Dynamics of Winter Survival of Eggs and Juveniles of *Meloidogyne incognita* and *M. arenaria*

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Abstract: Winter survival dynamics of *Meloidogyne incognita* and *M. arenaria* were studied at nine sites in Texas for 2 years. Population survival from October until April was variable among sites, ranging from 0.1% to 33%. A negative correlation ($r = -0.86$, $P = 0.01$) was observed between initial population densities in October and survival percentage until the following April. Total population (eggs + J2) and population of eggs declined continuously during the survival period. Populations of juveniles (J2) increased initially, then declined. The total populations were 82% eggs in October; hatch of these eggs was believed responsible for the observed increase in the population density of J2. Viable eggs were recovered from the soil until March. Eggs are as important as J2 in winter survival of *M. incognita* and *M. arenaria* in Texas. Survival data were analyzed by a simple mathematical model.

Key words: root-knot nematodes, modeling, population dynamics, egg viability.

Development of predictive advisory programs for management of plant-parasitic nematodes requires knowledge of nematode biology, ecology, and pathogenicity. Predictability of seasonal fluctuations in nematode population densities is especially important. Nematode populations generally reach a maximum in the fall and are at a minimum in the spring. Collection of soil samples for advisory purposes in the spring, therefore, increases the probability of detection failures (3). Collection of samples in the fall ensures that growers will have ample time to implement appropriate nematode management systems. While most advisory programs in the United States recommend that fields be sampled in the fall to estimate nematode population densities, damage functions used to predict crop response to a given nematode population density are generally based on population densities present at or near the time of planting (7). Therefore, estimates of population densities in the spring must be based on samples collected several months earlier.

There are numerous reports on the overwintering dynamics of *Meloidogyne* spp. Survival of *M. incognita* was reported to be greater at soil depths below 30 cm than at 0–30 cm (6,15). Host plants also influence winter survival (13). Populations of *M. incognita* second-state juveniles (J2) increase markedly at midwinter due to egg hatch

(2). Although eggs are more resistant than are J2 to low temperatures (1,17), most studies on winter survival are based on bioassays or extraction of J2 from soil. In Oklahoma, J2 were believed to be more important than eggs for survival because no viable eggs were recovered from the soil after mid-December at depths less than 60 cm (6).

Winter survival of *M. incognita* and *M. arenaria* was studied to obtain data required to support a nematode advisory program in Texas. Specific objectives were to determine winter survival of J2 versus eggs, to determine mean population survival, and to estimate the rate of decline of the total population during winter. Mathematical models have been devised which quantify relationships defined by these objectives (11). A preliminary report of this work has been presented (16).

MATERIALS AND METHODS

Overwintering survival of *Meloidogyne* spp. was monitored at eight sites from November 1982 through April 1983. Test sites were located in northern Texas as follows: Lubbock County, one site previously planted to cotton and infested with *M. incognita* (Kofoid & White) Chitwood; Howard County, four sites all previously planted to cotton and infested with *M. incognita*; Eastland County, two sites previously planted to peanuts and infested with *M. arenaria* (Neal) Chitwood; and Rusk County, one site previously in weed fallow and infested with *M. incognita*. Three replicate plots (10 × 30 m) were established at each site. At approximately monthly intervals,

TABLE 1. Overwinter survival of *Meloidogyne* species in Texas.*

Test site		Species†	Fall population density (eggs and J2/ 300 cm³)	% of population as eggs		% winter survival of total population
				November	April	
Lubbock County		Mi	180	73	87	24.0
Howard County	I	Mi	685	92	21	5.2
	II	Mi	735	59	0	15.5
	III	Mi	1,609	98	39	2.9
	IV	Mi	2,155	99	0	0.4
Rusk County		Mi	73	73	25	33.0
Brazos County 0–20 cm		Mi	3,840	85	0	0.1
20–40 cm		Mi	828	63	0	4.5
Eastland County	I	Ma	6,486	93	0	1.2
	II	Ma	444	87	90	2.2
Mean ± SE				82.2 ± 4.5	23.6 ± 10	8.9 ± 3.6

* Values are means of three replicate, composite samples, except for Brazos County which had five replicate samples. 0–20 cm and 20–40 cm refer to soil depth from which samples were collected.
† Mi = *M. incognita*, Ma = *M. arenaria*.

