DEVELOPMENT OF *GLOBODERA ROSTOCHIENSIS* DURING THREE DIFFERENT GROWING SEASONS IN CHILE

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ABSTRACT

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Field experiments were conducted in central Chile, in 1988-1989, to investigate the development of *Globodera rostochiensis* during three different potato growing seasons. Juveniles emerged from cysts throughout the year and no diapause was observed. Second-stage juveniles of the nematode in potato roots were numerous until 3–5 weeks after plant emergence and then declined. All nematode stages were present in the roots during the growing season. However, only 10–20% of the total population developed into cysts by harvest for summer and winter sown potatoes. In contrast, 40% of the population developed into cysts by harvest for spring sown potatoes. Cyst nematodes completed one generation with each potato crop; if potato was cropped repeatedly during one year, an additional generation developed on each crop. White females and brown cysts developed within 58–120 and 125–358 day degrees, respectively. Developmental time was greater in summer than in winter under conditions of central Chile.

Key words: Globodera rostochiensis, hatching, nematode development, potato, potato cyst nematode, *Solanum tuberosum*, temperature.

RESUMEN

Greco, N. y I. Moreno L. 1992. Desarrollo de *Globodera rostochiensis* durante tres temporadas de crecimiento en Chile. Nematrópica 22:175–181.

Se llevaron a cabo tres ensayos de campo en 1988-1989 en la región central de Chile para investigar el desarrollo de *Globodera rostochiensis* durante tres temporadas de cultivo. Estadíos juveniles se emergieron de los quistes todo el año sin presentar diapausa. La población de juveniles del segundo estadío en las raíces de papa fue alta hasta 3–5 semanas después de la emergencia de la planta; luego este disminuyó. Durante la temporada de cultivo, todos los estadíos se encontraron presentes en las raíces. Sin embargo, en papa sembrada en verano e invierno solamente el 10–20% de la población total se desarrolló hasta formar quistes antes de la cosecha. En contraste, en papa sembrada en la primavera, el 40% de la población se desarrolló hasta formar quistes. Los nematodos completaron una generación con cada cosecha de papa. Cuando se plantó papa dos o tres veces por año, se desarrolló una generación adicional en cada siembra. Hembras blancas y quistes de color café se desarrollaron entre 58–120 y 125–358 días-grados, respectivamente. El tiempo requerido para desarrollar un ciclo fue mayor en verano que en invierno bajo las condiciones ambientales de la región central de Chile.

Palabras clave: desarrollo de nematodos, eclosión, *Globodera rostochiensis*, nematodo quiste de la papa, papa, *Solanum tuberosum*, temperatura.

INTRODUCTION

The potato cyst nematode, *Globodera rostochiensis* (Woll.) Behrens, is widespread in many countries in South America (4,7). It was recently reported to occur in several potato growing areas of Chile (5) causing severe yield loss. Although information on the distribution of the nematode was adequate, knowledge of the yield loss associated with different population densities of *G. rostochiensis* was lacking as was information on the biology of the nematode under field conditions in Chile. The purpose of this research was to investigate hatching

and development of *G. rostochiensis* throughout the year in Chile.

MATERIALS AND METHODS

The experiments were undertaken at La Ligua (160 km north of Santiago), province of Petorca, geopolitical Region V, at sea level in fields comprised of sandy-loam soil (sand 46%, silt 19%, clay 35%). This area was chosen because it was heavily infested with the nematode.

Hatching: To determine if eggs within cysts of *G. rostochiensis* hatch promptly or require a dormancy period, a fallow field infested with 64 nematode eggs/g of soil was sampled monthly from 23 February 1988 until 17 January 1989. An auger 30 cm long and 1.5 cm in diameter was used to collect 60 random cores that were composited to provide one 2–3 kg sample. The sample was thoroughly mixed and cysts were extracted from four 200-cm^3 subsamples with a Fenwick can; 100 cysts per subsample were placed in 2-cm-diam sieves (250 μm aperture). The sieves were put in 3-cm-diam plastic Petri dishes, containing 5 ml of a 0.6 mM sodium metavanadate solution and incubated 4 weeks at 21 C. Emerging second-stage juveniles were counted at weekly intervals. The hatching solution was renewed weekly at the time of collecting juveniles. At the end of the test the cysts were crushed according to Bijloo's modified method (10). Eggs and juveniles were counted and hatching percentages were calculated.

