The Relationship Between Soil Populations of *Meloidogyne incognita* and Yield Reduction of Soybean in the Coastal Plain[1]

ROBERT A. KINLOCH[2]

Abstract: In a replicated field plot experiment, the population density of *Meloidogyne incognita* was monitored biweekly through the overwintering period (December through April) between soybean crops. The population survived as second-stage juveniles whose numbers remained stable through the winter months and did not decline until February. The yields of plots planted with a *M. incognita* susceptible cultivar were negatively correlated with the numbers of juveniles recovered at all preplanting sampling dates. In the mid-winter period (December through February), a regression equation describing the relationship predicted a yield reduction (slope) equivalent to 5.36 kg/ha for each juvenile in a 10-cm^3 soil sample. In two subsequent field experiments, conducted in different sites and years, mid-winter (November) sampling gave yield reduction predictions of 4.65 and 6.69 kg/ha. Tests of the null hypothesis gave no evidence to indicate that the three slopes differed ($P = 0.05$). A regression analysis of combined data from the three experiments determined a mid-winter predictive yield reduction of 5.31 kg/ha for each juvenile in the 10-cm^3 sample. As the sampling time approached the planting date, there were changes in the predictive yield reductions due to each juvenile in a sample. These are best described by the equation, $\hat{\gamma}$ (yield loss) $= 54.47 - 0.67X + 0.0023X^2$, where X equals the days remaining between sampling and planting. Soil sampling should be performed during mid-winter (November through January) for the most reliable prediction of soybean yield loss. *Key words:* root-knot nematode, population dynamics, *Glycine max*.

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There has been an increasing awareness among phytonematologists concerning the need to establish the relationships between the detectable numbers of plant-parasitic nematodes and their influence on the growth and yield of the crops with which they are associated (2). Research in this area has been stimulated by the increasing concern about the overuse of pesticides and rising crop production costs. The equations describing the relationship between nematode numbers and crop response would be utilized to determine nematode population threshold levels below which a particular control method can be considered unnecessary, depending on prevailing economic factors (4).

Studies of these relationships have been conducted between several nematode and crop species (1,3,6,8,9). Investigated relationships on annual crops have generally dealt with the responses of plants grown in pots or micro-plots to nematode population levels artificially established at the time of seeding or transplanting. However, to have practical value, the host response equation should be derived from field experiments involving naturally occurring nematode populations. In either case, there is an unavoidable delay between the time of collection of samples for determination of nematode infestation levels and the time of application of any responsive measure that a derived equation would deem suitable. This would depend on the time necessary for shipping and processing samples as well as purchasing and delivery of any control materials. Hence, host response equations are best determined for nematode populations existing at some point in time before the need for grower reaction.

The following field experiments were conducted to determine an equation describing the relationship between soil infestation levels of the southern root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, and yield reductions of soybean, *Glycine max* (L.) Merr., and to determine the influence that the time of sampling for nematodes, relative to soybean planting, would have on the equation.

MATERIALS AND METHODS

Three field experiments were conducted

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[1]Florida Agricultural Experiment Station, Journal Series No. 3259.
[2]University of Florida, Agricultural Research Center, Jay, FL 32565.
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on sites naturally infested with *M. incognita* at the University of Florida Agricultural Research Center, Jay, Florida. The sites are loamy sand ultisols (typic paleudult) typical of soils throughout the Coastal Plain region of the southeastern United States.

Experiment I consisted of the sequential sampling of 12 field plots that were delineated across a site that had been previously cropped to soybean. The plots (1.8 m × 1.8 m) were located such that six were positioned in areas that were heavily infested with *M. incognita* while the others were situated on locations across the periphery of the infested site. Each plot was aligned such that it was transversed by two stubble rows (0.9 m apart) remaining from the previous crop.

