Xiphinema americanum as Affected by Soil Organic Matter and Porosity[1]

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Abstract: The effects of four soil types, soil porosity, particle size, and organic matter were tested on survival and migration of *Xiphinema americanum*. Survival and migration were significantly greater in silt loam than in clay loam and silty clay soils. Nematode numbers were significantly greater in soils planted with soybeans than in fallow soils. Nematode survival was greatest at the higher of two pore space levels in four soils. Migration of *X. americanum* through soil particle size fractions of 75-150, 150-250, 250-500, 500-700, and 700-1,000 μ was significantly greater in the middle three fractions, with the least occurring in the smallest fraction. Additions of muck to silt loam and loamy sand soils resulted in reductions in survival and migration of the nematode. The fulvic acid fraction of muck, extracted with sodium hydroxide, had a deleterious effect on nematode activity. I conclude that soils with small amounts of air-filled pore space, extremes in pore size, or high organic matter content are deleterious to the migration and survival of *X. americanum*, and that a naturally occurring toxin affecting this species may be present in native soil organic matter.

Received for publication 29 November 1971.

[1]Journal Paper No. J-7049 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 1337. Supported by Grant No. 12-14-100-9168(34), Agricultural Research Service, U.S. Department of Agriculture.

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Most studies pertaining to soil porosity support the theory that lighter soils provide a better environment for some plant-parasitic nematodes than do heavier ones (3, 4, 9, 16, 18). Little work has been conducted measuring porosity *per se*, but the importance of pore size was demonstrated by Wallace (22, 23). He found that soils with small particles contained pores too small to allow nematode passage, and that soils with large particles contained pores so

large that a leverage problem resulted.

Additions of crop residues and organic amendments to infested soils generally have reduced nematode populations (5, 7, 11, 12, 13, 14, 15, 21). Walker (20) found that bacteria and fungi are required for control of *Pratylenchus penetrans* Cobb in soil amended with soybean meal, indicating that a microbial degradation product may be the controlling factor. Fatty acids isolated from decaying residues are toxic to nematodes (1, 6, 8, 17). Native soil organic matter apparently has not been utilized in controlled tests.

The effects of four soil types, soil porosity, particle size, and organic matter on survival and migration of *Xiphinema americanum* Cobb are reported.

MATERIALS AND METHODS

GENERAL PROCEDURES: Soil samples were collected from the upper 15-cm of Albaton silty clay, Tripoli clay loam, Edina silt loam, and Hagener loamy sand. The last two soils contained a larger volume of air-filled pore space than the first two, and the clay loam contained nearly twice as much organic matter as any of the other soils. All samples were passed through a 1-mm sieve and fumigated with 0.454 kg methyl bromide/0.765 m^3 of soil and aerated for 7 days.

Particle size was altered by sieving the loamy sand into five size fractions of 75-150, 150-250, 250-500, 500-700, and 700-1,000 μ. Two pore space levels of the four soil types were obtained by collecting the soils in a relatively undisturbed state with an Ühlen sampler and, in a disturbed state, by collecting them with a shovel. The undisturbed samples were compacted, and contained less air-filled pore space than did the disturbed samples. Organic matter was altered in the loamy sand and silt loam by adding 0, 4, 8, and 12% muck by weight to each.

SURVIVAL OF *XIPHINEMA AMERICANUM*: The effects of soil type, particle size, porosity, and organic matter were tested in four separate experiments. Soils to be tested were placed in 7.6-cm pots, and water containing 200 *X. americanum* was pipetted into 1.5-cm-deep holes in the center of each pot. Nematodes were covered with 0.5-cm of soil and three soybean seeds (*Glycine max* [L.] Merr. 'Amsoy') were planted in half the pots in each experiment. Each treatment was replicated three times. Plants were thinned to one/pot 7 days after emergence. The soil was maintained at field capacity for 8 weeks at 24-30 C with an automatic watering device (2). Juveniles and adults were counted at the termination of each experiment.

MIGRATION OF *XIPHINEMA AMERICANUM*: A modification of the Wallace method (22) was used to test soil property effects on movement of *X. americanum*. Soils to be tested were placed uniformly in 5-cm sections of 0.83-cm I.D. Tygon® tubing, watered to field capacity, and infested at one end with 200 *X. americanum* in a drop of water. Additional Tygon tubing 1.27-cm I.D. X 5-cm was sealed at one end and placed at each end of the tubes containing soil to maintain moisture and to provide additional air. Tubes were incubated in a horizontal position at 20 C for 5 days in the dark, after which each 5-cm tube was cut 1-cm from the point of infestation. Nematodes were counted in each section, and results expressed as the percentage of the number recovered that had migrated 1-cm or more.

Nematodes were also observed in 1-mm thick layers of the five particle size fractions of the loamy sand on glass slides.

