INFLUENCE OF *GLOBODERA ROSTOCHIENSIS* ON YIELD OF SUMMER, WINTER AND SPRING SOWN POTATO IN CHILE

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ABSTRACT

Greco, N., and I Moreno L. 1992. Influence of *Globodera rostochiensis* on yield of summer, winter, and spring sown potato in Chile. Nematropica 22:165–173.

Three microplot experiments were conducted in Chile to determine the effect of population densities of *Globodera rostochiensis* on the growth and yield of summer, winter, and spring sown potatoes (*Solanum tuberosum*). Microplots were 30-cm-diam, 50-cm-deep, concrete bottomless tubes filled with 28.3 L of soil infested with *G. rostochiensis* in a geometric series of nematode densities between 0 and 512 eggs/g of soil. Growth reduction of potato plants was evident only at ≥ 64 eggs/g soil on young summer potato, but occurred at 32 eggs/g soil on young spring potato. The tolerance limits of summer sown potato were 1.3 and 1.56 eggs/g soil for tuber and dry foliar weights. respectively. The tolerance limit for spring sown potato was 1.56 eggs/g soil for both parameters. The nematode reproduced poorly on summer and winter potatoes and well on spring potato, with reproduction rates of 8, 8.9, and 39, respectively. Nematode equilibrium densities for summer, winter, and spring potatoes were 39, 66, and 360 eggs/g soil. Results indicate that under the environmental conditions of central Chile, the buildup of nematode populations and yield losses of potato to nematodes are substantially lower on summer and winter sown potato than on spring sown potato.

Key words: Globodera rostochiensis, nematode reproduction, pathogenicity, potato, potato cyst nematode, *Solanum tuberosum*, tolerance limit, yield losses.

RESUMEN

Greco, N. y I. Moreno L. 1992. La influencia de *Globodera rostochiensis* sobre el rendimiento de papa sembrada en el verano, invierno y la primavera en Chile. Nematrópica 22:165–173.

Se realizaron tres ensayos con microparcelas en Chile para evaluar el efecto de varias densidades poblacionales de *Globodera rostochiensis* sobre el crecimiento y rendimiento de la papa (*Solanum tuberosum*) sembrada en verano, invierno y primavera. Como microparcelas se utilizaron tubos de concreto sin fondo de 30 cm de diámetro y 50 cm de profundidad, los cuales fueron rellenados con 28.3 L de suelo infestado con *G. rostochiensis* en una serie geométrica de densidades entre 0 y 512 huevos/g de suelo. Se observó una reducción en el crecimiento de plantas de papa en densidades equivalentes a ≥ 64 huevos/g de suelo para papa joven de verano y a 32 huevos/g de suelo en papa joven de primavera. Los límites de tolerancia de papa sembrada en verano fueron 1.3 y 1.56 huevos/g de suelo para pesos de los tubérculos y el follaje seco, respectivamente. El límite de tolerancia de papa sembrada en primavera fue 1.56 huevos/g de suelo para ambos parámetros. El nematodo se reprodujo mal en papa de verano e invierno y bien en papa de primavera, con tasas de reproducción de 8, 8.9 y 39, respectivamente. Densidades equilibrantes del nematodo para papa de verano, invierno y primavera fueron 39, 66 y 360 huevos/g de suelo, respectivamente. Los resultados indican que bajo las condiciones ambientales de la región central de Chile, el incremento de poblaciones de nematodos y las pérdidas de rendimiento de papa debidas a nematodos probablemente son considerablemente más bajos en papa sembrada en el verano e invierno que en papa sembrada en la primavera.

Palabras clave: estimación de pérdidas, *Globodera rostochiensis*, límite de tolerancia, nematodo quiste de la papa, papa, patogenicidad, reproducción de nematodos, *Solanum tuberosum*.

INTRODUCTION

The golden potato cyst nematode, *Globodera rostochiensis* (Woll.) Behrens, originated in the Andean mountains and today is found in most of the potato growing regions of the world (3,5). In Chile, the nematode is distributed mainly in the central portion of the country (geopolitical Regions IV and V), where it causes severe yield loss of potato (4).

