Relationships Between the Population Density of Meloidogyne incognita and Growth of Tobacco[1]

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Abstract: Seedlings of tobacco cultivars resistant (NC95) and susceptible (McNair 30) to *Meloidogyne incognita* were grown in 15-cm diameter clay pots containing steamed soil infested with 0, 1, 2, 4, 8, 16, 32, and 64 eggs of *M. incognita* per 1.5 cm^3 soil. Plants were maintained in the greenhouse for 3 weeks, and then transferred to the field for 12 weeks. Growth of tobacco was expressed separately as dry weight of leaves and as plant height. Least squares regression analysis showed that tobacco growth-nematode density interactions are in agreement with Seinhorst's exponential model $Y = m + (1\text{-}m)\ cz^P$. Tobacco growth was not affected significantly as nematode density was increased from 0 to tolerance levels, which were approximately 2 and 1 eggs per 1.5 cm^3 soil for the resistant and susceptible cultivars, respectively. As nematode density was increased beyond tolerance level, tobacco growth decreased sharply until a minimum yield was approached. The minimum leaf weights and plant heights of the resistant cultivar at the highest nematode density were greater than those of the susceptible cultivar. *Key Words:* Initial nematode density, resistant and susceptible cultivars, exponential function.

Root-knot, caused by *Meloidogyne incognita* (Kofoid and White) Chitwood, is an important disease of tobacco *Nicotiana tabacum* L. Most advisory control programs suggest the use of resistant cultivars with little attention to tolerant cultivars. Unfortunately, there are few root-knot resistant cultivars, and it has been shown that such genetic materials may impose a selection pressure upon *M. incognita*, resulting in the emergence of new pathotypes (9, 10) which render the resistant cultivars less effective.

The concept of tolerance has long been used by plant pathologists to define host-parasite interactions in a relative manner. According to Jones (5) a tolerant host can support relatively high nematode densities without suffering appreciable damage. Schafer (11) defined tolerance as "that capacity of a cultivar resulting in less yield or quality loss relative to disease severity or pathogen development when compared with other cultivars or crops."

Crop damage caused by plant parasitic nematodes is directly dependent upon the population density and rate of reproduction of the nematodes (8, 12, 14). Understanding the quantitative relationships between nematode density and plant growth is essential, therefore, in planning nematode control programs (1, 7, 8).

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There are many reports on the population dynamics of plant parasitic nematodes, yet experimental data on the quantitative relationships between the population density of *M. incognita* and tobacco growth are fragmentary. Such studies have been conducted with other host-parasite interactions. Lownsbery and Peters (6) described the relationships between log density of *Heterodera tabacum* (Lowns. and Lowns.) and yield of shade tobacco as a linear regression. Daulton (2) working with *M. javanica* (Treub) Chitwood found that tobacco yield was decreased rectilinearly as the root-knot index increased. Seinhorst (12) described the regression of plant growth on the logarithm density of nematodes as an exponential curve and defined the tolerance limit as the population density at which host damage becomes obvious. Seinhorst's model was disputed by Oostenbrink (8) who showed that the regression of plant growth on the logarithm of the density of nematodes is a straight line. Oostenbrink's equation, however, did not include factors which account for plant growth at low nematode densities. He suggested that at such low population densities, nematodes may cause low yields, stimulate plant growth, or establish neutral relations with the host. Although Oostenbrink (8) indicated that it is not possible to combine such different biological phenomena into one mathematical equation, Seinhorst (13) proposed a new model incorporating two equations, one for growth stimulation and one for loss in yield at low nematode densities.

The objectives of this investigation were to determine the tolerance limits of resistant (NC95) and susceptible (McNair 30) tobacco

TABLE 1. Relation between initial density of *Meloidogyne incognita*, root-knot indices, and final population density on resistant NC95 and susceptible McNair 30 tobacco cultivars.

Initial density (P_i = eggs/1.5 cm^3 soil)	Mean root-knot indices[a]		Mean final density (P_f = larvae/1.5 cm^3 soil)	
	NC95	McNair 30	NC95	McNair 30
0	0	0	0	0
1	0.2	0.8	0	13
2	0.4	1.2	0	26
4	0.6	2.0	0.2	24
8	0.6	2.8	0.4	39
16	0.8	3.6	0.5	79
32	1.6	3.8	0.6	94
64	2.2	4.0	0.9	14

[a]Root-knot indices of tobacco where 0 = 0% galled roots; 1 = 0-25%; 2 = 26-50%; 3 = 51-75%; 4 = 76-100% galled roots.

cultivars, by studying the quantitative relationships between densities of *M. incognita* and yield of these tobacco cultivars. In this study, the term "yield" is used to indicate growth as measured by dry weight of leaf and plant height rather than by yield of cured leaf.