20 soil cores (2.5 cm d × 30 cm deep) were removed from each plot and combined by local cooperators into a single composite sample per plot. All samples were shipped by parcel post to College Station, Texas, and processed within 10 days of collection. Five replicate plots (15 × 30 m) were established in Brazos County in a field previously planted to cotton and infested with *M. incognita*. Composite soil samples were collected at monthly intervals from October 1983 through April 1984 from soil depths of 0–20 and 20–40 cm. All samples were immediately transported to the laboratory and processed. Soils were loamy sands with > 85% sand (based on mechanical analysis), < 2.0% organic matter, and pH from 7.5 to 8.5 at each test site. All test sites for both 1982–83 and 1983–84 were maintained in a fallow condition during the study period.

A single 300-cm³ aliquot of each sample was processed for both J2 and eggs. The centrifugal-flotation method (12) was used to extract J2 from the soil, while eggs were extracted by a modification of the method of Byrd et al. (4). To extract eggs, the residue remaining on the 250-μm-pore sieve from initial sieving during the centrifugal-flotation process was collected in 150-ml beakers and the volume brought to 100 ml with water. Each sample received 25 ml of commercial bleach (5.25% NaOCl) followed by vigorous stirring for 4 minutes. The suspension containing eggs was then poured through a 75-μm-pore sieve nested over a 26-μm-pore sieve. Eggs caught on the 26-μm-pore sieve were rinsed into beakers, the volume was adjusted to 50 ml, and eggs in a 5-ml aliquot were counted using a stereo microscope. Estimates of the in situ rates of egg hatch and J2 mortality for the Brazos County site were obtained using a model for winter survival dynamics of *Meloidogyne* spp. eggs and J2 (11).

Viability of recovered eggs was measured by incubating eggs at 24 C in small hatching chambers constructed of 1.8-cm-i.d. plastic pipe cut into 1.5-cm lengths with 21-μm-pore nylon cloth glued to the bottom. Chambers were nested in 5-ml plastic beakers containing sufficient water to cover the nylon cloth. Juveniles hatching from the eggs and migrating through the nylon cloth were counted every 2–3 days for 14 days.

TABLE 2. Hatch of eggs of *Meloidogyne incognita* collected from two soil depths from December 1983 through March 1984.

Sample date	% egg hatch*	
	0–20 cm	20–40 cm
December	3.8	9.4
January	15.2	8.3
February	4.6	6.8
March	0.0	8.1
LSD 0.05	6.1	NS

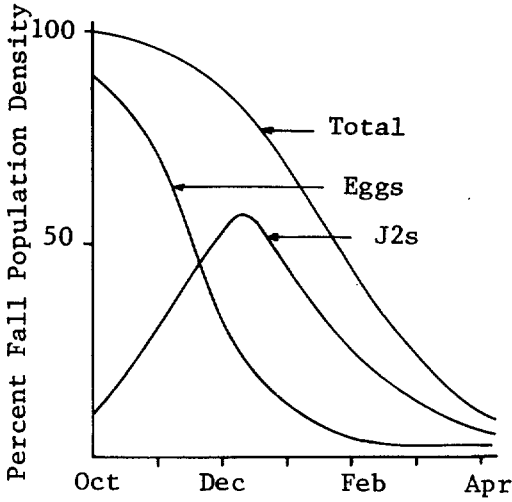* Values are means of 3–5 replications with a minimum of 50 eggs per replication.

FIG. 1. Schematic representation of winter survival dynamics of *Meloidogyne* spp. averaged over nine sites. Total population includes eggs and J2s.
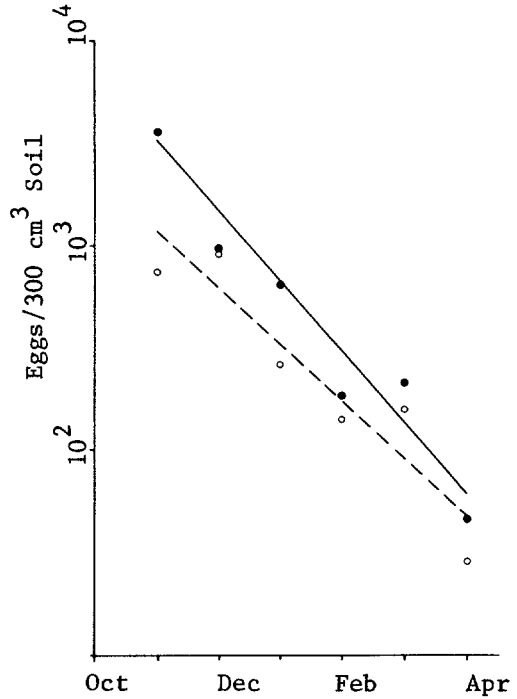