Information on *G. rostochiensis* biology, population dynamics, pathotypes, and loss thresholds for potato is lacking in Chile. Seinhorst (6,7,9,10) described models that relate population densities of nematodes at planting to plant yields and to post-harvest nematode populations. Such models have been used to characterize interactions between *G. rostochiensis* and potato in Europe. However, differences in environment may affect nematode-crop interactions. In Chile, potato crops sown in spring, summer, and winter are present in the field at the same time. This offers a unique opportunity to investigate the behaviour of *G. rostochiensis* under different climatic growing conditions. Our objective was to employ Seinhorst's models to investigate interactions between potato growth and *G. rostochiensis* populations in central Chile in summer, winter, and spring.

MATERIALS AND METHODS

The experiments were conducted in 1988–1989 at La Serena, Region IV, Chile, in a field with a sandy soil (sand 81.8%; silt 3.6%; clay 14.6%; organic matter 0.5%; pH 8). One hundred forty microplots (30 cm in diameter and 50 cm long), made of concrete bottomless tubes, were set into the soil. The bottom 5 cm of each microplot was filled with soil free of nematodes and then 28.3 L of soil, infested at the appropriate nematode population density, was added to fill the microplots to within 5 cm of the upper edge of the microplot rim.

Nematodes were reared on the susceptible potato cv. Ultimus in clay pots in a plastic-house. Soil from these cultures was mixed and the nematode population density was estimated. Using a concrete mixer, appropriate amounts of infested soil and fertilizers were then thoroughly mixed with soil of the same type that had been fumigated with methyl bromide 2 months earlier, to provide population densities of 0, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, 256, or 512 eggs of *G. rostochiensis*/g soil. In each experiment there were 10 replicates per inoculum level (treatment), in a randomized block design. One potato tuber (cv. Ultimus) was planted in each microplot. Ten more microplots, infested with 64 nematode eggs/g soil, were left fallow to determine the decline of the nematode population in the absence of a host.

Microplots received routine cultural practices during the experiments. Shoot emergence, foliar symptoms, and plant height were recorded every 2 weeks. At harvest, the tuber yield and dry foliar weight for each microplot were measured. A 1.5–2 kg soil sample, composite of 20 cores, was collected from each microplot after crop harvest with an auger 1.5 cm in diameter and 30 cm long. Cysts were extracted from 200 g of air-dried soil with a Fenwick can, counted, and crushed with Bijloo's modified method (11). Then the eggs were counted.

Three sequential experiments included potato sown in summer (19 February 1988), spring (1 October 1988), and winter (26 June 1989); potatoes from the three experiments were harvested on 22 June 1988, 4 January 1989, and 15 November 1989, respectively.

Data on tuber yield and plant height were fitted by Seinhorst's plant damage model (6,10), $y = m + (1 - m)z^{P-T}$ (equation 1) where y = the relative yield (the ratio between the yield at a given Pi and that at Pi ≤ T) with y = 1 for Pi ≤ T, m = the minimum relative yield (y at very high Pi), Pi = the population density of the nematode at sowing (in eggs/g soil), T = the tolerance limit (Pi above which yield loss occurs), and z = a constant with $z^{-T} = 1.05$.

Data on final egg populations at harvest (Pf) were fitted by Seinhorst's nematode population model (7,8), $Pf = axy\ (-^{e}\log q)^{-1}\ (1 - q^{Pi}) + (1 - x)Pi + sx(1 - y)Pi$ (equation 2), in which a = the maximum reproduction rate of the nematode; x = the proportion of nematode eggs that would hatch in the presence of a host if it were not damaged by nematodes, y = y from equation 1, s = the proportion of eggs that do not hatch in the absence of a host, Pi = Pi in equation 1, and q = a constant < 1.

Curve fits for both equations were achieved visually with the aid of transparent overlays.