Development: The purposes of this experiment were to: *i*) monitor nematode development in different potato growing seasons; *ii*) determine the number of nematode generations completed during a single growing season; *iii*) estimate physiological time required for development of each nematode life stage. A field 100 m long and 10 m wide, initially infested with 13 eggs of *G. rostochiensis*/g soil, was sown to potato cv. Ultimus on 23 February and harvested 3 June 1988, sown again on 23 September 1988 and harvested 6 January 1989, and sown once again on 25 June to be harvested 6 October 1989.

Four potato root samples and four rhizosphere soil samples were collected weekly, beginning at plant emergence from soil until harvest. The roots in each sample were gently washed free of soil, cut into 0.5-cm-long pieces, and mixed; 10-g subsamples were processed according to Coolen's method (1). The nematodes of each developmental stage in two 5-ml aliquants of a 50-ml nematode suspension were counted.

Second-stage juveniles and males were extracted from four 100-cm^3 subsamples of soil using Baermann funnels (potatoes sown in February 1988), or from 500-cm^3 subsamples of soil by Coolen's method (1) (potatoes sown in September 1988 and June 1989). Cysts were extracted with a Fenwick can from 200-g samples of dried soil, separated from organic debris with the ethanol method (9), and counted.

Soil temperature was measured daily at the 20-cm depth to estimate accumulated day degrees above 10 C, which is considered as the basal temperature required for the development of *G. rostochiensis* (8). Soil moisture content was determined at each sampling and expressed to as percentage of soil dry weight (Tables 2, 4, 6).

Potatoes were furrow irrigated whenever required to maintain soil moisture at a level suitable for plant growth.

RESULTS

Hatching: The ability of juveniles in the laboratory to emerge from field-collected cysts increased from February to April, when 84.4% of the eggs that were assayed, hatched. Thereafter, hatchability declined slightly during the winter and remained at 50–60% until the next summer (February) with no evidence of a dormancy period. Most eggs were capable of hatching throughout the year, provided temperature and moisture content of the soil were suitable.

Nematode development: For potatoes sown in summer (February 1988), the first root and soil samples were collected on 24 March, when 120 day degrees above 10 C had accumulated. At that time, most of the nematodes within the roots were second-stage juveniles, 8% were fourth-stage females, 12% were fourth-stage males, and only 2% were adult females (Table 1). With increasing time the population distribution shifted toward adult stages. The first cysts (3 out of 1 325 specimens) were detected on 21 April (358 day degrees after plant invasion) and represented 10% of all specimens at the end of the growing season (June 3).

Large numbers of second-stage juveniles were found in soil samples (286–500/100 cm^3) in March, but numbers rapidily declined during April and were negligible thereafter (Table 2). Males were rare in the soil samples until the end of March but were prevalent during April and then declined until potato harvest. Cysts and eggs per cyst in soil samples (Table 2) remained constant until April 14. New cysts then began to develop and eggs per cyst increased toward the end of the season.

For potato sown in spring (September 1988), the first samples were collected on 7 October, when plants were 2–3 cm high. Most of the nematodes within the roots were second-stage juveniles (947/10 g of roots) by 14 October. As time progressed the distribution of developmental stages shifted toward the later juvenile and adult stages (Table 3). Females were few on 14 October, after an accumulation of 80 day degrees, but were 12% of the total specimens on 11 November. The

Table 1. Life stages of *Globodera rostochiensis* recovered from 10 g of roots from potato sown in summer (February 1988) in central Chile.

Life stage	Sampling date										
	24 Mar	31 Mar	7 Apr	14 Apr	21 Apr	28 Apr	5 May	12 May	19 May	26 May	3 Jun
J2	469	519	765	179	26	27	11	13	10	16	44
J3	225	891	494	346	339	227	77	33	32	14	32
J4	71	204	204	166	176	169	155	38	46	18	51
♂	106	172	254	171	670	438	145	149	80	37	50
♀	19	10	71	59	111	82	103	90	80	102	124
Cyst	0	0	0	0	3	9	6	9	46	31	35
dd[z]	120	187	246	304	358	407	439	467	501	535	570

Each value is the mean of four replications. The coefficient of variation, based on the residual error, is 172%.
[z]dd = Day degrees above 10 C.