Starting on 8 December 1976 (168 days before planting), all plots were sampled for *M. incognita* juveniles every 2 weeks until 28 days prior to planting. The samples consisted of two cores (2.5 × 20 cm deep) taken from a 40-cm wide band along each stubble row. The four cores from each plot were mixed manually in the field and a 100-cm^3 subsample was extracted. The remaining soil was returned to the sampling holes. The samples were sieved through 40 and 325 mesh screens (420μ and 44μ openings, respectively). The material retained by the 325 screen was processed by sugar-centrifuge flotation for nematode extraction (7). The extracted nematodes were dispersed in water in a gridded counting dish and identified and enumerated as *M. incognita* juveniles per 10 cm^3 soil. The plots remained undisturbed throughout the sampling period until immediately before planting, when they were fertilized with 336 kg/ha 0–30–15 (N-P-K), disced to 15 cm deep, chisel-ploughed to 30 cm deep, and disced again. The plots were planted 25 May 1977 with *M. incognita* susceptible cultivar 'Pickett 71' in rows located in the same position as the rows from which soil had been previously sampled. Standard practices of cultivation and insect control were carried out during the growing season. There were no applications of materials with nematicidal properties. The crop was harvested 12 October 1977 and the yields were adjusted to 14% seed moisture content.

Experiments II and III were conducted to confirm the winter sampling equations obtained in Experiment I. In November 1978 and again in November 1979, 16 field plots, each consisting of two rows 15 m long set 0.9 m apart, were established in previous soybean stubble rows. The site was different from that in Experiment I but it had the same soil type and was also naturally infested with *M. incognita*. Soil samples were taken and processed as previously described, with the exception that cores were taken from each 2 m of row. The following May, 180 days after sampling in both experiments, the plots were treated as previously described then planted to *M. incognita* susceptible cultivars ('Davis' in Exp. II, 'Pickett 71' in Exp. III). Yields from both experiments were adjusted to 14% seed moisture content. Correlations between yield (kg/ha) and the nematode data were calculated for each sampling date in the three experiments.

RESULTS AND DISCUSSION

In Experiment I, initial levels of *M. incognita* juveniles among the 12 plots ranged from 16 to 426/10 cm^3 soil with a mean and standard error of 170 ± 43 (Fig. 1). There were no significant changes in the soil infestation levels from December to February. However, numbers of juveniles declined rapidly during February, and by the last sampling date, 28 days before planting, the numbers of juveniles ranged from 0 to 59/10 cm^3 soil with a mean and standard error of 15 ± 5.

Yields per plot ranged from 0 to 0.9 kg (=2686 kg/ha) with a mean and standard error of 0.52 ± 0.09 kg (=1580 ± 294 kg/ha). Linear regression analyses gave significant negative correlations between yield and the numbers of juveniles at each sampling date (Table 1). There was a very close similarity of slopes in the regression equations derived from the nematode counts obtained during the period of insignificant population decline, 168 to 112 days before planting. The regression equation for the combined data taken during this entire period was $\hat{y} = 2352 - 5.31X$, $r = -0.76^{**}$. Thus for each juvenile recovered per 10-cm^3 soil sample within this period there would be a predicted yield loss of 5.31 kg/ha.

