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Decline of *Globodera rostochiensis* as Influenced by Potato Root Diffusate Movement and Persistence in Soil[1]

J. A. LaMondia, Denise Rawsthorne, and B. B. Brodie[2]

Abstract: Decline of *Globodera rostochiensis* populations occurring naturally in soil and those added to potato hills and furrow centers in nylon bags was correlated with root weight of Hudson, Rosa, and Katahdin potatoes at two locations in New York. Cysts in bags were added to soil at planting and at 1, 3, 5, 7, and 9 weeks after emergence (AE). Fallow decline required only 2–4 weeks in soil and did not increase with time. Decline due to growing potatoes was greater in hills than in furrow centers, and resistant Hudson potatoes stimulated greater nematode hatch for longer times in both hills and furrows than did resistant Rosa and susceptible Katahdin. Potato root diffusate (PRD) was produced in highest concentration early in the season; decreased egg hatch with time was probably the result of declining PRD production and inactivation of PRD in soil. Decreasing potato row spacing from 92 cm to 46 and 23 cm between rows increased *G. rostochiensis* decline in furrow centers, with the majority of decline occurring within 1–3 weeks AE. Replanting potatoes after 1 week of trap crop growth failed to favor population reduction over a single full season crop.
Key words: *Globodera rostochiensis,* golden nematode, *Solanum tuberosum,* potato, resistance, root exudate, population dynamics, trap crop.

Eggs within cysts of the golden nematode, *Globodera rostochiensis,* hatch primarily in response to an unidentified factor present in potato root diffusate (PRD) (10,14). Until recently, it was thought that this factor was highly unstable and could not persist in the soil for long periods of time (2). There is now evidence from both field (8) and greenhouse research (9) that the active factor can move through soil and remain active for up to 100 days (13). Such data have increased our understanding of the spatial differences in the population dynamics of *G. rostochiensis* under susceptible and resistant potato cultivars (5).

The zone occupied by furrow populations of *G. rostochiensis* represents approximately 30% of the total soil volume to plow depth (8). This soil is not influenced by root growth of potato plants. Data from studies on diffusion of the active factor present in PRD show it is possible that at least 15% of the soil volume in which cyst nematodes are found may be affected little by diffusate produced by potato roots (9). Previous data concerning the fate of furrow populations are conflicting. It is reported both that encysted juveniles between rows largely escape stimulation by PRD (1) and that furrow populations decline because of PRD (8). Narrow row spacings increased *G. rostochiensis* populations in the furrow as a result of potato root growth (12).

The need for further information concerning *G. rostochiensis* population dynamics in furrows and persistence and movement of the active factor present in PRD was clearly indicated. Our objectives were to examine these factors and also to determine if the use of narrow potato row spacings and potato trap cropping could increase the efficacy of resistant potato cultivars in reducing *G. rostochiensis* populations.

Materials and Methods

The effects of potato-root diffusate on *G. rostochiensis* populations were investigated using cysts of uniform size and age (0.35–0.45 mm, produced in 1984) and naturally infested soil populations. Nylon bags (4 $cm^2 \times 1$ mm) attached to string and containing 15 cysts were placed 10 cm below the soil surface either in potato hills or in furrow centers. Potatoes were planted 23 cm apart in rows 92 cm apart. Viable eggs

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[1] Cooperative investigations of the U.S. Department of Agriculture Agricultural Research Service and Cornell University Agricultural Agricultural Experiment Station.

[2] Postdoctoral Associates and Research Plant Pathologist, USDA ARS, Department of Plant Pathology, Cornell University, Ithaca, NY 14853. Present address of first author: Connecticut Agricultural Experiment Station, New Haven, CT 06504.

TABLE 1. Decline of *Globodera rostochiensis* cyst contents 1–7 weeks after shoot emergence (AE) in furrow centers at four row spacings of resistant Hudson potatoes, Farmingdale, New York.

