organic matter in the topsoil.

Concentrations of DBCP in water significantly influenced movement of the DBCP through the soil (Fig. 2). The four rates of DBCP, applied separately in 5 cm of water, showed a significantly deeper penetration as the concentration increased. Maximum concentrations at all rates were detected in the topsoil (22 cm). DBCP was detected in subsoil at the applied rates of 40, 80, and 160 μg/ml in

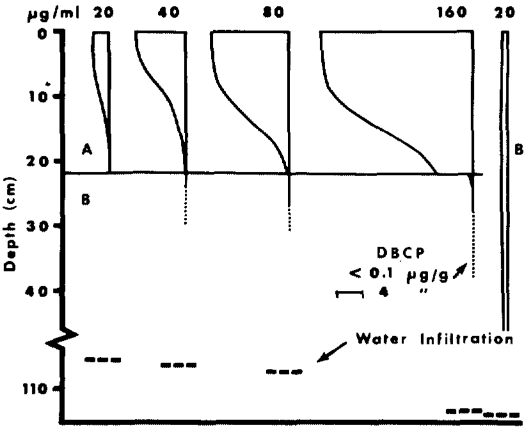


FIG. 2. Penetration of various rates of DBCP 7 days after application as an aqueous drench in 5 cm of water to an Astatula fine sand soil in A and B horizons (topsoil and subsoil) and B horizon (subsoil only).

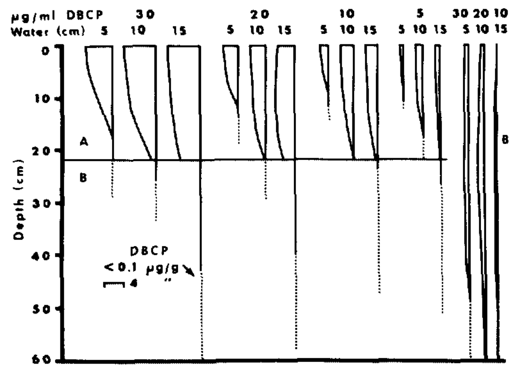


FIG. 3. Penetration of various rates of DBCP 3 days after application as aqueous drenches in 5, 10, and 15 cm of water to an Astatula fine sand soil (A, B horizon and B horizon).

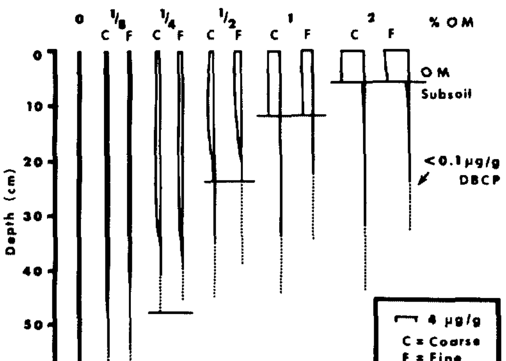


FIG. 4. Penetration of DBCP after 3 days in topsoil containing 0-2% organic matter of two particle sizes (Coarse, 105-250µm; fine < 44µ). DBCP applied to the soil surface as a 20 µg/ml aqueous drench in 5 cm of water.

nematicidal concentrations. High retention of DBCP in topsoil, accompanied by the depth of the wetting front, indicates the importance of sorption of DBCP by organic matter in this soil. A comparative 20 µg/ml aqueous solution of DBCP applied to subsoil only was less restricted in movement (Fig. 2).

An evaluation of the influence of water on depth of penetration of DBCP showed significant influence on movement. Aqueous solutions of DBCP at rates of 5, 10, 20, and 30 µg/ml applied in 5, 10, and 15 cm of water showed that greatest recovery of DBCP, regardless of the concentration or volume of drench applied, was from the topsoil (upper 22 cm) (Fig. 3). No concentrations of DBCP applied in 5 cm of water penetrated below 22 cm at nematicidal concentrations. Only the highest DBCP concentration used penetrated the topsoil in 10 cm of water. DBCP at each concentration was carried into the subsoil when applied in 15 cm of water. When DBCP was applied in comparable water rates to subsoils, infiltration of both water and DBCP was rapid and uniform, penetrating more than 20 cm below the topsoil-subsoil combination; which again demonstrated that DBCP is sorbed by the OM in the topsoil.

The study on influence of organic matter in Astatula fine sand revealed conclusively that the organic fraction was the principal factor influencing DBCP retention in this soil (Fig. 4). Further, sorptive capacity was quantitative, as DBCP penetration was proportional to the amount of OM in the soil. Compared to a subsoil fraction that was virtually free of organic matter, amounts as low as 0.125% OM limit penetration, whereas 1-2% OM effectively limit movement by retaining DBCP. Percent recovery of DBCP by depth is shown in Table 1.

One of the suggested methods of applying DBCP in citrus orchards for control of *T. semipenetrans* in Florida is by sprinkler irrigation in a minimum of 5 cm of water (9). Although nematode control is generally effective, variability in control suggested a closer appraisal of the movement of DBCP from the site of application. Carter and Reynolds (2) reported 85% control of *T. semipenetrans* in 10 days, but maximum control required 60 days. Our studies showed that effective concentrations of DBCP remained in the soil for at least 2 weeks, and other data not reported here showed longer retention. Although increasing the

TABLE 1. Percent DBCP retention in an Astatula fine sand of varying organic matter content and particle size 3 days after application of 20 μg DBCP/ml in 5 cm of water.

| Depth | % Organic matter | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | < 0.05 | 0.125 | | 0.25 | | 0.50 | | 1.0 | | 2.0 | | |
| (cm) | Subsoil | C[a] | F[a] | C | F | C | F | C | F | C | F |
| 6 | 9 | 11 | 15 | 17 | 19 | 21 | 33 | 42 | 45 | 77 | 85 |
| 12 | 9 | 14 | 17 | 22 | 21 | 24 | 30 | 43 | 47 | 8 | 8 |
| 18 | 11 | 15 | 18 | 24 | 23 | 13 | 23 | 6 | 4 | 6 | 4 |
| 24 | 11 | 15 | 17 | 18 | 20 | 6 | 13 | 4 | 3 | 4 | 2 |
| 30 | 13 | 14 | 13 | 11 | 13 | 3 | 1 | 3 | 1 | 3 | 1 |
| 36 | 13 | 12 | 8 | 4 | 3 | 1 | | 2 | | 2 | |
| 42 | 13 | 10 | 6 | 3 | 2 | | | | | | |
| 48 | 9 | 5 | 4 | 1 | | | | | | | |
| 54 | 5 | 3 | 2 | | | | | | | | |
| 60 | 3 | 1 | | | | | | | | | |
| >60 | 4 | | | | | | | | | | |

[a]Coarse (C) = 105 to 250μm, Fine (F) = < 44μm.

concentration of toxicant will increase the zone of coverage, greatest penetration occurred when adequate water was applied. Because DBCP in irrigation water is an effective method of control, optimum penetration can be achieved by regulating the amount of water applied according to the depth of topsoil. With an Astatula fine sand, 10 to 15 cm of water resulted in adequate DBCP movement.

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