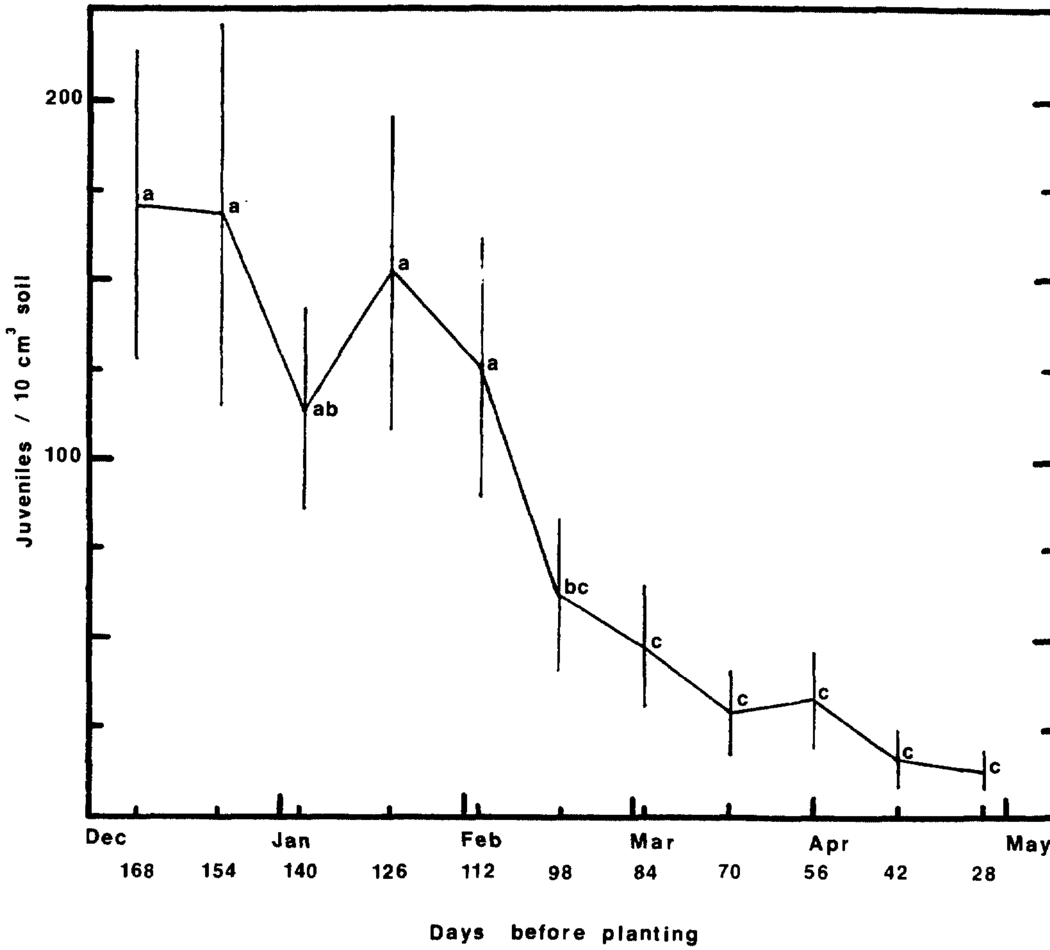

Fig. 1. Numbers of infective juveniles of *Meloidogyne incognita* per 10 cm³ soil sampled at various days before soybean planting. Mean of 12 replicates. Data points ± standard errors followed by the same letter are not significantly different according to Duncan's multiple-range test ($P = 0.05$).

Yields from Experiments II and III were significantly negatively correlated with the numbers of juveniles in the soil 180 days before these experiments were planted. Nematode, yield, and correlation data from Experiments II and III are presented along with the 168-day sample from Experiment I (Table 2). Tests of the null hypothesis comparing these three slopes, –5.36 (Exp. I), –4.65 (Exp. II), and –6.69 (Exp. III) indicated differences among them only at $P \geq 0.73$. Hence, there was no evidence to reject their equality at $P \leq 0.05$. These data were collected in three different years, and differences in the intercepts of the regression equations (significant at $P = 0.14$) reflect the seasonal impact of factors other than root-knot nematode on the soybean yields. To establish a common regression equation for the three years' data, seasonal yields were adjusted by adding 317 kg (i.e., 2490 – 2173) and 538 kg (i.e., 2490 – 1952) to each yield figure obtained in Experiments II and III, respectively. A regression analysis on the combined yield adjusted data gave a negative correlation ($r = -0.79^{**}$) between yield and the number of *M. incognita* juveniles in 10 cm³ soil collected 168 or 180 days before soybean planting. The relationship is described by the equation,

$$\hat{Y} = 2474 - 5.31X \text{ (Fig. 2).}$$

As the sampling date approached the time of planting in Experiment I, there was a progressive increase in the slopes of the derived regression equations (Table 1). A regression analysis produced a significant negative correlation between the various

