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Development of an empirical model to predict losses in eggplant (*Solanum melongena* L.) production caused by Verticillium wilt

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Abstract

A model relating Verticillium wilt assessment in early stages of eggplant growth to total crop losses is proposed, based on the results of 3 years experimentation. The model resulted from the integration of the area below the yield versus disease regression curve and the ordinates axis, represented losses, on axis Y from Y_0 to Y_{100} which are the limits of % yield losses and leaf symptom index (LSI) on X-axis from X_0 to X_5 which are the limits of LSI. According to mathematical functions the following model is proposed:

$$\int_0^5 f(x)\,dx = A = (0.5/n)(0 * n_0 + 2 * n_1 + 4 * n_2 + 6 * n_3 + 8 * n_4 + 5 * n_5),$$

where n is the total number of plants counted, $n = n_0 + n_1 + n_2 + n_3 + n_4 + n_5$, where n_0, n_1, n_2, n_3, n_4 and n_5 are the numbers of plants belonging in each rank of the LSI, and the area A has limits 0–5. The algorithm obtained by the model is interpolated in the data of yield losses of each rank of the symptom index found in the experimental work, and the resultant number is the final estimation for future losses. The model has been validated with several results from other experiments and gave high accuracy ($R^2 = 0.961$) at least for the cultivars used in the experiments.

Keywords: *Verticillium dahliae*; *Solanum melongena*; Yield loss thresholds

1. Introduction

Verticillium wilt (*Verticillium dahliae* Kleb.) is the most destructive fungal disease of eggplant (*Solanum melongena* L.) in greenhouse or field crops in Greece (Thanassoulopoulos, 1976; Bletsos et al., 1997). One month after transplanting when sectioning or destruction of the plant must be avoided, assessment of disease intensity is based on progressive disease symptoms such as yellow-bronze leaf spots, leaf and shoots drying up, growth reduction and finally death of the plant. The soil inoculum density (Pullman and DeVay, 1982; Gutierrez et al., 1983; Paplomatas et al., 1992), the soil temperature (DeVay and Pullman, 1984) and the susceptibility of cultivars (Bletsos et al., 1997) are the main factors affecting the early or late disease incidence. The work of Ashwoth et al. (1979) on Verticillium wilt has emphasized the direct relationship of vascular discoloration of cotton stems to the inoculum density of the pathogen in the soil. Pullman and DeVay (1981) determined the relationship between inoculum density at planting time and foliar symptom development in one cotton cultivar. Later, Gutierrez et al. (1983) constructed a model simulating Verticillium wilt in relation to cotton growth and development. They considered the compensation effects derived from the inoculum density of *V. dahliae*. Although the model gives good predictive values it is not easy for growers to use it. Paplomatas et al. (1992) developed an equation to guide growers in choosing the best yielding cotton cultivars by investigating the relationship between soil inoculum levels

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and disease incidence. However, it is desirable to make the earliest possible disease assessment in order to give as precise as possible an estimation of the future yield. This early estimation will enable the growers to decide if it is economic to continue the cultivation of the crop. It is well known that the yield of plants infected at an early stage of growth is almost nil (Kamal and Saydam, 1970). This period is considered to be critical to calculate future losses and avoid further expenses when great losses are predicted. To date, only two papers have been published concerning the assessment of yield losses of eggplants and they have concentrated on the final stage of cultivation (Thanassoulopoulos, 1976; Bletsos, 1997).

The present work is an effort to construct an empirical model so that early assessment of disease incidence would provide the growers with information on whether they should continue with the crop.

2. Materials and methods

The work was carried out from 1999 to 2002 in the experimental fields of the National Agricultural Research Foundation (NAGREF), Agricultural Research Center of Macedonia and Thrace, Thessaloniki, Greece.