Table 2. Dynamics of *Globodera rostochiensis* in a field planted to potato in central Chile in summer (February 1988).

Sampling date	Soil moisture (%)	Juveniles/ 100 cm³ soil	Males/ 100 cm³ soil	Cysts/ 200 g soil	Eggs/ 200 g soil	Eggs/ cyst
24 Mar	—	286	0	62	627	10
31 Mar	—	500	1	72	496	7
7 Apr	7.9	44	1	76	655	7
14 Apr	5.3	73	84	88	941	5
21 Apr	3.7	34	77	83	2 067	10
28 Apr	7.4	5	68	135	5 179	42
5 May	5.1	12	40	120	5 050	43
12 May	5.3	9	7	147	12 733	74
19 May	10.9	7	4	165	20 072	109
26 May	8.9	7	5	161	27 937	178
3 Jun	—	4	0	230	43 201	187

first cysts (2 out of 1 322 specimens) were also detected at that time when 266 day degrees had accumulated. At harvest (6 January) most of the nematodes in the roots were females or cysts. The remaining nematodes (15/10 g of roots) were second-stage juveniles and intermediate stages were not detected.

Analysis of soil samples revealed that an average of 70 second-stage juveniles/ 50 cm³ soil were present at the beginning of October (Table 4). The number of second-stage juveniles remained low until mid December, but increased by the end of the season. Appreciable numbers of males were usually detected in soil samples from 21 October until early December. Numbers of eggs (Table 4) declined until 28 October. The eggs per cyst and cysts per 200 g of soil (Table 4) began to increase concomitantly with the development of new cysts in early November (Table 3) and reached maximum densities during December.

For winter sown (June) potatoes, the first samples were collected on 23 August

Table 3. Life stages of *Globodera rostochiensis* recovered from 10 g of roots from potato sown in spring (September 1988) in central Chile.

Life stage	Sampling date										
	14 Oct	21 Oct	28 Oct	4 Nov	11 Nov	18 Nov	25 Nov	5 Dec	15 Dec	29 Dec	6 Jan
J2	947	158	41	195	66	30	9	12	4	18	15
J3	624	876	518	346	438	99	102	72	51	2	0
J4	268	222	682	479	205	751	189	31	72	6	0
♂	160	387	390	445	453	1 272	173	56	104	2	0
♀	34	82	32	100	158	308	219	40	66	29	4
Cyst	0	0	0	0	2	94	51	5	17	38	13
dd[z]	80	117	163	216	266	331	398	589	693	847	930

Each value is the mean of four replications. The coefficient of variation, based on the residual error, is 168%.
[z]dd = Day degrees above 10 C.

Table 4. Dynamics of *Globodera rostochiensis* in a field planted to potato in central Chile in spring (September 1988).

Sampling date	Soil moisture (%)	Juveniles/ 50 cm³ soil	Males/ 50 cm³ soil	Cysts/ 200 g soil	Eggs/ 200 g soil	Eggs/ cyst
7 Oct	—	67	0	—	—	—
14 Oct	—	74	5	102	651	6
21 Oct	—	17	29	63	555	9
28 Oct	—	44	6	69	102	2
4 Nov	2.2	7	59	187	1 625	9
11 Nov	2.2	3	1	98	4 440	45
18 Nov	2.3	55	15	212	6 640	31
25 Nov	2.4	11	62	—	—	—
5 Dec	12.9	20	58	307	30 430	99
9 Dec	3.8	—	—	252	42 240	168
15 Dec	2.0	77	2	319	13 477	42
29 Dec	5.1	340	0	512	26 060	51
6 Jan	7.8	197	5	314	18 914	60

(46 day degrees after plant invasion). Nematodes in the roots (Table 5) were 80% third-stage juveniles, 6% second-stage, 6% fourth-stage females, and 8% fourth-stage males. Second-stage juveniles represented only 1–3% of the population until 12 September. Males were numerous (19–45%) throughout the study. Females were first found on 29 August. Cysts were detected on 21 September after 125 day degrees had accumulated. Cysts contained well embryonated eggs by 6 October (240 day degrees) when roots were dying.