Table 1. Correlations between soybean yield† and numbers of *Meloidogyne incognita* infective juveniles per 10 cm^3 soil sampled at various days before planting.‡

Date	Days before planting	*M. incognita* juveniles/ 10 cm^3 soil (X) Range	Mean ± std. error	Correlation with yield r	Regression equation yield, $\hat{\gamma}$ =
8 Dec	168	16-426	170 ± 43a§	−0.78**	2490- 5.36X
22 Dec	154	12-533	168 ± 53a	−0.81**	2345- 4.54X
5 Jan	140	7-268	113 ± 28ab	−0.75**	2462- 7.79X
19 Jan	126	7-381	151 ± 44a	−0.93**	2528- 6.28X
2 Feb	112	6-390	125 ± 37a	−0.60*	2192- 4.90X
16 Feb	98	0-216	61 ± 21 bc	−0.87**	2336-12.49X
2 Mar	84	0-144	49 ± 16 c	−0.85**	2350-15.67X
16 Mar	70	1-128	30 ± 12 c	−0.89**	2253-22.21X
30 Mar	56	1-145	34 ± 13 c	−0.78**	2186-17.71X
13 Apr	42	0- 90	16 ± 8 c	−0.70*	2001-26.34X
27 Apr	28	0- 59	15 ± 5 c	−0.75**	2219-41.94X

†Soybean yield range 0–2,686 kg/ha; Soybean yield mean 1,580 ± 294 kg/ha.
*$P = 0.05$.
**$P = 0.01$.
‡Mean of 12 replicates.
§Means followed by the same letter are not significantly different according to Duncan's multiple-range test ($P = 0.05$).

slopes (i.e., predicted yield loss due to each juvenile in a 10-cm^3 soil sample) and the days remaining before planting. This relationship may be described quadratically, $\hat{\gamma}$ (yield loss) = $54.47 - 0.67X + 0.0023X^2$, or exponentially, $\hat{\gamma} = 50.12/(1.01^x$, where X represents the days remaining before planting (Fig. 3). The quadratic relationship is more representative of the data over the range of the observed sampling dates. However, the exponential relationship is more reliable as to what can be expected beyond this range, especially with increased time between sampling and planting. Thus, as the sampling date approaches time of planting, the significance of each juvenile recovered increases with respect to predicting yield loss. A 10-fold increase in importance can be assigned to each juvenile when sampled just prior to planting over its value when sampled during the winter months. This reflects the difference in numbers of juveniles present in the soil between these periods.

These experiments demonstrate the feasibility of determining soybean yield loss due to *M. incognita* when the nematode is recovered from soil sampled prior to the planting of the soybean crop. However, time of sampling will have a critical influence on predicted yield loss estimates. This nema-

Table 2. Correlations between soybean yields and numbers of *Meloidogyne incognita* infective juveniles per 10 cm^3 soil sampled in three field experiments.†

	Days between sampling and planting	*M. incognita* juveniles/10 cm^3 soil Range	Mean ± std. error	Soybean yield kg/ha Range	Mean ± std. error	Correlation coefficient r	Regression equation $\hat{\gamma}$ =
Exp. I	168	16-426	170 ± 43	0-2686	1580 ± 294	−0.78**	2490-5.36X
Exp. II	180	0-351	43 ± 22	677-2562	1986 ± 132	−0.78**	2173-4.65X
Exp. III	180	1-200	47 ± 15	420-2487	1636 ± 149	−0.66**	1952-6.69X