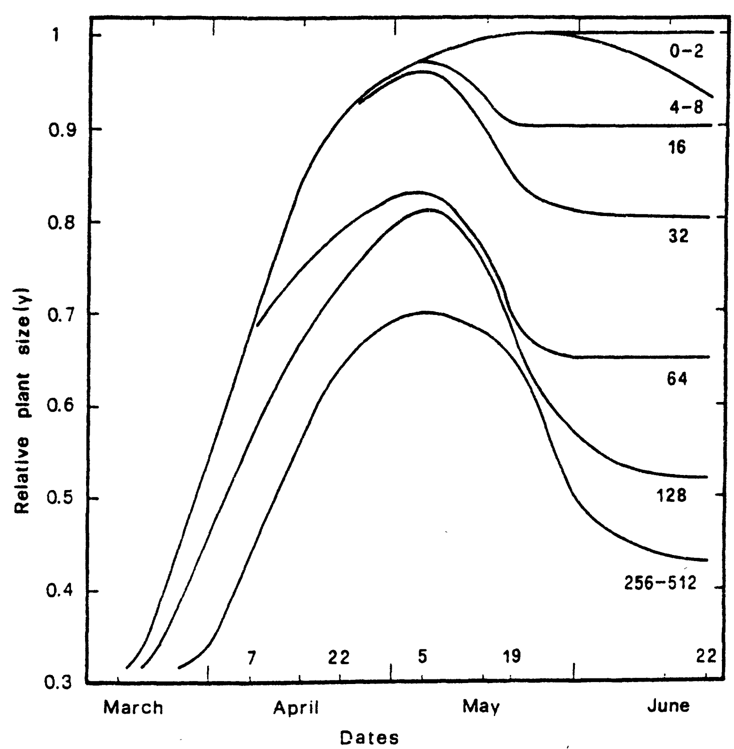

Fig. 1. Growth curves of potato sown in microplots in summer, derived from relative plant heights from 19 February until 19 May and dry weight of shoots at harvest, as affected by a range of initial population densities of *Globodera rostochiensis* (expressed in eggs per gram of soil at the end of each curve).

RESULTS

Effect of G. rostochiensis *on potato yield:* Inoculum levels did not influence plant emergence. However, symptoms of nematode infection (stunting, yellowing, and senescence of the plants) appeared earliest in microplots with highest population densities.

Growth curves based upon plant heights of summer sown (February) potato until May and on dry foliar weights at harvest (Fig. 1), indicated that as early as 17 April, plant growth was suppressed in microplots infested with ≥ 64 eggs/g soil (Fig. 1). Reductions in foliar growth were not observed until 29 April (50 days after plant emergence) in microplots infested with ≤ 32 eggs/g soil. Damage thresholds for *G. rostochiensis* were 1.3 eggs/g soil for tuber yield and 3.1 eggs/g soil for dry foliar weight (Fig. 2). At population densities greater than T, yields were greatly suppressed by the nematode. Reductions in yield of 20, 50, and 70% were measured in microplots infested with 12, 32, and 128 eggs/g soil, respectively. The lowest relative yields (m) were 0.3 and 0.4, respectively, for tubers and dry foliar weights and occurred in microplots infested with ≥ 128 eggs/g soil.

The winter sown (June) potato plants became infected with downy mildew in the spring. Damage from downy mildew was so severe that growth curves for foliage were of questionable value. However, yield data (not shown) indicated tolerance limits of 0.8 and 0.3 eggs/g soil for tuber and dry foliar weights, respectively, with minimum tuber yields (m) of 0.35.

In the spring experiment (October sowing), nematodes did not reduce plant emergence, but severe foliar symptoms of nematode infection were observed in the microplots with Pi ≥ 32 eggs/g soil. In microplots with Pi ≥ 128 eggs/g soil, growth reduction was obvious by mid-November. Growth was also suppressed, but to a lesser degree, in microplots with Pi ≤ 32 eggs/g soil (Fig. 3). Chlorosis was associated with initial nematode infestation as low as 8 eggs/g soil. Tolerance limits for spring.sown potato were similar to those of summer potato (1.56 eggs/g soil both for tuber and dry foliar weights) (Fig. 4). Minimum yields were 0.08 for tuber weight and 0.38 for dry foliar weight. Yield losses of 20, 50, and 90% occurred in microplots with Pis of 9, 28, and 128 eggs/g soil, respectively.

Nematode reproduction: In the summer experiment, nematode population densities increased only in microplots with Pi ≤ 32 eggs/g soil. Nematode population densities declined in microplots infested with ≥ 64 eggs/g soil (Fig. 5). The Seinhorst population model (equation 2) fitted to the observed Pf values, indicated a maximum reproduction rate (a) of 8, with hatching coefficients of x = 0.9 (90%) and s = 0.6 (60%). However, for Pi ≥ 32 a good fit was obtained only if it was assumed that the maximum nematode population (M) that potato would support in the absence of damage was about 100 eggs/g soil. However, Pf at Pi ≥ 256 eggs/g soil was 22% of the nematode population at planting and was only one third of that occurring in the absence of potato plants (s), suggesting that potato plants affected the nematode population in a soil volume larger than that exploited by potato roots, possibly due to diffusion of hatching factor into the soil. The estimated equilibrium density was 39 eggs/g soil.