In the soil, the numbers of cysts and eggs increased after 21 September (Table 6). Increases in the numbers of males preceded the increase in females and cysts (Table 6). Males were numerous from 6 to 12 September. However, after this period the numbers of males declined to non-detectable levels. Numbers

Table 5. Life stages of *Globodera rostochiensis* collected from 10 g of roots from potato sown in winter (June 1989) in central Chile.

Life stage	Sampling date						
	23 Aug	29 Aug	6 Sep	12 Sep	21 Sep	28 Sep	6 Oct
J2	72	24	118	54	0	0	4
J3	1 007	507	1 016	218	8	0	63
J4	82	394	1 214	468	64	17	55
♂	101	608	2 481	842	123	25	106
♀	0	112	710	417	164	80	75
Cyst	0	0	0	0	46	12	75
dd[z]	46	58	75	95	125	160	233

Each value is the mean of four replications. The coefficient of variation, based on residual error, is 182%.
[z]dd = Day degrees above 10 C.

Table 6. Dynamics of *Globodera rostochiensis* in a field planted to potato in central Chile in winter (June 1989).

Sampling date	Soil moisture (%)	Juveniles/ 50 cm^3 soil	Males/ 50 cm^3 soil	Cysts/ 200 g soil	Eggs/ 200 g soil	Eggs/ cyst
23 Aug	11.5	44	0	103	852	8
29 Aug	11.5	92	1	131	1 807	14
6 Sep	9.6	18	89	115	1 102	10
12 Sep	8.5	9	206	107	814	8
21 Sep	2.0	—	—	214	5 671	26
28 Sep	6.8	50	1	133	6 063	46
6 Oct	6.0	0	0	285	22 558	79
24 Oct	5.5	26	0	330	33 354	101

of juveniles declined to non-detectable levels by 6 October (Table 6). A second generation of juveniles was not detected.

In all seasons females usually turned yellow in 1–2 weeks, when they contained few eggs. Well embryonated eggs were observed 2 weeks after cyst formation.

DISCUSSION

Globodera rostochiensis can develop and reproduce throughout the year in Chile. Only a small proportion of the nematodes that invade roots of potatoes sown in summer (February) or winter (June) reaches the cyst stage, indicating that reproduction of the nematode during this period is poor. In contrast, most nematodes infecting spring sown potato develop into cysts by harvest, resulting in greatly increased population densities. Potato can be cultivated during three very different climatic periods in Chile. However, a decline was observed of the second-stage juveniles within the roots of summer sown potatoes and of all of the nematode stages in winter sown potato in late September. Moreover, the lack of further development of second-stage juveniles at the end of the spring potato season indicated that only one generation the potato golden nematode can develop in central Chile on each potato crop. This is similar to population dynamics observed in England (2,6) and in Italy on early potato (3).

Knowledge of the day degrees required by the nematode to develop to the cyst stage could be used to plan harvest time to precede cyst development and thereby minimize reproduction. However, the day degrees above 10 C required for cyst development varied with the growing season; it was least on winter sown potato (125), intermediate on the spring potato (266), and greatest on summer potato (358). The day degrees above 10 C required for development to the cyst stage on spring potato was within 9 day degrees of that required during the same season in Italy (3), while day degree requirement on summer potato (358) was 171 day degrees less than that of the same season but at higher temperatures in Cyprus (8). Thus, although no specific investigation was undertaken to determine the basal temperature for the development of the Chilean population of the nematode, we believe that the magnitude of the observed differences in day degrees required by *G. rostochiensis* to complete its life cycle in different areas and cropping seasons could be attributable to interaction between nematode metabo-

lism and plant physiology, rather than to differences in the basal temperature for development.

In Regions IV and V of Chile, potato is often cultivated repeatedly in the same field, sometimes twice each year. Our results indicate that juveniles emerge from cysts throughout the year and on spring potato can emerge from newly formed cysts. Therefore, only one generation is completed during every crop of the year. Raising two crops in the same field in one year will greatly increase population densities. This effect is particularly important in spring sown potato, where cyst production is the greatest.

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