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Anhydrobiotic Coiling of Nematodes in Soil

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Abstract. Nematodes of three genera (*Acrobeloides* sp., *Aphelenchus avenae*, and *Scutellonema brachyurum*) were induced to coil and enter anhydrobiosis in drying soil of two types: sandy loam and loamy sand. Coiling was studied in relationship to soil moisture characteristics. Coiling and the physiological state of anhydrobiosis occurred before the water in sandy soils reached a water potential of –15 bars. Coiling was maximum at 3–6 bars, depending on the soil type and nematode species. It appeared that induction of coiling and anhydrobiosis were determined by

Scutellonema brachyurum (Steiner, 1938) Andrassy, 1958, was collected before each experiment from moist soil around a banana plant on the Riverside campus of the University of California. All nematodes were extracted by the Baerman funnel technique for 24 h. Mixed larvae and adults were used in all experiments.

Soil moisture characteristics. The soil moisture of two soils, a loamy sand (92.4% sand, 3.9% silt, and 3.7% clay) and a sandy loam (72.8% sand, 21.2% silt, and 6.0% clay), was controlled on a pressure plate extractor (14) maintained at 20 C. Fig. 1 illustrates a cross-section of the extractor and soil sample. Pressure plates [5-bar pressure plate extractor (Cat. No. 1600) and 15-bar ceramic plate extractor (Cat. No. 1500); Soil Moisture Equipment Co., Santa Barbara, California] with two ranges of suction were used, 0–3 bars for preparing soils with suctions up to 3 bars, and 0–15 bars for preparing soils with suctions of 3–15 bars. For each suction, soil moisture content was determined by the weights of five replicates before and after samples were placed for 24 h in an oven at 105 C.

The surface area of each soil type was determined by the ethylene glycol monoethyl ether (EGME) adsorption method (3, 11) on dry soil. Soil was dried at 105 C for 24 h and then 1.1 g of dry soil was covered with 1 ml of EGME and placed in a desiccator over $CaCl_2$ for 72 h. The soil was weighed again to determine the amount of EGME adsorbed on the soil surface. The surface area, S, was calculated as follows:

$$S(m^2/g \text{ dry soil}) = \frac{\text{quantity of EGME adsorbed (g)}}{\text{quantity of dry soil (g)} \times k}$$

at 20–25 C, k = 0.000286 g/m²

The average thickness of the water film around soil particles was calculated by measuring the surface area of the loamy sand (11.2 m²/g) and sandy loam (15.2 m²/g) and then estimating the soil moisture content when each particle was covered with one monomolecular layer of water (MLW). The formula and calculations are as follows:

$$\text{Soil moisture content (g water/g dry soil)} = \frac{\text{Soil surface area } (m^2/g \text{ dry soil}) \times \text{molecular water weight (g)}}{\text{Molecular water surface (Å)} \times 6.023 \times 10^{23}}$$

Molecular water weight = 18^{-20} g
Molecular water surface = 10.8 Å

Soil moisture contents of the loamy sand and sandy loam were found to be respectively 3.1×10^{-3} g water/g dry soil and 4.3×10^{-3} g water/g dry soil (15).

$$\text{No. MLW} = \frac{\text{Soil moisture content (g water/g dry soil)}}{\text{Soil moisture content when each soil particle is covered with 1 MLW (g water/g dry soil)}}$$

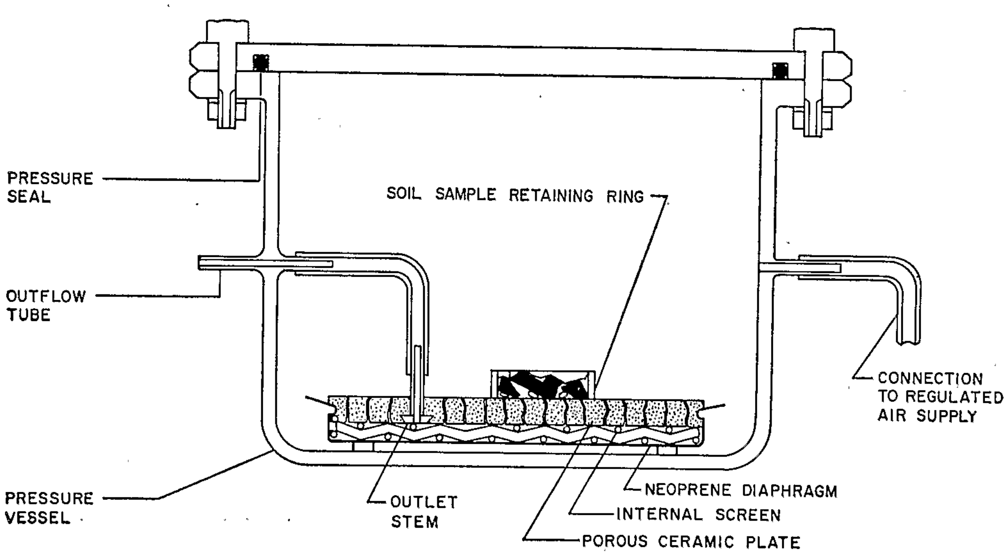


FIG. 1. Cross-section of ceramic pressure-plate cell showing soil sample in the extractor.