The maximum nematode reproduction rate (a) on winter sown potato was 8.9 and similar to that observed for summer potato (Fig. 5). Final populations (Pf)

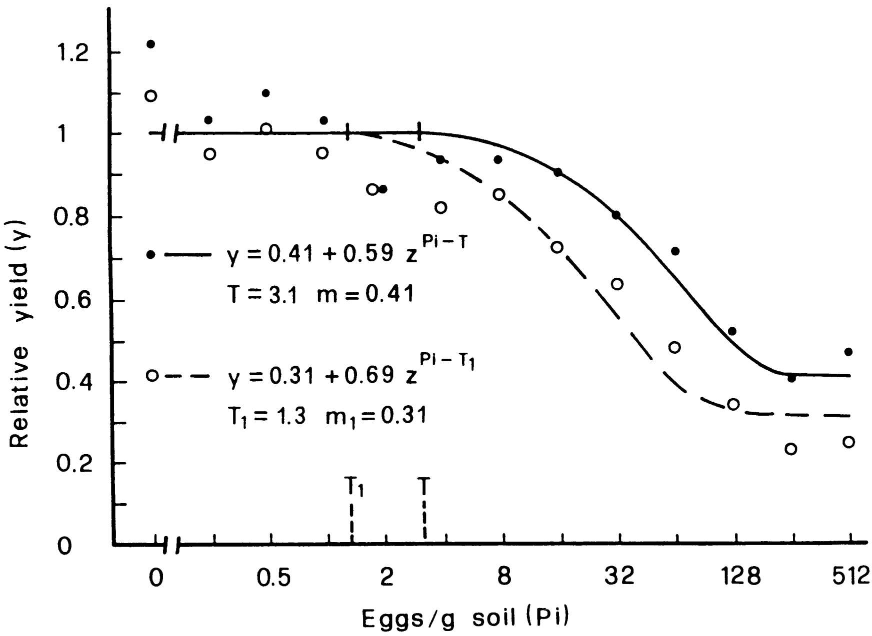

Fig. 2. Effect of initial population density (Pi) of *Globodera rostochiensis* on relative yield (y) of potato sown in summer (19 February 1988) based on tuber weights (○---) and dry foliar weights (●——).

at Pi ≤ 16 eggs/g soil were very similar to those of summer potato and fitted equation 2 best for x = 0 and s = 0.9. For larger Pi values a reasonably good fit was possible by assuming that M = 150 eggs/g soil and that the equilibrium density was 66 eggs/g soil.

The maximum nematode reproduction rate for spring sown potato was 39 (Fig. 5), about five times that of summer and winter sown potatoes. Most of the nematodes had developed into cysts by harvest. Although maximum nematode population densities (M) were variable, an estimate of 1 500 eggs/g soil was derived. No substantial changes in the nematode egg population was observed in the absence of the host. The estimated equilibrium density was 360 eggs/g soil.

Numbers of cysts per 200 g soil were similar with summer and winter sown potatoes but significantly smaller than those obtained with spring potato at all Pi (Table 1). The eggs per cyst were also similar in the microplots with summer and winter potatoes, but significantly larger than those of spring potato at Pi ≤ 32 eggs/g soil. The frequency of new cysts was lowest in the summer potato, intermediate in the winter potato, and highest with spring potato. Apparently no new cysts were formed on summer and winter potatoes at Pi ≥ 64 and Pi ≥ 128 eggs/g soil, respectively.

