Journal of Nematology 29(4):474–477. 1997.

SeinFit, a Computer Program for the Estimation of the Seinhorst Equation

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Abstract: A computer program, "SeinFit," was created to determine the Seinhorst equation that best fits experimental data on the relationship between preplant nematode densities and plant growth. Data, which can be entered manually or imported from a text file, are displayed in a data window while the corresponding graph is shown in a graph window. Various options are available to manipulate the data and the graph settings. The best-fitting Seinhorst equation can be calculated by two methods that are both based on the evaluation of the residual sum of squares. Depending on the method, a range of values for different parameters of the Seinhorst equation can be chosen, as well as the number of steps in each range. Data, graphs, and values of the parameters of the Seinhorst equation can be printed. The program allows for quick calculation of the damage threshold density—one of the parameters of the Seinhorst model. Versions written for Macintosh or DOS-compatible machines are currently available through the Society of Nematologists' World Wide Web site (http://ianrwww.unl.edu/ianr/plntpath/nematode/SOFTWARE/nemasoft.htm).

Key words: computer program, crop loss assessment, damage threshold, management, nematode, SeinFit, Seinhorst equation, yield loss.

Several methods have been used to relate nematode population densities in the soil at planting and yield of host-plants (Barker and Olthof, 1976). The model developed by Seinhorst (1965), commonly referred to as the Seinhorst equation, has been used frequently since its publication. The model is of the form:

$$y = y_m, \text{ for } x \leq t, \quad (1)$$

$$y = y_m \cdot m + y_m \cdot (1 - m) \cdot z^{(x-t)}, \text{ for } x > t \quad (2)$$

where:
y = crop yield or other plant growth parameter; x = the nematode population density (often referred to as P); t = the nematode population density below which yield reduction cannot be measured (= the tolerance limit or damage threshold density, in many articles also represented as T); y_m = mean crop yield where the nematode density is below the tolerance limit (t); m = a constant, usually between zero and one, such that $y_m \cdot m$ is the yield at the highest possible nematode density; and z = the slope-determining parameter (value between zero and one).

The Seinhorst model has the advantage that one of its parameters (t) indicates the damage threshold density, i.e., the minimum nematode population in the soil that inhibits plant growth (Barker and Olthof, 1976). Traditional calculation of the Seinhorst equation that best fits the experimental data is rather difficult and time-consuming because the model is segmented. Moreover, three parameters, of which one occurs in the exponential part of the equation, must be determined. Therefore, a program (SeinFit) was written to enable researchers to calculate the best-fitting Seinhorst curve in a matter of minutes. In this paper, we describe the data entry and options available in the SeinFit program, explain how the calculations are performed, and present guidelines for program use.

Materials and Methods

Program language and computer requirements: The SeinFit program was written in C++, with Metrowerks CodeWarrior (Metrowerks, Austin, TX). It is a "Fat Binary": a stand-alone application containing both 680×0 and PowerPC native code for optimum performance on both Macs and PowerMacs.

Received for publication 13 November 1996.
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The authors thank P. J. McLeod for reviewing this article.

The program requires 487 kilobytes of memory and 300 kilobytes of disc space. Results can be printed on any printer. A DOS version, written in C++ with Turbo C++ (Borland International, Scotts Valley, CA), also has been developed. An HP printer (Hewlett-Packard, Boise, ID) supporting the PCL-5 language is required to print the results from the DOS version.

User interface: Data pairs (x, y) can be either entered manually in a spreadsheet-like data window ('New Data') or imported from a text file ('Import Data'). The format of the data can be changed using the 'Column Format' option. Any data point can be selected or unselected for use in calculating the Seinhorst equation or plotting on the graph (Fig. 1A). In addition to the plotted data points and the graph, the following items can be displayed in the graph window: the fitted Seinhorst equation; the value of the mean yield (y_m) at $x \leq$ t; the values of the parameters m, z, and t; the coefficient of determination (r^2); and the sum of squares (Fig. 1B). The program automatically recalculates the Seinhorst equation and updates the graph when the 'Auto Update' option is selected after changes are made in the data window. The thickness of the lines and dots in the graph can be chosen, as well as the scale and the minimum and maximum values of the x and y axis.