Treatments. Each experiment consisted of 30 polyethylene rings (2.5 cm in diameter and 1 cm high) placed on the pressure plate to represent 6 treatments each with 5 replicates. About 5 cc of dry soil was added to each ring. The samples were then moistened with water by capillary action to saturation. Nematodes were pipetted onto the surface of each wet soil sample. About 200 nematodes were used for *S. brachyurum,* and 1000 each of *A. avenae* and *Acrobeloides* sp.

Treatments consisted of 0, 0.1, 0.3, 0.5, 1, and 3 bars on the 0–3-bar plate and 0, 0.5, 1, 3, 6, and 9 bars on the 0–15-bar plate in those cases when nematodes did not reach maximum coiling on the 0–3-bar plate. Starting at saturation, suction was increased to the next treatment for 24 h, the container

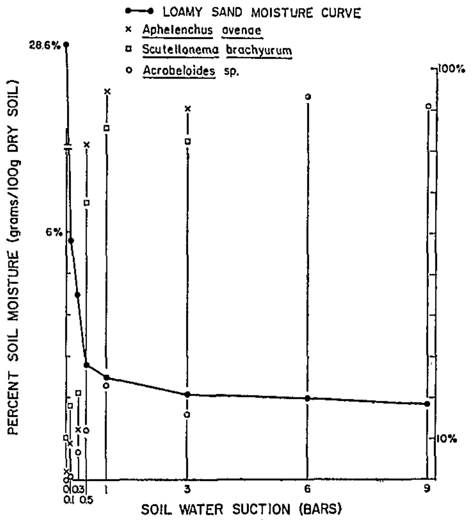
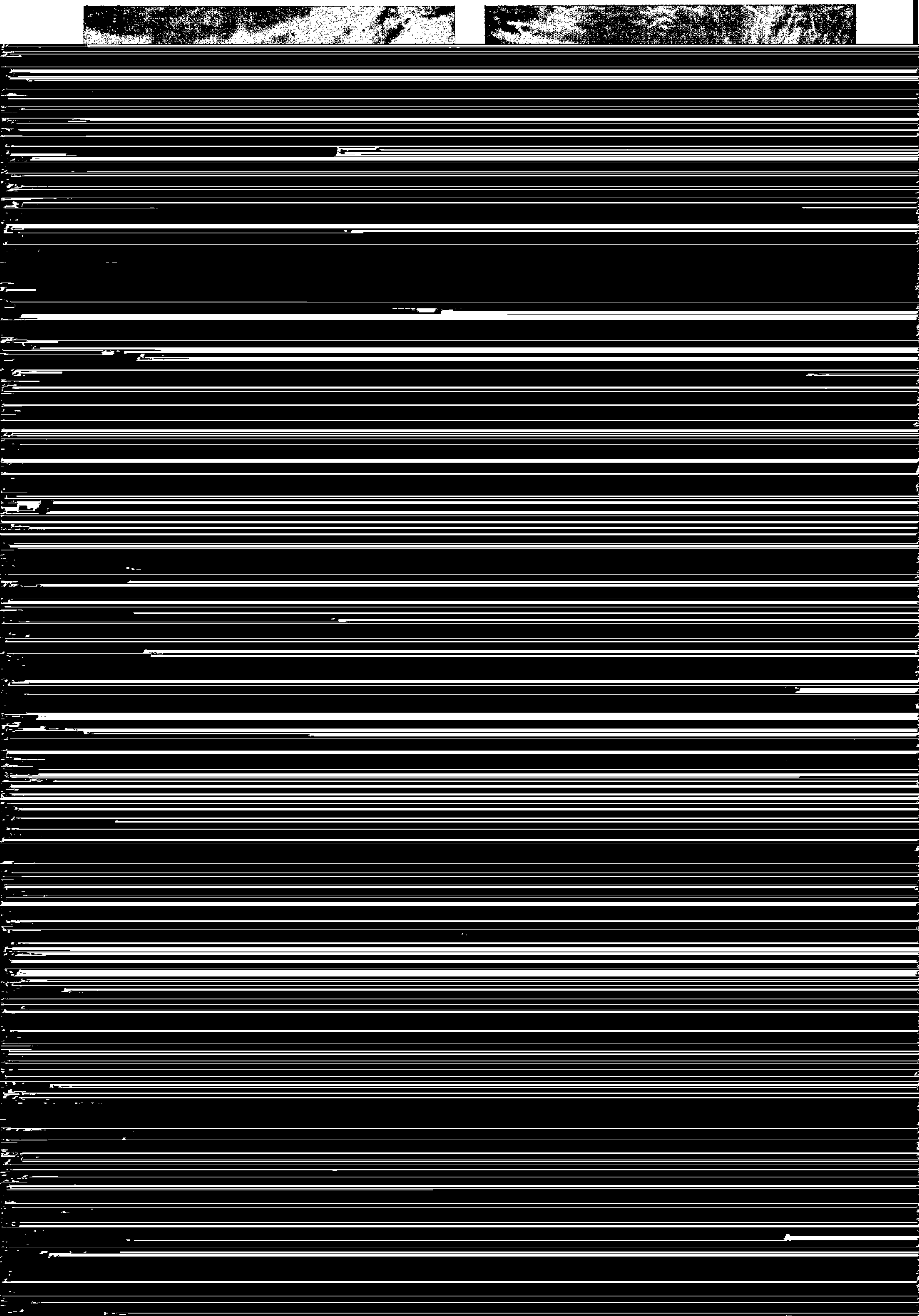