DISCUSSION

Our results provide useful information on the impact of *G. rostochiensis* on the yield of potato in Chile. Generally, the growth reduction of spring sown potato was more severe than that of summer and winter sown potatoes and at Pi ≤ 32 eggs/g soil was not obvious until

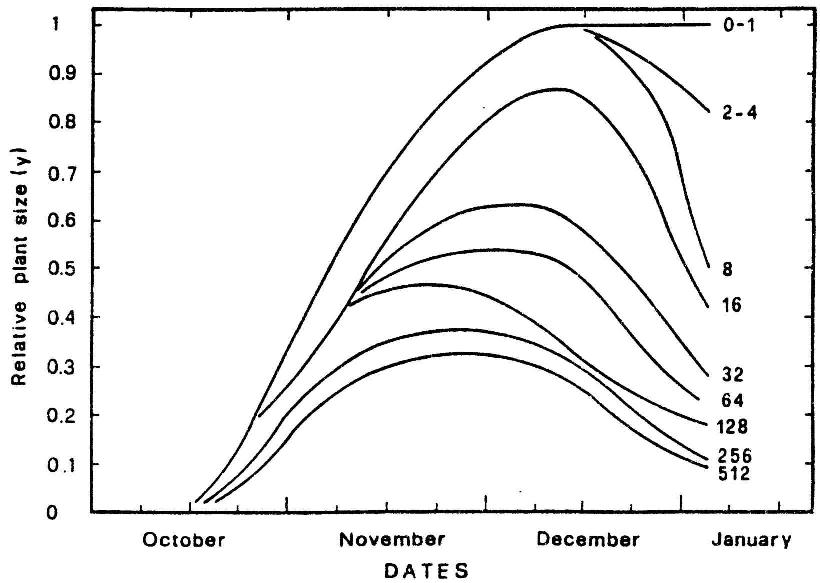

Fig. 3. Growth curves of potato sown in microplots in spring, derived from relative plant heights from 1 October until mid December and dry weight of shoots at harvest, as affected by a range of initial population densities of *Globodera rostochiensis* (expressed as eggs per gram of soil at the end of each curve).

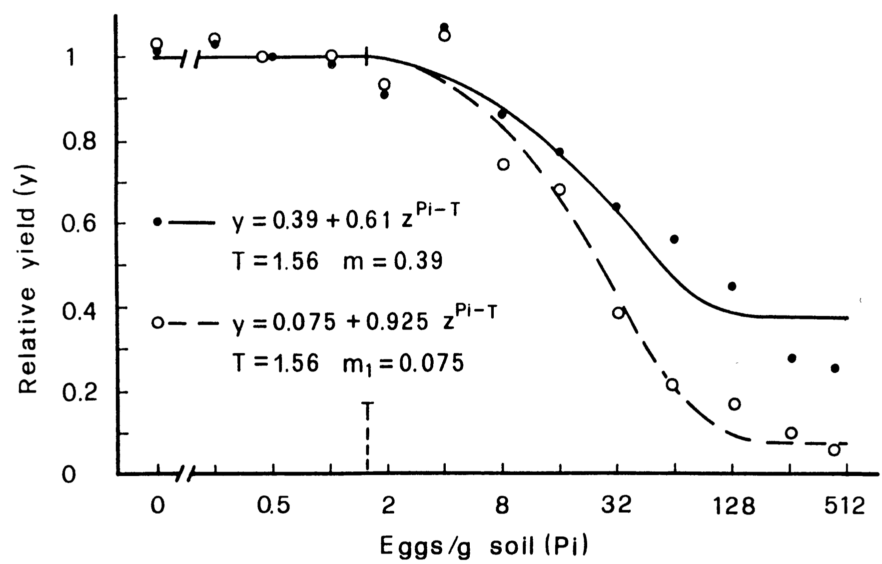

Fig. 4. Effect of initial population density (Pi) of *Globodera rostochiensis* on relative yield (y) of potato sown in spring (1 October 1988) based on tuber weights (o——) and dry foliar weights (•——).

