THE CORRELATION OF ROOT GALLING WITH EGGS IN ROOT AND JUVENILES IN SOIL OF ROOT KNOT NEMATODES (*MELOIDOGYNE* SPP.) INFECTING GREENHOUSE VEGETABLES

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Summary. Data of root galling and densities of eggs in the roots and juveniles of *Meloidogyne* spp. in the soil, from microplot greenhouse experiments conducted in Crete, were used to explore the existence of correlations through linear regressions. At low root galling indices, there was a positive strong linear regression between root galling indices and eggs in the roots, and a modest regression between root galling indices and nematode juveniles in the soil. With high root galling indices, the linear relationship was not significant. It is concluded that high root galling indices are not necessarily associated with large numbers of nematode eggs in the roots and juveniles in the soil; such observations should be considered when interpreting results on control of *Meloidogyne* spp.

Keywords: Cucumber, linear regression, *Meloidogyne incognita*, *M. javanica*, tomato.

Root-knot nematodes (*Meloidogyne* spp.) are the most important nematodes threatening world agricultural production due to their global distribution, broad host ranges, the severity of the damage they cause and their involvement in disease complexes (Sasser, 1980).

In Crete, where greenhouse vegetables are grown almost all the year round, root-knot nematodes cause severe problems due to the continuous culture of susceptible crops and the high temperatures, which allow these nematodes to develop several generations during a crop cycle. In these cases, roots of heavily infected plants have large compacted galls (with the majority of egg masses embedded inside the root tissues) and show localized or extended root decay. Because egg masses are not visible on the root surface, the only feasible way to record egg number is root maceration and sieving. It has been noticed that in such heavily galled and rotted roots the number of eggs is relatively low compared to the apparent degree of infestation. This may cause confusion with the interpretation of the results and the statistical analysis of the experimental data. An example, using data from published work (Tzortzakakis and Gowen, 1994), is presented in Table I, where despite the control plants having the largest root galling index (RGI), eggs in the roots and juveniles in the soil were less than in plants with lower RGI. Therefore, the aim of this work was to investigate whether linear regression models can describe correlations of RGI with egg density in roots and juveniles in soil using data from previously published microplot greenhouse experiments for control of *Meloidogyne* spp. (Tzortzakakis and Gowen, 1994; Tzortzakakis *et al*., 1999, 2000; Tzortzakakis, 2000; Tzortzakakis and Petsas, 2003).

The experiments were all conducted at different times, in two greenhouses in Crete that were infested with either *M. javanica* or *M. javanica*/*M. incognita* and cropped to tomato and cucumber. Each treatment had four replicated plots and, at the end of the crop cycle, all plants per plot (between six and sixteen) were uprooted and the RGI of each was estimated according to Bridge and Page (1980). The RGI values used in the correlation analysis were the average of all plants within a plot. Also, all of the roots within a plot were cut into small pieces and mixed to form a homogeneous sample from which representative sub-samples of 10-50 g were taken. These were left in water for two days to soften, macerated in a kitchen blender and the slurry washed through 150 µm and 38 µm sieves. The eggs from the 38 µm sieve were collected in a beaker and counted to estimate the density per g of root. Juveniles from 200-500 g soil samples were recovered in modified Whitehead trays and counted.

Of the linear regression models tested, the best was that based on $\log_{10}$ (variable+1) transformations. As a rough guide to the strength of the correlations based on r values, the proposal of Fowler *et al.* (1998) was used (r from 0.70 to 0.89 indicates strong while from 0.40 to 0.69 modest correlation). The plotting of egg density in the roots against RGI values of 10 or less gave a strong correlation for tomato (174 observations) and cucumber (64 observations) with almost identical lines (Fig. 1). When the regression was run on data with RGI values lower than 6 for tomato and lower than 5 for cucumber the correlations based on r and P values were still high, almost the same as those on for the data in Fig. 1. However, when the regression was run using data with RGI equal to or higher than 6 for tomato and 5 for cucumber, there was no fit as indicated by the non-significant

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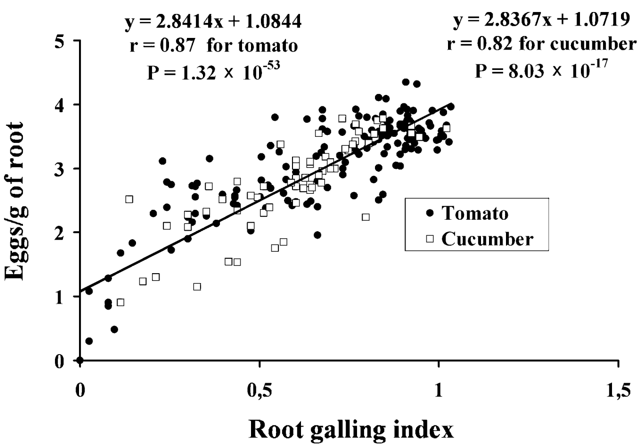

Fig. 1. Number of eggs per g of root plotted against root galling index for tomato (n = 174) and cucumber (n = 64) (all data are $\log_{10}+1$ transformed). The two lines are essentially identical (n = no of observations).