Distance between potato hills	Mean number viable juveniles per cyst				
	1	3	5	7	$\bar{x}$
Fallow	21.2	22.0	18.5	13.9	18.9
92 cm	22.9	25.1	8.3	2.4	14.7
46 cm	14.7	16.0	0.6	0.4	7.9
23 cm	7.8	2.1	1.3	0.4	2.9
$\bar{x}$	16.6	16.3	7.2	4.3	

Linear contrasts	Level of significance
Fallow vs. potatoes	0.01
92-cm spacing vs. 46-cm and 23-cm spacings	0.02
23-cm spacing vs. 46-cm spacing	NS
Decline 5 and 7 weeks AE vs. 1 and 3 weeks AE	0.001
Spacing by time interaction	0.05

Pi = 80.9 eggs/cyst; F spacing = 22.91; F weeks AE = 18.14; MSE = 52.9.

Number of eggs per cyst negatively correlated with root weight ($r = -0.71$) and weeks AE ($r = -0.58$) ($P = 0.05$).

Spacing of hills negatively correlated with root weight ($r = -0.54$) ($P = 0.05$).

TABLE 2. Decline in *Globodera rostochiensis* cyst contents 1–7 weeks after shoot emergence (AE) in furrow centers at three row spacings of resistant Hudson and Rosa potatoes, Prattsburg, New York.

Distance between potato hills	Mean number viable juveniles per cyst				
	1	3	5	7	$\bar{x}$
92 cm	26.9	21.6	31.3	42.6	30.6
46 cm	6.0	15.3	17.8	2.7	10.5
23 cm	11.0	5.3	2.8	1.5	5.2
$\bar{x}$	14.6	14.1	17.3	15.6	

Linear contrasts	Level of significance
92-cm spacing vs. 46-cm and 23-cm spacings	0.001
23-cm spacing vs. 46-cm spacing	NS
Spacing by time interaction	0.01

Pi = 80.9 eggs/cyst; F spacing = 43.82; F weeks AE = 0.36; MSE = 65.8.

Root weight negatively correlated with eggs per cyst ($r = -0.76$) and with spacing ($r = -0.75$) ($P = 0.01$).

per cyst were determined by crushing 15 cysts before planting and at various times during the potato growing season. Naturally infested soil populations were estimated by means of twenty 50-cm^3 soil cores per 17-m^2 plot taken before planting and again after harvest. Cores were bulked, and 500 cm^3 soil was processed for cysts (11). Recovered cysts were crushed to determine viable eggs per cubic centimeter of soil before planting and again after harvest.

Decline in *G. rostochiensis* cyst contents over time in furrow centers was investigated under bare fallow and three potato row spacing regimes in Farmingdale and Prattsburg, New York, in 1985. At Farmingdale, potatoes were planted into a silty clay loam (14.3% sand, 52.5% silt, 33.2% clay, pH 5.1) previously left fallow and planted to a rye winter cover crop. Potatoes were planted 17 April, 90% shoot emergence occurred 13 May, and vines were killed on 13 August 1985, one week before harvest.

At Prattsburg, potatoes were planted into a silty clay soil (9.1% sand, 46.9% silt, 44.0% clay, pH 5.0) planted to susceptible potatoes the previous year and to a rye winter cover crop. Potatoes were planted 30 May, 90% shoot emergence occurred 24 June, and vines were killed on 26 August. Potatoes were grown without irrigation at both locations. Potato rows were 92, 46, and 23 cm apart. Air dried cysts (initial content = 80.9 eggs/cyst) were buried at planting and removed 1, 3, 5, and 7 weeks after 90% potato emergence. Spacing treatments and the potato varieties Hudson and Rosa were randomized and replicated four times in a randomized block design at Prattsburg. Spacing treatments of Hudson were randomized in the field and replicated six times at Farmingdale. Fresh root weight in the furrow centers was determined by screening two 1,500-cm^3 core samples when bags were removed from each location. The effects of resistant potatoes on naturally infested *G. rostochiensis* populations were also monitored in these plots. Initial densities ranged from 0.06 to 22.44 eggs/cm^3 soil. Potato rows were planted 92, 46, and 23 cm apart with Hudson potatoes 23 cm apart within rows.

TABLE 3. Potato root weights in furrow centers 1–7 weeks after shoot emergence at two locations in New York.