ACTIVITY OF *XIPHINEMA AMERICANUM* IN SOIL EXTRACTS: Muck soil was extracted with water and 0.1 N sodium hydroxide. Sodium hydroxide extracts were separated into humic and fulvic acid fractions by acidification of the extract to pH 2.0. This resulted in precipitation of the humic acid fraction while the fulvic acid fraction remained in solution (10). The precipitate was redissolved in sodium hydroxide, and both fractions were adjusted to pH 7.0. Controls consisted of water and sodium hydroxide extracts of the loamy sand in which the organic matter had been destroyed by hydrogen peroxide. Toxicity to *X. americanum* was tested by adding water extracts and humic and fulvic acid fractions to water containing 200 nematodes in a 1:1 (v/v) ratio in a 50-mm petri dish. The effect of the solution on nematode activity was observed at 0, 4, 8, 16, 24, 32, and 48 hr. Nematodes were termed active if they were observed moving or if they moved after being touched with a probe. Twenty nematodes were counted in the water extracts, and 50 in the acid fractions. Four replications were used in the water extracts experiment, and five in the tests involving acid fractions. The results were expressed as percentages of active nematodes.

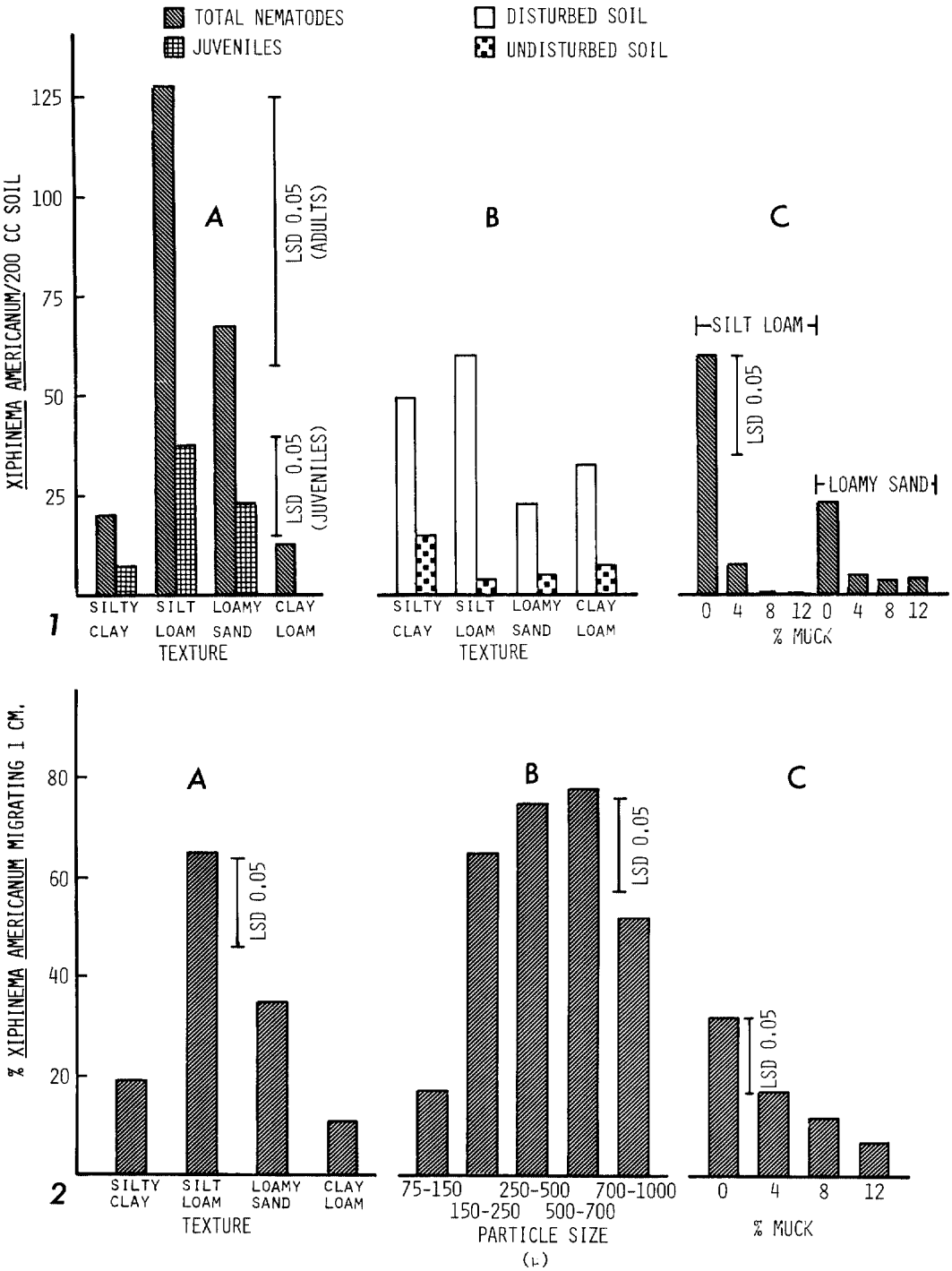

FIG. 1-2. **1.** Numbers of *Xiphinema americanum* per 200 cc of soil after 8 weeks' incubation. Each bar represents the mean of combined planted and fallow treatments. Each pot was initially infested with 200 nematodes: **A.** in four soil types; **B.** in disturbed versus undisturbed samples; **C.** in soils amended with various amounts of muck. **2.** Percentage of *X. americanum* migrating 1 cm or more after 5 days' incubation: **A.** in four soil types; **B.** in various particle size fractions; **C.** in soils amended with various amounts of muck.