**$P = 0.01$.
†Mean of 12 (Exp. I) and 16 (Exps. II and III) replicates.

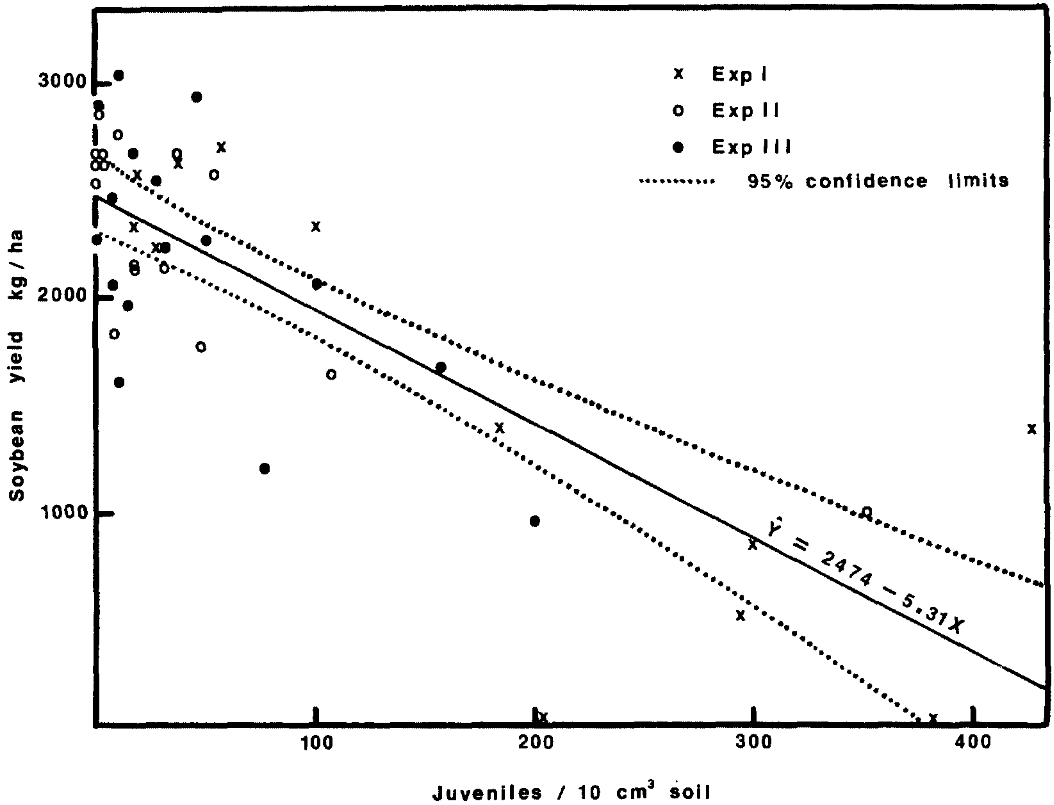

Fig. 2. Relationship between soybean yield and incidence of *Meloidogyne incognita* infective juveniles sampled 168 (Exp. I) and 180 (Exps. II and III) days before planting. Combined regression of data from three field experiments. Yield data from Exps. II and III are seasonally adjusted.

tode survives the winter in the Coastal Plain as second-stage infective juveniles free in the soil. Populations remain static during the winter period and decline during the months of spring prior to planting. During winter, when the nematode populations are relatively stable, yield losses of approximately 5 kg/ha for each juvenile/10 cm^3 soil can be predicted when extraction procedures described herein are employed. As sampling time approaches planting, yield loss predictions are more subject to the dynamics of nematode population decline and their relationship to the time of planting. Population decline appears to be related to increases in soil temperature during spring (Kinloch, unpublished data). Such increases vary from year to year. This and the fact that soybean planting in the Coastal Plain is usually accomplished at some time within a 30–40-day period confounds any reliance that can be placed on an equation describing yield loss estimates and the time remaining between sampling and planting. Consequently, soil sampling for advisory purposes should be performed during winter when the nematode populations are static.