Row spacing	Root fresh wt. (g/2,500 cm³ soil)								
	Farmingdale				Prattsburg*				$\bar{x}$ over locations
	1	3	5	7	1	3	5	7	
92 cm	0.0	0.3	1.3	1.5	0.0	0.0	0.0	<0.01	0.4 a
46 cm	0.5	1.0	2.8	1.8	0.3	0.3	1.5	1.8	1.2 b
23 cm	0.8	2.3	3.0	7.5	1.0	4.0	5.3	4.8	3.6 c
$\bar{x}$ over locations					0.4 a	1.3 b	2.3 c	2.9 c	

Means followed by the same letter not significantly different (LSD).
MSE = 1.88; df = 95; F location = 0.46; F week = 16.53; F spacing = 46.03; LSD location = 0.56; LSD week = 0.79; LSD spacing = 0.68.
* Means of two cultivars.

Plants were removed by killing the vines and disking plots 3, 5, or 11 weeks after emergence. Other plots double cropped to potatoes were disked 1 week after plant emergence and replanted to the same planting regime for an additional 10 weeks.

To study PRD persistence and movement over time, cysts (mean egg content = 140 ± 46) in bags were buried in hills and in furrows at planting and at 1, 3, 5, 7, and 9 weeks after plant emergence for each of resistant Hudson and Rosa and susceptible Katahdin potato cultivars and fallow. These times represent 13, 10, 8, 6, 4, and 2 weeks in soil. All bags were removed at harvest (13 weeks after planting), and the number of viable contents remaining was determined.

RESULTS

The number of viable eggs per cyst under fallow or resistant potatoes in the center of rows 92, 46, or 23 cm apart declined over time, with decline at 1 and 3 weeks after emergence less than at 5 and 7 weeks (Table 1). More eggs per cyst occurred under fallow than in any of the plots with potatoes. Fewer viable eggs remained per cyst under 23-cm and 46-cm spacings than under 92-cm spacings, with no difference between 23-cm and 46-cm spacings. In addition, the number of remaining viable eggs per cyst was negatively correlated with root weight in the furrow centers and with weeks after emergence.

When this experiment was repeated at another location, there was no significant effect of time on decline in cyst contents 1 week after potato emergence (Table 2). The number of viable eggs per cyst decreased with narrow row spacings. More eggs per cyst occurred with 92-cm spacing than with 23-cm or 46-cm spacings. Root weight in the furrow centers was again negatively correlated with viable eggs per cyst and with row spacing.

Potato root weights in furrow centers increased with time and with decreased row spacings, but no differences occurred between Prattsburg and Farmingdale (Table 3). As expected, root weights increased with time after emergence. Root weights were significantly different with each row spacing regime. Root weights were greatest in 23-cm row spacings and least in 92-cm spacings.

TABLE 4. Reduction of natural *Globodera rostochiensis* populations by trap cropping with resistant Hudson potatoes 1–11 weeks after shoot emergence at three row spacings, Farmingdale, New York.

Distance between potato hills	Population reduction after trap crop (%)				
	3	5	11	1 and 10 (double cropping)	$\bar{x}$
92 cm	82.4	73.2	83.9	87.5	81.7 a
46 cm	69.9	91.3	96.1	89.6	86.7 ab
23 cm	91.0	97.7	95.0	97.1	95.2 b
$\bar{x}$	81.0	87.4	91.6	91.4	

Means followed by the same letter not different (LSD).
Fallow decline = 46.0%; F spacing = 4.31; MSE = 119.

TABLE 5. *Globodera rostochiensis* eggs per cyst added in hills and furrows under three potato cultivars after 2–13 weeks exposure in soil.

	Eggs per cyst						$\bar{x}$ over hill and furrow
	13	10	8	6	4	2	
Hill							
Fallow	39	48	50	58	65	133	64 a
Katahdin	8	33	43	35	54	120	50 b
Hudson	7	16	18	23	30	51	30 c
Rosa	9	15	21	27	60	121	49 b
Furrow							
Fallow	45	47	44	48	59	135	
Katahdin	27	29	40	40	68	111	
Hudson	14	21	18	26	46	95	
Rosa	19	26	37	51	62	190	
$\bar{x}$ over hill and furrow	21 a	29 b	34 bc	38 c	55 d	113 e	

Class	Level of significance
Host	0.0001
Site	0.0002
Time	0.0001
Host*site	0.0002
Host*time	0.0001
Host*site*time	0.0001

Pi = 140 ± 46 eggs/cyst.
Numbers followed by the same letter not different (LSD).
F host = 59.5; F site = 14.9; F time = 235.1; MSE = 155.1; df = 176; LSD host = 5.0; LSD site = 3.5; LSD time = 6.1.