TABLE 1. Relationship of soil suction, soil moisture, and water film thickness in number of monomolecular layers of water (MLW) to coiling and survival of adults and larvae of *A. avenae, S. brachyurum*, and *Acrobeloides* sp. in two soil types.

Suction (bars)	Soil moisture content (%)	Water-film thickness (MLW)	% coiled nematodes			% activity after treatment		
			Aphelenchus avenae	*Scutellonema brachyurum*	*Acrobeloides* sp.	*Aphelenchus avenae*	*Scutellonema brachyurum*	*Acrobeloides* sp.
Sandy loam (72.8-21.2-6.0)								
0.0	37.8	89	0	0	0	89	98	97
0.1	16.0	38	0	11	0	88	98	84
0.3	9.0	21	1	18	0	93	99	97
0.5	5.7	13	3	24	0	93	93	100
1.0	4.8	11	1	28	0	95	94	95
3.0	3.7	9	2	35	2	94	96	78
6.0	3.4	8	96	80	86	95	94	87
9.0	3.0	7	97	90	80	95	97	83
Loamy sand (92.4-3.9-3.7)								
0.0	28.6	92	2	10	0	91	97	96

when the soil moisture content reached 3.4% or when the water film was 8 MLW thick. Generally, there was an inverse relation between soil moisture content and coiling, i.e., as the soil pore spaces began to empty, the nematodes began coiling. Coiling was maximum when the water film around the soil particles reached 8–6 monomolecular layers of water, regardless of soil

in the loamy sand and at 3.4% in the sandy loam. Freckman (10) suggested that nematodes went in and out of anhydrobiosis in desert soils at a moisture content of about 2.5%. On the basis of calculated water film thickness around soil particles in monomolecular layer of water (MLW) in both soils, it appeared that there was a closer relationship between number of MLW and



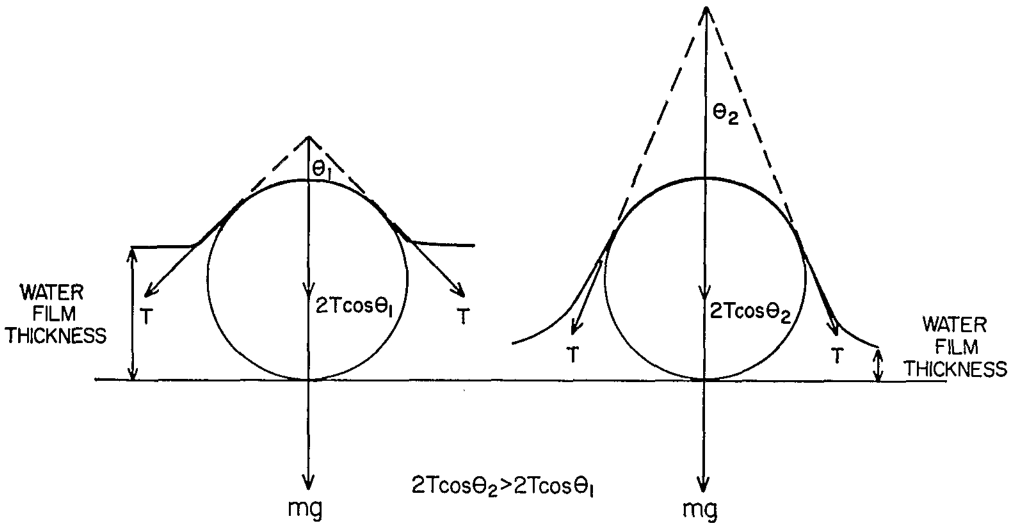


FIG. 5. A comparison of the external physical forces acting on a nematode at rest in a water film [after Wallace (1959)].

anhydrobiosis by slowly drying moist soil. Depending upon soil types, the nematodes may begin coiling at about 0.5 bar of suc-

water loss and survival. J. Exptl. Zool. 193: 323-334.

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