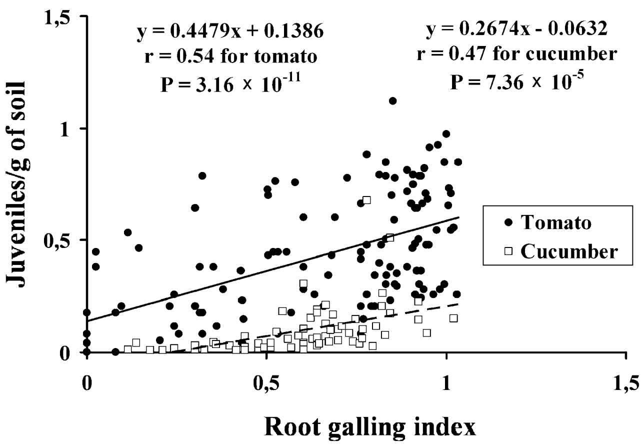

Fig. 2. Number of juveniles per g of soil plotted against root galling index for tomato (n = 128) and cucumber (n = 64) (all data are $\log_{10}+1$ transformed). The solid line is for tomato and the doted for cucumber (n = no of observations).

Table I. Values of root galling index, eggs per g of root and J_2s (second stage juveniles) per 200 g of soil at the end of a microplot greenhouse experiment for management of *Meloidogyne* spp with two treatments on cucumber.

Treatment	Root galling index	Eggs	J_2s
Control	8	3,831	84.8
Pasteuria penetrans	5.4	4,000	54
Oxamyl	5.1	4,275	95.3

Data adapted from Tzortzakakis and Gowen (1994).

P values (Table II). The juvenile density in the soil was at best only modestly correlated with RGI for tomato and cucumber (Fig. 2) and with high RGI values there was no correlation (Table II).

The effect of root decay on the relationship between root galling and egg mass number has been investigated in cucumber and shown to have an adverse effect on that relationship, resulting in fewer egg masses on severely galled and decayed roots (Walters *et al.*, 1992). These findings agree with my results for cucumber and tomato although I used the RGI value instead of a necrosis index.

The results presented here were derived from only a few observations and the values of 6 and 5 as the thresholds for high values of RGI were arbitrarily selected so as to provide sufficient observations for analysis. They indicate that with low RGI (<6 for tomato and < 5 for cucumber) there is a high probability of a strong positive linear correlation between RGI and eggs in roots and a high probability of a positive but poor linear correlation between RGI and juveniles in soil. On the other

Table II. Description of the best linear models based on r and P values for correlating root galling index with eggs in root and juveniles in soil of *Meloidogyne* spp.

Root galling index	Best linear model	No. of observations	r value	P value
	Relationship between root galling index and eggs per g of root for tomato			
< 6	y = 3.34x + 0.90	102	0.85	1.16×10^{-29}
≥ 6	y = 0.52x + 3.11	72	0.10	0.39
	Relationship between root galling index and eggs per g of root for cucumber			
< 5	y = 3x + 0.99	52	0.79	3.03×10^{-12}
≥ 5	y = 1.69x + 2	12	0.30	0.33
	Relationship between root galling index and juveniles per g of soil for tomato			
< 6	y = 0.39x + 0.16	75	0.45	4.39×10^{-5}
≥ 6	y = 0.38x + 0.21	53	0.09	0.53
	Relationship between root galling index and juveniles per g of soil for cucumber			
< 5	y = 0.17x - 0.02	52	0.47	0.0004
≥ 5	y = -0.79x + 0.90	12	0.30	0.33

hand, with large RGI values there is no probability of linear relationships between these variables.

When experiments for management of *Meloidogyne* spp. are conducted in warm areas, where multiple nematode generations per crop cycle can develop, the roots of control plants are usually heavily galled at the end of the crop. However, these heavy gallings are not always associated with large numbers of eggs in the roots and juveniles in the soil and, therefore, such findings should be considered when interpreting the results and deriving conclusions.

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