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Winter Survival of *Meloidogyne incognita* in Six Soil Types[1]

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Abstract: Winter survival of *Meloidogyne incognita* in six soil types (Fuquay sand, Norfolk loamy sand, Portsmouth loamy sand, muck, Cecil sandy clay loam, and Cecil sandy clay) was determined in microplots at one location from November 1981 to May 1982 and from November 1982 to March 1983. Survival, based on second-stage juveniles (J2) of *M. incognita,* from November 1981 until May 1982 ranged from 1% in the muck soil to 6% in a Cecil sandy clay loam, but survival rates were much higher the next year following a winter with higher average temperatures. Survival rates of J2 from November to March ranged from 20 to 40% the first winter and from 38 to 87% the second. Soil type did not have a striking effect on the overwintering capabilities of *M. incognita.* There were no differences between clay and sand soils, whereas survival of J2 in the muck tended to be lower than in the mineral soils.

Key words: *Meloidogyne incognita,* southern root-knot nematode, population dynamics, soil type, survival.

The population dynamics of *Meloidogyne* spp. have been studied for various environmental conditions (7,9,12,18,20). Maximum population densities of this genus on annual crops in North Carolina usually occur from September to November (3,16). *Meloidogyne* population densities generally decline during winter and in spring may be undetectable (2). Because of such poor survival rates, nematode advisory programs recommend fall sampling of fields to estimate the initial inoculum for the following growing season (2). Winter survival of *Meloidogyne incognita* (Kofoid and White) Chitwood in North Carolina is estimated from 1 to 10% of the population present at harvest (18). Spring population levels may be estimated based on extrapolations using regression or other population models (11). This approach may not be accurate, since winter survival of nematodes is influenced by a number of environmental parameters and management practices.

Soil type and associated edaphic parameters may alter the survival of nematode populations during winter. The objective of this study was to determine the effects of soil type (primarily texture) on the winter survival of *M. incognita.*

MATERIALS AND METHODS

Six soil types introduced into microplots at Central Crops Research Station, Clayton, North Carolina, were used for these studies. Soils and particle analyses were Fuquay sand (91% sand, 3% clay, 6% silt, 0.6% OM), Norfolk loamy sand (84% sand, 4% clay, 12% silt, 1.4% OM), Portsmouth loamy sand (72% sand, 10% clay, 18% silt, 2.7% OM), a muck (58% sand, 9% clay, 33% silt, > 30% OM), Cecil sandy clay loam (53% sand, 29% clay, 18% silt, 2.2% OM), and Cecil sandy clay (48% sand, 39% clay, 13% silt, 0.9% OM). Plots were infested with 20,000 *M. incognita* juveniles (J2) and eggs/500 cm^3 soil and planted to 'Lee 68' soybean in May 1981 and 1982. A randomized complete block design was used with five replications per soil type.

Soil samples were collected from each soil type at ca. 4-week intervals from November 1981 to May 1982 and from November 1982 to March 1983. Ten to twelve 2.5-cm-d cores 15–20 cm deep were taken from each plot and composited. J2 were extracted from 500 cm^3 of the composited samples by a combination of elutriation and

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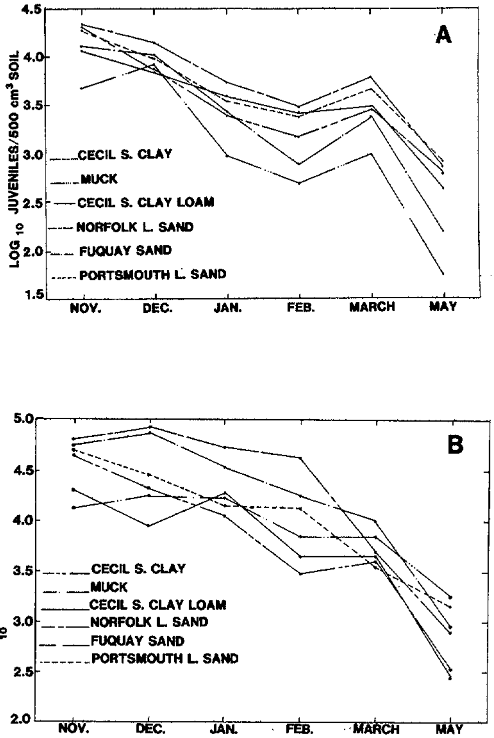

FIG. 1. Population densities of *Meloidogyne incognita* in six soil types in microplots at Central Crops Research Station, Clayton, North Carolina (1981–82). A) Second-stage juveniles. B) Eggs.

centrifugation (El + C) (1). Extraction efficiency of EL + C for *Meloidogyne* spp. J2 is 20–40% (5). The extraction efficiency of El + C for different soils has not been determined. Eggs were extracted by a NaOCl method (10).

Soil temperatures were monitored continuously at 15 cm using a thermograph or a 'CR21 Micrologger' (Campbell Scientific, Logan, UT) in one plot of each soil type. Soil moisture, grams water/gram soil × 100, was determined at each sampling date in 1981. Known moisture holding characteristics of the soil were used to convert percentage of soil moisture to moisture tensions (cm).