FIG. 2. Winter survival dynamics of eggs of *Meloidogyne incognita* at two soil depths at the Brazos County site. Data are plotted on a logarithmic scale; the fitted lines were calculated using least squares (● = 0–20 cm depth, O = 20–40 cm depth).

Ambient winter air temperature and rainfall data were obtained from regional meteorological stations. All test sites were within 20 km of these stations.

RESULTS

Data from 1982 to 1983 and 1983 to 1984 were similar; populations of *M. arenaria* and *M. incognita* behaved similarly. At eight of the nine test sites, the total population (eggs + J2) declined continuously from October until April. In one site, the total population increased from November through January; no samples were collected during December. Survival for all populations was highly variable, with a mean survival until April of 8.9% (Table 1). Differences in survival percentage among sites were not correlated with rainfall or ambient monthly mean temperatures. Survival percentage was negatively correlated ($r = -0.86$, $P = 0.01$) with $\log_{10}(x)$ transformations of fall populations. During the 1983–84 study period, population survival was greater at 20–40 cm than at 0–20 cm deep (Table 1).

Eggs comprised the majority of the population present in October and November (Table 1). By April, however, only 23.6% of the population was present as eggs. Eggs were not recovered from all samples collected in April. Viability of eggs recovered from December 1983 through March 1984 (Brazos County) was low, based on percentage of egg hatch (Table 2). Viable eggs were detected as late as March, the last date for which eggs were found in those samples. Differences in egg hatching between those recovered from 0–20 cm deep and those recovered from 20–40 cm were not significant, except for the March samples when no eggs hatched from samples collected at 0–20 cm.

The total nematode population and eggs declined continuously at all test sites, but dynamics of J2 were different (Fig. 1). The population density of J2 increased through December and January by 1.6–9.0-fold and then declined. A proposed model for overwinter nematode population dynamics (10) was fitted to the data obtained from the Brazos County (1983–84) site. The numbers of eggs are plotted logarithmically, at depths of 0–20 and 20–40 cm, against time (Fig. 2). The slopes of the fitted lines (0.027 day^{-1} at the shallow, 0.022 day^{-1} at the deep soil profile) differed significantly ($P = 0.05$). Numbers of J2 were plotted against
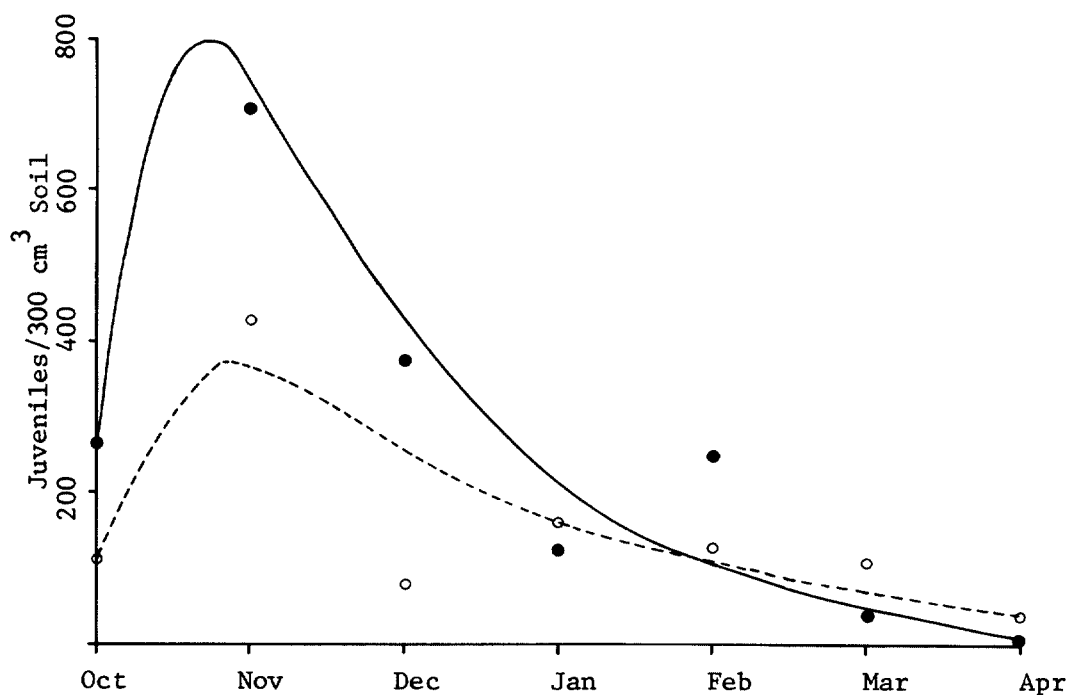
FIG. 3. Winter survival dynamics of J2 of *Meloidogyne incognita* at two soil depths at the Brazos County site. Data are plotted untransformed; the lines were calculated using an iterative technique to fit a proposed model for overwintering population dynamics (10) (● = 0–20 cm depth, O = 20–40 cm depth).

