THE RELATION BETWEEN NEMATODE DENSITY AND DAMAGE TO PLANTS

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An equation for the relation between the density of stem nematodes or virus transmitting nematodes in the soil and the proportion of attacked plants can be derived if two suppositions are made: 1. the “average nematode” is the same at all densities. 2. the nematodes act independently of each other.

If now \( y \) = the proportion of the plants that is not attacked and \( P \) = the density of the nematode then

\[
y = z^P \quad (1).
\]

In this equation \( z \) is a constant \(<1 \) and equal to the proportion of the plants not attacked at a nematode density \( P = 1 \) (competition curve of Nicholson). The results of a pot experiment by Sayre & Mountain and field observations by Kaai are in close agreement with this equation.

To describe the relation between the density of populations of root infesting nematodes and the yield of attacked plants an equation must express two phenomena:

1) Up to a certain density (the tolerance limit) the yield is not affected (damage only to tissue that is not essential to the growth of the plant, power of recovery of the plant), 2) a certain minimum yield \( (0_{\text{min}}) \) remains unaffected by the nematodes even at the highest densities (because of temporary or continuous inaccessibility of part of the host tissue). The equation

\[
y = \frac{0_{\max} - 0_{\text{min}}}{0_{\max} - 0_{\text{min}}} \cdot z^P = z^{P - T} \quad (2),
\]

in which \( 0_p \) = yield at nematode density \( P \), \( 0_{\max} \) = yield in the absence of nematodes and \( T \) = tolerance limit, fulfills these requirements. The results of many experiments reported in the literature are in good agreement with this theoretical relation between nematode density and yield. In most cases \( 0_{\text{min}} \) is between 0.1 \( 0_{\max} \) and 0.5 \( 0_{\max} \). The tolerance limit depends on the nematode species, the plant species and external conditions.

Introduction

The relation between the population density of a nematode and the damage it causes to plants has been described as a linear regression between log nematode density and weight or length of the damaged plants (Lownsbery & Peters, 1955; Jones, 1956; Hesling, 1957; Seinhorst, 1960; Hoestra & Oostenbrink, 1962), as a regression according to a quadratic curve between these quantities (Peters, 1961) and as a linear regression between log nematode density and probits of numbers of diseased plants (Sayre & Mountain, 1961). In all these cases the approximation of the theoretical relationship to that actually observed is fair to good.
However, all three types of relationship are purely empirical. There is no theoretical reason for any of them. A reasonably close agreement between observational data and any of the graphs fitted to them except that of Sayre & Mountain cannot exist above and below certain nematode densities as then yields would have to be either infinitely high or nil in the absence of nematodes and negative at very high densities. Extrapolating from yields observed at a range of densities assuming one of these relationships (as was done by Hoestra & Oostenbrink, 1962) can therefore easily lead to wrong conclusions, mostly overestimation of the damage at low nematode densities. All that can be derived from the linear and non-linear regressions mentioned above and calculated regression coefficients is that there is a certain probability that in the experiments the proportion of healthy plants or the size or weight of the plants was smaller at the higher than at the lower densities of the nematodes. They do not convey any understanding of the quantitative relation between nematode density and growth of plants. The constants in the equations and the transformations of the variables have no biological meaning.

**Derivations of models**

In a proper mathematical model all variables and constants are abstractions of characters of the organism or population under investigation (e.g. population density, capacity of one specimen to collect a certain amount of food or to destroy a certain amount of plant tissue per unit time). Mathematical models can only be developed after the characters and behavioural peculiarities that are relevant to the relation between variables to be investigated have become known. The operations prescribed by the model (equation) are logical consequences of these (drastically simplified) characters and behavioural peculiarities. The relationships mentioned in the introduction are no proper models but only attempts to find regression lines that fit well to observations. Their constants and operations do not represent anything biological. They can only be used to compare different sets of data or data with a theoretical regression line.

To develop suitable models for the relation between nematode density and damage to plants two types of relation must be distinguished: 1) that between nematode density and proportion of exposed plants attacked and 2) that between nematode density and production of vegetable matter by the exposed plants. Examples of damage of the first kind are the attack in onions and flower bulbs by *Ditylenchus dipsaci* and the transmission of virus to plants by nematodes. In both cases there is a clear distinction between diseased and healthy plants and it does not matter whether the initial infection is light or heavy because there is little chance of recovery. Attacks by root nematodes, on the contrary, are mostly of the second kind. It is not the presence or absence of nematodes in or at the roots but the weight of vegetable matter produced that is important. Lost roots can be replaced by the plant to a certain extent, furthermore damage also depends on the relation between root damage and shoot growth. It is clear that in the first case the relation between nematode density and damage is simpler than in the second.