MATERIALS AND METHODS

Uniform fifty-day-old seedlings of *M. incognita*-resistant'NC95' and susceptible 'McNair 30' tobacco cultivars were transplanted in 15-cm clay pots containing 1,500 cm^3 steamed sandy-clay-loam soil infested with 0, 1, 2, 4, 8, 16, 32, and 64 eggs of *M. incognita* per 1.5 cm^3 soil. These eggs were obtained, using the method developed by Hussey and Barker (3), from the progeny of a single egg mass which was propagated on tomato *Lycopersicon esculentum* Mill. 'Rutgers' for 45 days in a greenhouse. A randomized split plot design with four replications and four plants per treatment was employed. Nematode density was the main plot with tobacco cultivar the sub-plot. The test was maintained in the greenhouse for 3 weeks and then transferred, on July 25, to the field for 12 weeks to expose the experiment to more natural conditions. Flue-cured tobacco fertilizer of 3-9-9 analysis was used at rates of approximately 1,600 and 560 kg per hectare as preplant and postplant (side dressing) applications, respectively. The plants were watered every other day, throughout the test, with approximately 500 ml of water per pot except on rainy days. Mature leaves were harvested in four separate primings. The leaves from each priming were dried until constant weight was obtained. All plants in this test flowered and were not topped. At the end of the experiment, plant heights were recorded and tobacco yield (Y) was expressed separately as dry weight of leaves and as height of plants.

These data were subjected to a three step statistical analysis. First a Duncan's multiple range test was performed on tobacco yield, among levels of nematode density, to locate the threshold level of *M. incognita*. Next the best fit of the data to the model, $Y = m + (1-m)cz^P$, (13, 14) was determined by least squares regression (15). Linear regression was used by transforming the model to $Y^* = \log(Y - m) = \log [(1 - m) c] + P \log z$. This also provided estimates for the model parameters c and z. Finally, to determine if the model was adequately explaining the data, a test for departure from linearity in the transformed model (4) was carried out.

RESULTS AND DISCUSSION

Root-knot indices of NC95 and McNair 30 increased as the initial nematode density (P_i) was increased from 0 to 64 eggs per 1.5 cm^3 soil (Table 1). Root-knot indices of NC95, however, were much lower than those of McNair 30 at all nematode densities. The final nematode density (P_f), was much higher on McNair 30 as compared to NC95 (Table 1). On McNair 30, P_f increased sharply as P_i was increased from 0 to 32 eggs per 1.5 cm^3 soil. Further increase in P_i was associated with a sharp decrease in P_f. This was probably due to damage by nematodes which resulted in less available food for their subsequent reproduction (14). On NC95, P_f increased much less as P_i was increased from 0 to 64 eggs per 1.5 cm^3 soil. Reproduction of *M. incognita* was evident from the presence of

enormous numbers of mature females with egg masses in roots of McNair 30. No reproduction was evident on NC95, and the low number of larvae recovered at final density determinations may have been those which hatched from initial inoculum and remained in the soil.

This investigation established a quantitative relationship between the initial population density of eggs of *M. incognita* and growth of resistant NC95 and susceptible McNair 30 tobacco cultivars. Least square regression analysis showed that tobacco yield-nematode density interactions could be represented by the exponential function $Y = m + (1\text{-}m)cz^P$ for densities $P \geqslant$ tolerance level. There were no differences in plant height nor in dry weight of leaves, (Fig. 1 and Table 2), of either tobacco cultivar, as P_i was increased from 0 to the tolerance levels, which were approximately 2 and 1 eggs per 1.5 cc soil, for NC95 and McNair 30, respectively. As P_i was increased beyond the tolerance level, plant height and dry leaf weight exhibited a rapid exponential decrease which then leveled off to a minimum yield near a density of 64 eggs per 1.5 cm^3 soil. Tobacco plants apparently have more roots than are necessary to support their top growth, and can also replace damaged roots by adventitious roots. Root damage which occurs below the tolerance level, therefore, may not result in depressed top growth (12). This study showed that the tolerance limit and the minimum yield of NC95 were greater than those of McNair 30 (Fig. 1 and Table 2). *M. incognita* produced galls on both cultivars, however, reproduction was not evident on NC95. Therefore, blocked reproduction on NC95 prevented progressive damage from successive generations that occurred on McNair 30.

This information is important for planning root-knot control programs and also for predicting crop losses (1, 7, 8). If P_i is lower than the tolerance limit of McNair 30 or NC95, appreciable damage could not occur, and nematicidal treatments are not necessary. If P_i, however, is well above the tolerance limit of these cultivars, serious losses could be expected. Nematicidal treatments, under these conditions, are essential to decrease P_i to a level below the tolerance limit where appreciable damage would not occur.