The utilization of nematode enumeration for predicting crop yield loss is dependent on several practical problems that need to be solved. The most difficult will be the determination of the minimum number of samples required for reliable nematode population estimates (5). For practical reasons, advisory samples are taken at a much lower frequency than those taken in this study.

Postsampling problems include the mortality of nematodes before their extraction from the samples. Current nematode advisory samples are generally shipped between sampling site and the processing laboratory in unrefrigerated containers. It has been my experience that populations of *M. incognita* juveniles may suffer considerable mortality in such transit. Mortality

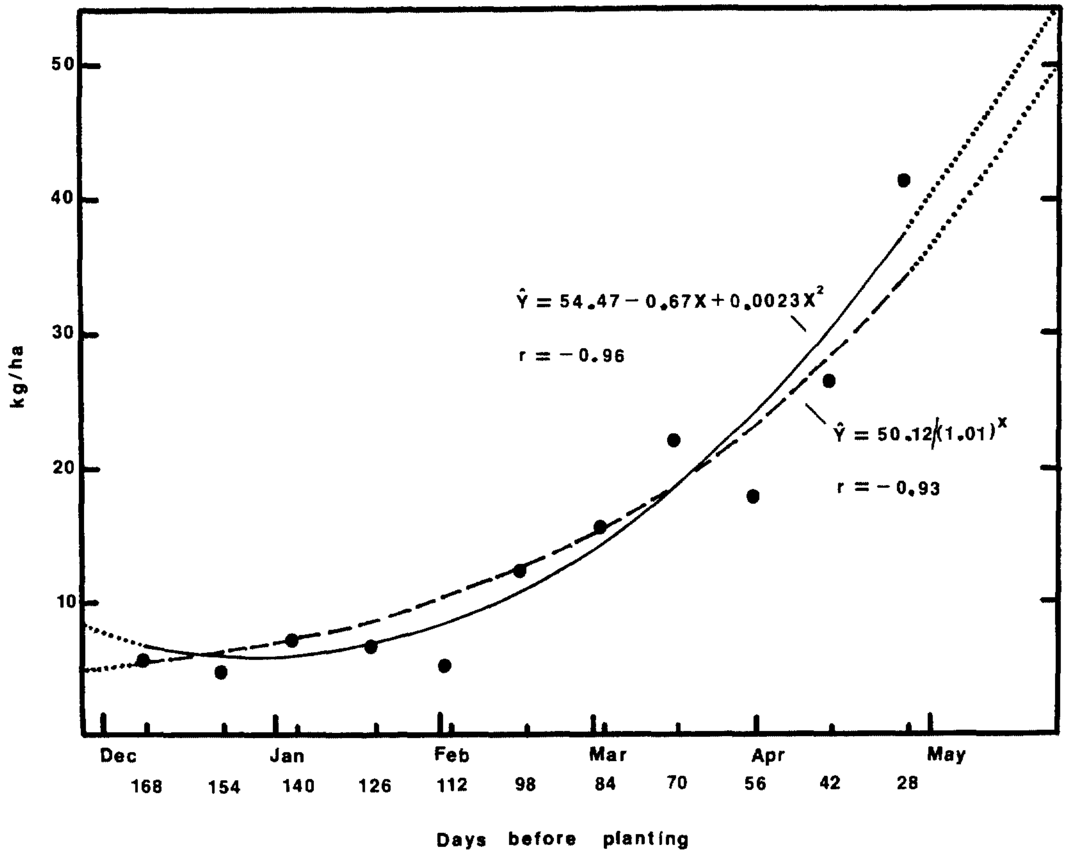

Fig. 3. Relationship between predicted yield loss of soybean for each *Meloidogyne incognita* juvenile recovered in 10 cm^3 soil sampled at various days before planting.

rates under various time and transit conditions need to be determined. There is also a need to relate nematode extraction efficiency between procedures used in advisory laboratories with those used in the original research studies that determine nematode and crop yield loss equations.

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