Analysis of variance was performed on all data. Survival percentage, (final population/November population) × 100, of J2 and eggs in soil types were compared for differences at $P = 0.05$ by Waller–Duncan k-ratio *t*-test. Data were subjected to regression analyses to compare J2 and egg numbers over time. The numbers of nematodes (X) were converted to $\log_{10}(X + 1)$ to stabilize the variance of the data. Maximum R^2 improvement analysis (15) was used to determine the relationship of J2 and egg population densities to days after harvest, soil temperature, soil moisture tensions (cm), and soil texture.

RESULTS

Numbers of J2 present in November 1981 declined greatly with survival ranging from 1 to 6% in May 1982 (Fig. 1A). During most of the first winter, highest numbers of J2 were recovered from the Norfolk loamy sand and lowest numbers from the muck. There was a general decrease of J2 from November to February. J2 numbers in all soils increased slightly in March due to egg hatch which was related to an increase in soil temperature (Fig. 2). J2 survival in May ranged from only 1% in

TABLE 1. Survival percentages of *Meloidogyne incognita* juveniles and eggs in microplots in different soil types.

	Juvenile survival†			Egg survival†		
Soil types	March 1982	May 1982	March 1983	March 1982	May 1982	March 1983
Fuquay sand	23 a	2 a	52 a	35 a	2 b	22 a
Norfolk loamy sand	30 a	4 a	48 a	8 a	1 b	5 a
Portsmouth loamy sand	31 a	5 a	72 a	11 a	3 b	3 a
Muck	20 a	1 a	38 a	71 a	16 a	8 a
Cecil sandy clay	24 a	3 a	87 a	11 a	1 b	5 a
Cecil sandy clay loam	40 a	6 a	52 a	25 a	2 b	18 a

Means within columns followed by the same letter do not differ significantly at $P = 0.05$ by Waller-Duncan k-ratio *t*-test.
† Survival percentage = (final population/November population) × 100.

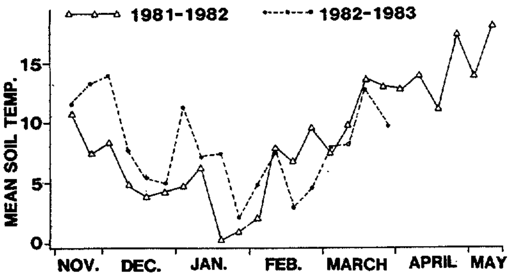

FIG. 2. Weekly mean soil temperatures at a 15-cm depth at the Central Crops Research Station from November 1981 to May 1982 and from November 1982 to March 1983.

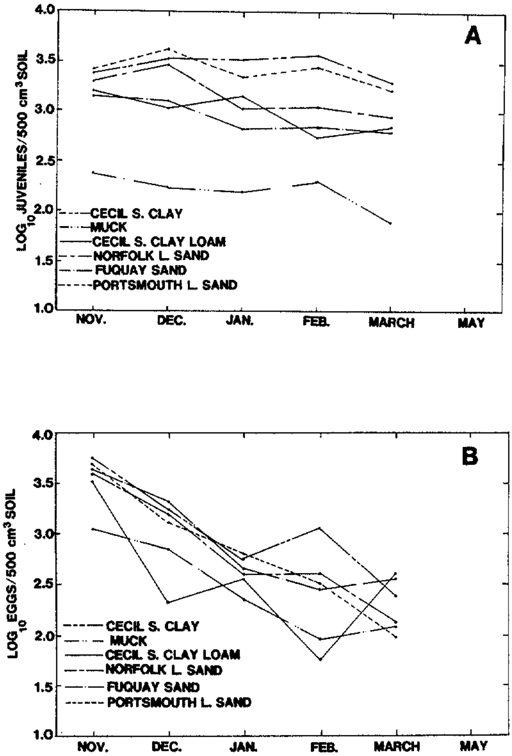

FIG. 3. Effect of six soil types on population densities of *Meloidogyne incognita* in microplots at Central Crops Research Station, Clayton, North Carolina (1982–83). A) Second-stage juveniles. B) Eggs.

the muck to 6% in the Cecil sandy clay loam (Table 1).

There was a gradual decrease in egg numbers over the winter and spring, with lowest numbers recovered in May (Fig. 1B). Egg numbers varied little from November 1981 to January 1982. Higher egg numbers were found in the Fuquay sand and Norfolk loamy sand from November to February. Egg survival in March ranged from 8% in the Norfolk loamy sand to 71% in the muck. Survival in May 1982 was highest in the muck (16%) and lowest in the Norfolk loamy sand (1%) and Cecil sandy clay (1%).

Nematode reproduction during the 1982 growing season was much less than in 1981. Egg and J2 levels, therefore, were greatly reduced in November 1982, compared with the previous year. Higher J2 numbers, however, were recovered from the Portsmouth loamy sand and Cecil sandy clay than from the other soils throughout the winter of 1982–83 (Fig. 3A). Lowest numbers of J2 were extracted from the muck. All soils supported very high survival rates of J2 in March, ranging from 38 to 87%.