time (Fig. 3). The estimated rates of J2 mortality from the fitted model were marginally higher in the shallow soil profile (0.06 day^{-1}) than in the deep profile (0.04 day^{-1}), and in each case were higher than the rates of decrease for egg populations. The precision of the estimates of rates of juvenile mortality could not be calculated because of the iterative technique used to estimate model parameters.

DISCUSSION

Winter survival of *M. incognita* and *M. arenaria* in northern Texas was variable and was generally less than that reported for *M. incognita* in California (9) or North Carolina (2). Survival was negatively correlated with fall population densities but not related to differences in mean ambient temperatures or rainfall among sites. A negative correlation between winter survival of *Meloidogyne* spp. and population density was reported previously (14). Our data confirm previous reports (6,15) that *Meloidogyne* spp. have greater winter survival at deep than at shallow soil profiles.

The factors involved in the apparent re-lationship between fall nematode population densities and winter survival are unknown. One hypothesis is that during development of high populations of *Meloidogyne* spp. the host allocates fewer resources to each egg than it does with populations of lower density. The viability and survival potential of eggs from populations of high densities might, therefore, be expected to be reduced, compared with eggs from populations of lower density.

In contrast to an earlier report (6), we found that eggs play an important role in winter survival of *Meloidogyne* spp. At the onset of winter, eggs constituted the majority of the total population. Egg hatch is believed to be responsible for the dramatic increase in the population density of J2 observed during early winter. A similar increase in J2 populations, occurring in February, was reported from North Carolina (3). Furthermore, viable eggs were recovered from soil until March, indicating that eggs are the source of new J2 during the winter. The low hatch of eggs collected from December through March may partially be an artifact of NaOCl extraction

on egg viability. The best hatch of eggs exposed to NaOCl has been reported as $\leq$ 50% (10,17). The phenomenon of viable eggs remaining in the soil without hatching throughout most of the winter months was similar to the delayed hatching reported for *M. arenaria* (8). Our observations and those of others (8) support the hypothesis that a portion of the eggs produced by *M. incognita* undergo a period of dormancy (5). If eggs have a greater capacity than J2 for survival at low temperatures (1,18), then population survival would be enhanced if a portion of the population remained as eggs throughout most of the winter.

Although the schematic representation of the dynamics of winter survival of *Meloidogyne* spp. was developed subjectively, the fit of the model of Jeger and Starr (11) to the Brazos County data does provide support for the schematic representation of winter survival dynamics. Data from other test sites were consistent with the proposed relation between eggs and J2 during winter survival. In all cases, the J2 increased during the early winter months while eggs and the total nematode populations declined. The model was not fitted to these data, however, because of insufficient data points. Local cooperators were able to collect samples only 4–5 times during the 1982–83 study period.

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