Decline of naturally infested *G. rostochiensis* soil populations was greatest in the 23-cm row spacings and least in 92-cm spacings (Table 4). Decline increased with time, but differences were not significant. Double cropping (removing potato plants grown for 1 week and replanting at the same spacing) did not significantly increase nematode population reduction when compared with a full season of resistant potatoes.

Decline in viable eggs per cyst added to hills and furrows at planting or 1, 3, 5, 7, and 9 weeks after plant emergence increased with length of exposure to PRD in soil (Table 5). Cysts in hills had significantly fewer eggs than did cysts in furrows. Egg content was least for cysts added to soil at planting; greater for cysts added 1, 3, and 5 weeks after emergence; and greatest for cysts added 7 and 9 weeks after emergence. Potato cultivar affected the decline in eggs per cyst over time. Hudson potatoes resulted in greater decrease in eggs per cyst, in both hills and furrows, than did Rosa and Katahdin, which were similar. Fallow plots had more eggs per cyst than all potato cultivars. There were significant interactions between host and site and between host and time. Hudson had greater nematode decline in the furrow position than did Rosa and Katahdin, as well as decline for a longer time period during the growing season.

DISCUSSION

Greater decline of cyst contents in bags under resistant potatoes at Farmingdale than at Prattsburg possibly is because furrow root weight was correlated with weeks after potato emergence at Farmingdale but was not related to time at Prattsburg. These differences could also be caused by unknown environmental effects.

Decline of eggs per cyst in hills and in furrows was correlated with time of exposure to soil for all potato cultivars. In both positions, Hudson reduced eggs per cyst more than Rosa or Katahdin. Decline in cyst contents is associated with root growth (6,7), PRD concentration (7), and length of time of PRD production (7,13,14). Hudson has been shown previously to produce a more active PRD for a longer period of time than Rosa and Katahdin in greenhouse studies and also, by inference, in field studies (7,8).

Our data indicate that PRD is produced in highest concentration early in the season, as hatch in response to PRD is less for cysts added to soil 1 week after emergence than at planting, especially in the hill. The decreased hatch from cysts added later in the season may be due to a reduction in PRD production over time, or to breakdown of existing PRD in soil, or both. In the greenhouse PRD production continued over time but activity reduced with time (8). Our field data indicate that existing PRD activity in the furrows is lost, possibly because of microbial breakdown (13), 3 weeks after emergence of Rosa and Katahdin and 5 weeks after emergence of Hudson. These data confirm that PRD production decreases with time and that PRD activity is continually being reduced in soil.

Furrow centers should be interpreted as an area of minimum decline in nematode populations as decline in hills has repeatedly been shown to be greater than decline in furrows (1,4,5,8). A short season resistant potato trap crop planted to narrow spacings or a double cropping of potatoes during a single season resulted in a decline in *G. rostochiensis* numbers similar to fumigation. *G. rostochiensis* soil populations were exposed to highly active concentrations of PRD persisting for a long period of time by disking up Hudson potatoes after 1 week of growth and replanting to the same spacing (double cropping). The resulting population decline did not differ from the effect of growing a single potato crop. Apparently a certain percentage of *G. rostochiensis* eggs would not hatch during this season and doubly stimulating them with PRD did not significantly increase egg hatch. Forrest and Farrer (3) suggested that eggs within single *G. pallida* cysts could be classified according to their ability to hatch. This claim could also be applied to *G. rostochiensis*. The potential of double cropping should not be dismissed, however, since the natural soil populations at Farmingdale are extremely low as a result of continuous cropping of resistant cultivars. Higher populations composed of recently produced cysts may respond differently to such a management practice.

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