Specific values can be given to the parameters m, z, and t, with the option 'Manual' from the Curve Fit menu. These values are used to draw the graph and calculate the corresponding Seinhorst equation, coefficient of determination (r^2), and sum of squares once the "Plot" button is clicked. The Curve Fit menu contains two more options to calculate the equation and draw the graph, based on the two calculation methods described hereafter.

A 'Help' file contains an explanation of all the menu options and the calculation methods, as well as a description of the Seinhorst model. The data, the values of the parameters of the Seinhorst equation, and the graph can be printed.

Calculation methods: Two methods can be selected to calculate the Seinhorst equation. The 'Double Partial Derivative Method' was described by Ferris et al. (1981). In this iterative procedure, the residual sum of squares is evaluated over a range of t values covering the initial nematode population-

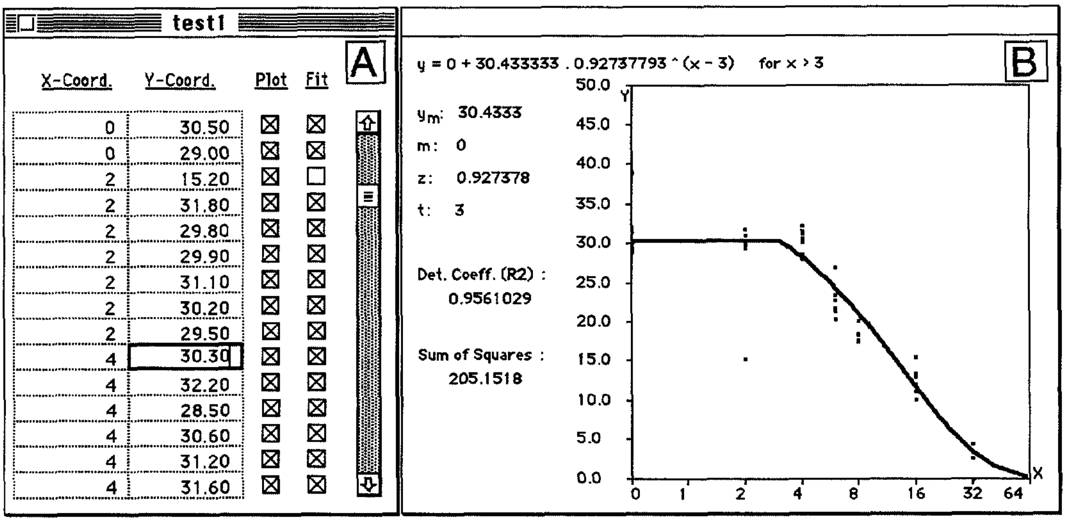

FIG. 1. Display of two windows of the SeinFit program on a Macintosh computer. A) Data window. The data points (x,y) can be selected to appear on the graph (Plot check box), and to be used in the calculation of the best-fitting Seinhorst equation (Fit check box). B) Graph window. Dots correspond with the data in the data window. The best-fitting Seinhorst equation, the values of its parameters (m, z, t), the mean yield (y_m), the coefficient of determination (r^2), and the sum of squares are shown in the graph window (x = preplant nematode density, y = yield or other plant growth parameter).

densities (x), unless differently specified. For every t value, an initial z value of 0.99 is selected. Using the estimated z and t values, an m value is derived with ($\delta SS/\delta m = 0$):

$$m = \frac{\Sigma y_i/y_m - \Sigma z^{(x_i - t)} - \Sigma y_i/y_m \cdot z^{(x_i - t)} + \Sigma z^{2 \cdot (x_i - t)}}{n - 2 \cdot \Sigma z^{(x_i - t)} + \Sigma z^{2 \cdot (x_i - t)}} \quad (3)$$

Using this m value, the partial derivative of the residual sum of squares with respect to z is calculated as follows, and evaluated in z.