RESULTS

SURVIVAL OF *XIPHINEMA AMERICANUM*: Results in Fig. 1 are presented as means of combined planted and fallow treatments. In the experiment testing four soil types, the number of juveniles and total number of *Xiphinema americanum* surviving were significantly greater (P = .05) in silt loam than in either clay loam or silty clay soils (Fig. 1A). There were no significant differences among the other soil types. Survival was 89% greater (P = .01) in treatments utilizing soybeans than in fallow treatments over all experiments involving plants.

The test comparing disturbed and undisturbed soils demonstrated the importance of pore space (Fig. 1B). The sieved soils, which contained more pore space, also contained significantly more (P = .01) *X. americanum* than did undisturbed field cores.

Survival percentages in different size fractions were not significantly different. Total numbers of *X. americanum* were low, however.

Significantly fewer nematodes were present in the silt loam (P = .01) and loamy sand (P = .05) amended with muck than in unamended soils (Fig. 1C).

MIGRATION OF *XIPHINEMA AMERICANUM*: Movement was greater (P = .05) in the silt loam than in all other soils. Significantly greater migration (P = .05) occurred in loamy sand than in silty clay or clay loam soils (Fig. 2A). Movement was significantly less (P = .05) in the smallest and largest particle size fractions of the loamy sand than in the middle three fractions (Fig. 2B). Visual observations of movement of *X. americanum* in 1-mm soil layers on glass slides revealed that the pores were too small for movement in the smallest fractions, and were large enough to cause leverage problems in the largest. The addition of muck to the silt loam and loamy sand resulted in a significant decrease (P = .05) in migration at the 8 and 12% levels of muck compared with the treatment receiving no amendment (Fig. 2C).

ACTIVITY OF *XIPHINEMA AMERICANUM* IN SOIL EXTRACTS: Water extracts and humic acid fractions of sodium hydroxide extracts had no effect on nematode activity. The fulvic acid fraction caused a significant decrease (P = .05) in activity compared with similar extracts of soils containing no organic matter (Fig. 3).

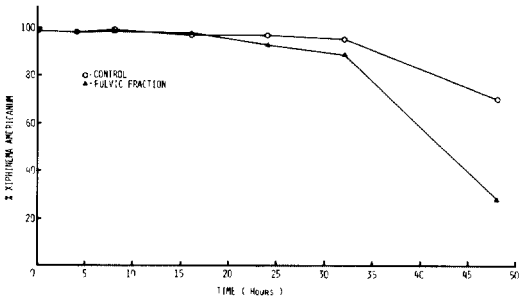

FIG. 3. Percentage of *Xiphinema americanum* active after 0, 4, 8, 16, 24, 32, and 48 hr in the fulvic acid fraction of sodium hydroxide extracts of muck.

DISCUSSION

Air-filled pore space is important in the ecology of *Xiphinema americanum*, since nematode survival and migration were greatest in soils with the largest amount of air-filled pore space in several experiments (Figs. 1A, B, 2A). Nematodes migrated farther and survived at a higher rate in the silt loam and loamy sand soils than in either the silty clay or the clay loam, presumably because silt loam and loamy sand contained the largest amount of air-filled pore space. Movement and survival were reduced in the silty clay, probably because air-filled space was limiting. These reductions are most probably related to the high percentage of organic matter in the clay loam. Larger populations in the disturbed than in the undisturbed soils also support this theory because all disturbed samples contained a larger amount of pore space than did those not disturbed. Although previous investigators did not measure pore space *per se*, coarse-textured soils generally contain more air, and the results of others usually correlate greater nematode activity with coarser-textured soils (3, 4, 18, 19).

Differences in the experiment measuring the effect of particle size on nematode movement are probably due to physical factors. The smallest particle-size fraction had the largest amount of air-filled pore space; therefore, aeration was not limiting. Visual observations also demonstrated the importance of physical factors, and are in agreement with the results of Wallace (22, 23).

Since nematode survival and movement were reduced by muck amendments, and activity was reduced in soil extracts, I

concluded that a substance in the organic fraction was toxic to *X. americanum*. The fulvic acid fraction is ill-defined, and could have contained contaminants such as fatty acids; therefore, toxicity may be due to something other than fulvic acids *per se*. Since fatty acids have been shown to be contaminants of the fulvic acid fraction (10) and they have also been shown to be toxic to several nematode species (1, 6, 8, 17), perhaps the unknown toxic factor could be such a compound. Additional work is needed to identify this factor.

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