The eggplant cv Tsakoniki, which is the most important Greek cultivar and the most susceptible to Verticillium wilt, was used throughout. In the first year the plants were transplanted into naturally infested soil (1.4 ± 0.72 propagules g^{-1} soil) (unpublished data) which had been cultivated for 5 years with eggplants. In the following three years the soil was artificially inoculated with additional inoculum in each year to ensure homogeneous distribution and to increase the incidence of disease symptoms. Inoculum in all cases was a mixture of *V. dahliae* isolates from tomato 'Early pack' and eggplant 'Tsakoniki'. The inoculum was prepared in glass jars as described previously (Thanassoulopoulos and Hooker, 1970; Bletsos et al., 1997, 1999) and the content of one glass jar (200 g inoculum), containing cornmeal-perlite medium inoculated with *V. dahliae*, with a concentration of 15×10^4 microsclerotia g^{-1} of medium (Bardas, 2002) was distributed and incorporated into 5 mounds and one plant was transplanted into each mound.

Eggplant seedlings 30 d-old were bare-root transplanted in three rows, with 10 plants per row (30 plants total in each year). The distance between rows was 2 m both in the field and greenhouse, and among plants 50 cm in the rows. Thirty plants were also transplanted in methyl bromide fumigated soil as controls.

A combination of leaf symptom index (LSI) ranging from 0 to 5 (0 = apparently healthy, 5 = dead plants or nearly so) and growth of the plant (A = plant growth normal to $\frac{3}{4}$ that of controls, B = plant growth $\frac{3}{4}$ to $\frac{1}{2}$ of controls and C = plant growth less than $\frac{1}{2}$ of controls) (Table 1) was used to estimate disease severity one month after transplanting.

It has been shown previously that disease symptoms and disease severity are positively correlated (Thanassoulopoulos, 1976). This early LSI of each plant was correlated to the total yield at harvest. The area enclosed between the curve (Fig. 1) and the *X*-axis is changing as the two derivative means, losses (*Y*-axis) and LSI (*X*-axis) are increased. Considering the curve $y = f(x)$, which is a table of values obtained through experimentation, in the interval a and b and supposing that the interval is subdivided by $n+1$ points, $x_1 = a$, $x_{n+1} = b$ it is possible that yield losses could be in every natural number between 0 and 100, it is possible to obtain an approximate value of

$$\int_a^b f(x)\,dx.$$

Erecting the corresponding ordinates Y_i and writing $\Delta\chi_\imath = x_{\imath+1} - x_\imath$ for the width of the $\imath$th interval form the sum

$$f(x_0)\Delta x_0 + f(x_1)\Delta x_1 + f(x_2)\Delta x_2 + \cdots + f(x_n)\Delta X_n.$$

This sum is usually denoted by the symbol

$$\sum_{i=0}^{n} f(x_i)\Delta x_i.$$

Table 1
Verticillium wilt symptom index of eggplant leaves

	Symptoms	Grade values assigned in presence of plant growth[a]		
		A	B	C[b]
0	No visual symptoms (apparently healthy)	0	1	2
1	Slight mottling mainly on lower leaves. Erratic yellow-bronze spots on leaf lamina with/without necrotic centre. Sometimes epinasty	1	2	3
2	Necrotic spots on leaf lamina, dead leaves and/or appreciable defoliation of lower leaves. Bronze-yellow spots on upper leaves. Slight wilt of plant tops	2	3	4
3	Severe wilting. Lower leaves abscised and/or severe defoliation. Brown or black discoloration of existing lower leaf-petioles. Partial death of intact plant	3	4	5
4	Plant with a leaf tassel only on the tip. Severe wilting	4	5	—
5	Dead plant or nearly so	5	—	—

[a]Plant growth was measured on the basis of plant height and general plant vigor.
[b]A, plant growth normal to $\frac{3}{4}$ of the normal compared to the average of control, B, $\frac{3}{4}$ to $\frac{1}{2}$ and C, less than $\frac{1}{2}$ of normal growth.