$$\frac{\partial SS}{\partial z} = \Sigma(2[y_i - y_m \cdot m - y_m \cdot (1 - m) \cdot z^{(x_i - t)}] \cdot [m - 1] \cdot y_m \cdot [x_i - t] \cdot z^{(x_i - t - 1)} \quad (4)$$

When this partial derivative is positive, z is decreased by 0.01 and m and $\partial SS/\partial z$ are recalculated. Once the derivative is negative, a new z at mid-point of the current and the previous z is chosen, and m and $\partial SS/\partial z$ are recalculated. This procedure is repeated until the difference between the present z and the previous z values becomes less than the interval of uncertainty. Finally, the sum of squares is calculated for those t, m, and z values. The t value with the smallest sum of squares, and the corresponding z and m values, are saved for the best-fitting curve. In the "Double Partial Derivative" dialog box, the defaults for the uncertainty interval for z, the minimum and maximum value for t, and the number of steps for t can be changed.

In the 'Grid Method,' the residual sum of squares is calculated for a range of t, z, and m values. These ranges, as well as the number of steps to be used in each of them, can be specified in the "Grid" dialog box. The t, z, and m values returning the smallest residual sum of squares are saved for the best-fitting curve.

The calculation of the optimum values of m, z, and t, the corresponding sum of squares, and the coefficient of determination are visualized when the 'Show Progress' option is marked.

Results and Discussion

SeinFit, a computer program, was created to describe the relationship between nematode population densities in the soil at planting and plant growth parameters, according to the Seinhorst model. As an example, SeinFit was used to relate preplant nematode densities of *Meloidogyne hapla* and weight of lettuce, as well as to determine the damage threshold density in greenhouse and field microplot tests (Viaene and Abawi, 1996). As with any model, caution in interpretation of the results is needed. Yield and nematode population data are often too variable to permit estimation of the parameters with confidence (Ferris, 1984). The Seinhorst equation that fits the data best does not always differ much from the second best-fitting equation. For example, a Seinhorst equation with $r^2 = 0.97$ can have a t-value of 2 nematodes/g soil, whereas the second best-fitting equation to the same data set has $r^2 = 0.96$ and indicates a damage threshold density of 3 nematodes/g soil. The damage threshold density calculated by SeinFit should therefore be interpreted with consideration of the values of r^2 for the Seinhorst equations that have t-values close to the t-value of the best-fitting equation.

The biology of the interaction between nematodes and host crops always should be kept in mind when drawing conclusions about the calculated values. It is possible to obtain values of m that are higher than one, resulting in a graph that shows an increase in yield as the nematode population density increases. A stimulation in plant growth caused by plant-parasitic nematodes has been reported for some crops (Wallace, 1971), but this usually occurs at low population densities. If population densities used in the experiment were not high enough to result in a minimum yield, m can be set to 0 to calculate the other parameters (z and t) of the Seinhorst equation (Ferris et al., 1981). It is also possible, however, that failure to obtain minimum yields is caused by factors other than low initial population densities, e. g. the covariation of nonpathogenic or weakly pathogenic nematodes with unmeasured variables that also affect plant growth.

Versions written for Macintosh or DOS-compatible machines are currently available through the Society of Nematologists' World Wide Web site (http://ianrwww.unl.edu/ianr/plntpath/nematode/SOFTWARE/nemasoft.htm).

Literature Cited

Barker, K. R., and T. H. A. Olthof. 1976. Relationships between nematode population densities and crop responses. Annual Review of Phytopathology 14:327–353.

Ferris, H. 1984. Nematode damage functions: The problems of experimental and sampling error. Journal of Nematology 16:1–9.

Ferris, H., W. D. Turner, and L. W. Duncan. 1981. An algorithm for fitting Seinhorst curves to the relationship between plant growth and preplant nematode densities. Journal of Nematology 13:300–304.

Seinhorst, J. W. 1965. The relation between nematode density and damage to plants. Nematologica 11: 137–154.

Viaene, N. M., and G. S. Abawi. 1996. Damage threshold of *Meloidogyne hapla* to lettuce in organic soil. Journal of Nematology 28:537–545.

Wallace, H. R. 1971. The influence of the density of nematode populations on plants. Nematologica 17: 154–166.