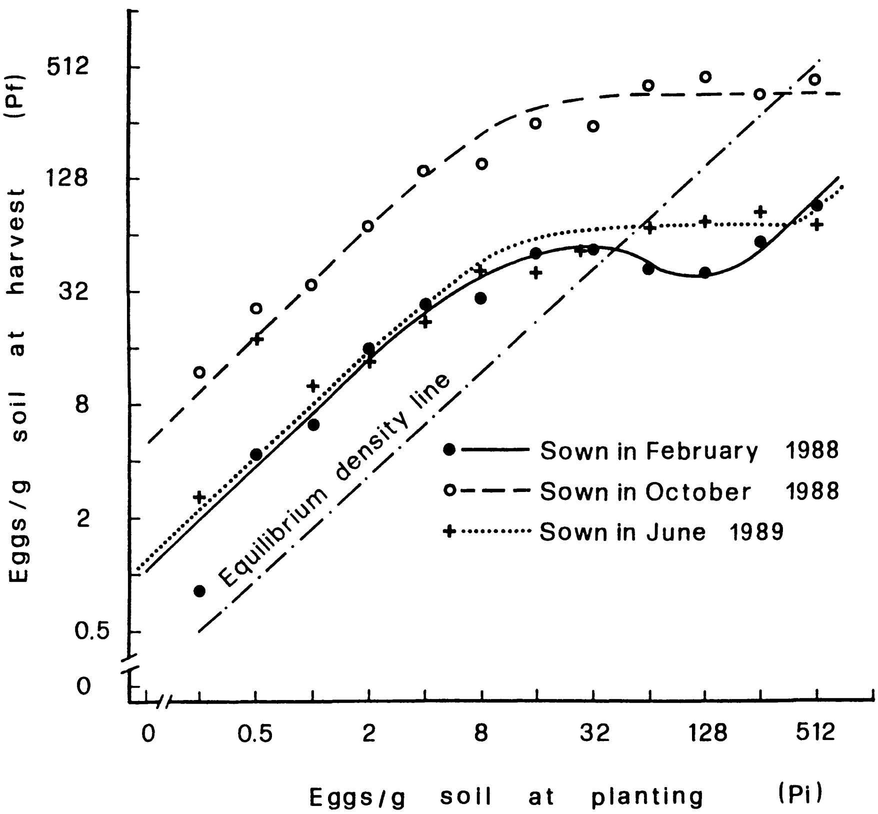

Fig. 5. Relationship between at planting (Pi) and post harvest (Pf) population densities of *Globodera rostochiensis* on potato sown in microplots in central Chile in summer (February), spring (October), and winter (June).

about 2 months after plant emergence. Therefore, very often farmers are probably unaware of nematode damage. The appearance of the foliar symptoms associated with nematode attack late in the season are commonly confused with environmental stresses such as drought. Yellowing and senescence of plants in midseason can also be misinterpreted as being a normal characteristic of an early maturing potato cultivar. Clearly the best way to predict yield losses associated with *G. rostochiensis* is by determining the nematode population density in soil before planting, rather than by visual observation of foliar symptoms and plant growth.

The tolerance limits of summer, spring, and probably winter potatoes, were similar to those reported in Europe (2,8) and Ecuador (1). However, the minimum yield of the spring potato (0.08) was much less than that of summer and winter sown potatoes. This indicates that the amount of yield lost at Pi $\geq$ T is much more severe on spring than on summer and winter sown potatoes. Moreover the reproduction rates and the maximum population densities of the nematode, observed at crop harvest, were

Table 1. Effect of the initial population density (Pi) of *Globodera rostochiensis* at sowing of potato on the final population (Pf) in terms of the numbers of cysts per 200 g of soil, the eggs per cyst, and the percentage of new cysts observed at harvest.

Pi	Pf								
(Eggs/g soil at sowing)	Cysts/200 g soil			Eggs/cyst			% new cysts		
	Su[z]	Wi	Sp	Su	Wi	Sp	Su	Wi	Sp
0.25	1.7	4.4	40	95	62	62	83.5	94.1	99.0
0.50	3.4	6.2	39	251	120	129	83.5	91.1	98.4
1	7.1	9.2	55	170	224	124	84.1	88.5	97.7
2	12.9	14.1	119	240	204	122	82.5	85.0	97.8
4	23.4	23.3	193	228	259	137	80.7	81.7	97.4
8	29.0	35.4	288	199	232	102	68.9	76.0	96.5
16	62.6	54.2	369	153	184	137	71.1	68.6	94.5
32	65.7	65.3	428	160	159	111	45.0	47.9	90.5
64	72.3	76.5	670	110	176	122	0.0	11.0	87.8
128	72.8	118	656	116	126	132	0.0	0.0	75.2
256	93.0	170	856	113	98	86	0.0	0.0	62.0
512	140	319	1 044	117	46	81	0.0	0.0	45.8

[z]Su = summer, Wi = winter, and Sp = spring sown potato.

largest on spring sown potatoes. If potatoes are sown in spring, longer rotation will be required to reduce nematode population densities below damage thresholds.

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