The application of the equation $Y = m + (1\text{-}m)cz^P$ in nematode advisory services, requires the determination of P_i, m, c, and z. P_i can be determined from the assay of soil samples at planting time. Estimates of c and z are obtained from the regression analysis (Table 3). It should be noted also that the yield Y in this equation is expressed as the ratio between the yield at nematode density P and the maximum yield, and that m represents the

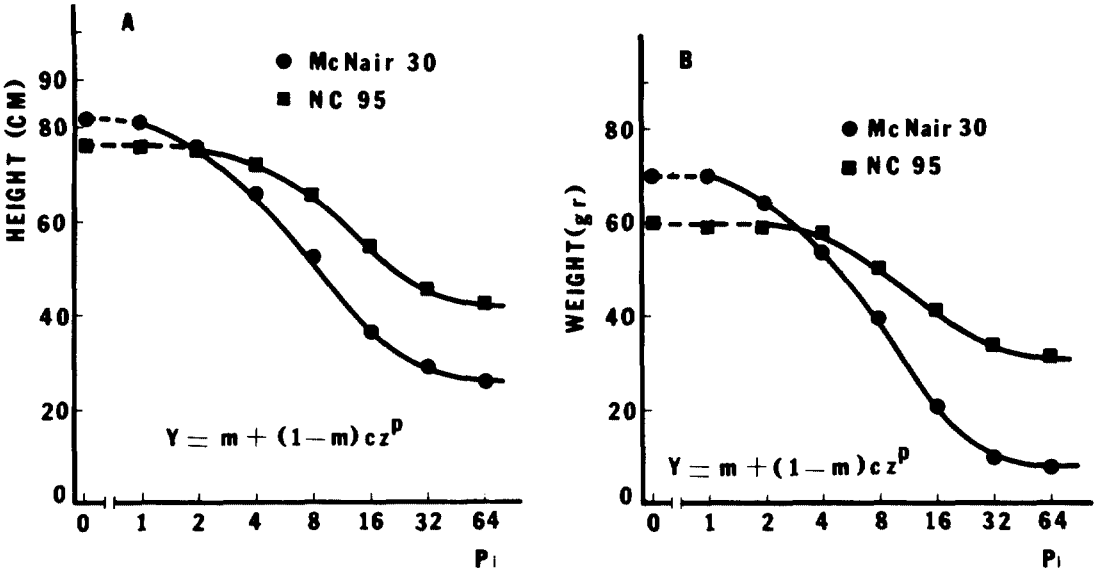

FIG. 1-(A,B). Relation between initial density (P_i - eggs) of *Meloidigyne incognita* and growth of the resistant NC95 and susceptible McNair 30 tobacco cultivars. P_i = eggs per 1.5 cm^3 soil; Y = tobacco growth expressed as **A)** plant height, and **B)** dry leaf weight.

TABLE 2. The effects of initial population density of *Meloidogyne incognita* on yield of susceptible McNair 30 and resistant NC95 tobacco cultivars.

Initial density (P_i = eggs/1.5 cm^3 soil)	Mean plant height (cm)[y]		Mean dry weight of leaves (g)[y]	
	McNair 30	NC95	McNair 30	NC95
0	81 a	76 a	70 a	60 a
1	81 a[z]	76 a	70 a[z]	60 a
2	76 b	75 a[z]	64 b	60 a[z]
4	66 c	73 b	54 c	57 b
8	52 d	66 c	38 d	50 c
16	37 e	55 d	21 e	41 d
32	28 f	46 e	10 f	34 e
64	26 g	42 f	7 g	31 f

[y]Averages of four replications. Numbers in each column followed by the same letter are not significantly different (Duncan's multiple range test, $P = 0.05$).
[z]Indicates the tolerance limit.

TABLE 3. Values of constants c, z, and m, in the model $Y = m + (1\text{-}m)cz^P$, for resistant NC95 and susceptible McNair 30 tobacco cultivars in the presence of *Meloidogyne incognita*.

Model constants	NC95		McNair 30	
	Leaf weight	Plant height	Leaf weight	Plant height
c	1.168	1.151	1.113	1.119
z	0.928	0.936	0.901	0.898
m	0.516	0.546	0.100	0.321

relative minimum yield when all available infection sites are occupied. For example, suppose plant height is used to express yield of NC95. In that case, the maximum height (Table 2) is 76 cm, and the predicted height at nematode density P is:

$$\frac{H_P}{76} = m + (1\text{-}m)cz^P$$

Substituting from Table 3, for c, z, and m:

$$H_P = 41.50 + 39.72\ (0.936)^P$$

for $P \geqslant 2$ eggs per 1.5 cm^3 soil. Other growth parameters could also be used in a similar manner to predict tobacco yield. Closer inspection of Table 3 indicates that, for a given cultivar, there is not much difference between c and z values for dry leaf weight and plant height. However, these differences become much greater between the two cultivars. Table 3 shows that c, z, and m values for NC95 are generally greater than those for McNair 30. This is probably due to the specificity in the reactions of NC95 and McNair 30 to infections by *M. incognita*.

Although this study was not conducted under classical field conditions, it constitutes the first report on the quantitative relationships between initial density of *M. incognita* and tobacco growth. Additional research employing microplot techniques with second-stage larvae must be completed under typical field conditions before such models can be used in broad scale advisory programs. Such research should determine the influence of different ecological factors on various host-parasite interactions. Nematodes do not exist as separate pure populations in nature. Nevertheless, in areas where *M. incognita* constitutes the major nematode problem, such studies should provide a practical basis for nematode advisory services and control programs.

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