The apparent stability in J2 numbers contrasts to a sharp decline in egg numbers in all soils (Fig. 3B). Egg numbers generally decreased in the sands and the muck through the winter. Several peaks in egg numbers in the Cecil sandy clay loam were observed. Egg survival in March ranged from 3% in the Portsmouth loamy sand to 22% in the Fuquay sand.

Even with lower nematode and egg population densities in 1982–83, overall survival of J2 was much higher in March 1983 than in the previous March. The survival rate in certain soil types in 1982–83 was twice that of the previous year. Greater survival may be attributed to higher fall and early winter soil temperatures followed by lower spring temperatures in 1982–83. This combination may have resulted in greater egg hatch during the second year which would explain higher J2 numbers and the low egg survival in March.

Data were subjected to regression analysis to characterize the population change over time for both winters. Data from Cecil sandy clay and Cecil sandy clay loam plots were combined, and data from the Norfolk loamy sand, Portsmouth loamy sand, and Fuquay sand plots were combined for regression analysis. Regression analysis for 1982–83 are not discussed because of poor fit of the models to the data. There was a linear decrease in J2 numbers as days after

TABLE 2. Regression equations of *Meloidogyne incognita* second-stage juvenile and egg population densities from November 1981 to May 1982 in six soil types at a common location.

Soil type	Equations†	
	Juveniles	Eggs
Clay‡	$y(\log_{10}) = 4.10569 - 0.00645(D)$ $R^2 = -0.55 \quad P = 0.01$	$y(\log_{10}) = 4.48672 - 0.00916(D)$ $R^2 = -0.58 \quad P = 0.01$
Sand§	$y(\log_{10}) = 4.25847 - 0.00767(D)$ $R^2 = -0.54 \quad P = 0.01$	$y(\log_{10}) = 4.62392 - 0.00631(D) - 0.00009(D)^2$ $R^2 = -0.68 \quad P = 0.01$
Muck	$y(\log_{10}) = 3.86255 - 0.01011(D)$ $R^2 = -0.58 \quad P = 0.01$	$y(\log_{10}) = 4.26165 - 0.00464(D)$ $R^2 = -0.36 \quad P = 0.01$

† Where D = days after soybean harvest.
‡ Data from Cecil sandy clay and Cecil sandy clay loam soils.
§ Data from Fuquay sand, Norfolk loamy sand, and Portsmouth loamy sand soils.

harvest increased in clay, sand, and muck soils (Table 2). A decreasing linear relationship also existed for egg survival in the clay and muck plots; however, a quadratic model best described the decline of eggs in sandy soils. Egg numbers in the Fuquay sand and the Norfolk loamy sand increased initially and then declined through the winter and spring.

Maximum R^2 improvement analysis selected variables accounting for much of the variability in J2 and egg numbers in 1981–82. Time after harvest, soil temperature, and silt percentage accounted for 52% of the variability of the J2 numbers. The variability of egg numbers was best explained by time after harvest and percentage of sand. There was a negative response of J2 and egg numbers to days after harvest which reflected the general decline in numbers of J2 and eggs over time. Silt percentage had a negative effect on J2 numbers, whereas sand had a positive effect on eggs.

Discussion

Soil type did not have a striking effect on the overwintering capabilities of *M. incognita.* There were no differences between clay and sand soils, whereas survival of J2 in the muck tended to be lower than in the mineral soils. The survival rate of 1–6% for J2 in all soil types in the 1981–82 experiment agreed with previous reports (3,19). Soil temperatures in January 1982 were near 0 C which has been shown to be lethal to *M. incognita* (4). The −1.1 C isotherm of average January temperature has been associated with the northern range of this nematode (21). The survival rate appeared to be much higher in 1983 than in the previous year. Moderate soil temperatures apparently favored nematode survival. Rate of survival also may have been influenced by the number of nematodes present in November 1982. Low initial populations have been correlated with higher survival rates (8,20).

Interactions of soil temperature and soil moisture influence nematode survival (6,22,23) and may affect survival in the muck. In 1981 soil moisture tensions varied among the soil types over time. Soil moisture levels during 1981–82 and 1982–83 probably were similar because rainfall patterns were similar. Moisture was not included in models selected by maximum R^2 improvement analysis.

Other factors affecting the survival rate of *Meloidogyne* spp. include nematode depth in soil (14), edaphic chemical factors (13), and aeration of the soil (24). Overwintering survival differs among *Meloidogyne* spp. (14) as well as among populations within the same species (6).

Although various edaphic factors may alter nematode survival, soil temperatures of 0 C or lower appear to be a major factor in *M. incognita* winter survival. Following severe winters in North Carolina, from 1 to 10% of the fall population can be expected to survive. In contrast, higher potential initial inoculum will be present after a moderate winter followed by a cool spring which delays egg hatch.

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