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LIFE-CYCLE OF *GLOBODERA ROSTOCHIENSIS* ON POTATO IN ITALY

by
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Summary. The life-cycle of *Globodera rostochiensis* was studied outdoors in 1980-1981, at Catania and Bari in a subtropical climate and at Avezzano in a temperate climate. Second stage juveniles (J_2) were able to invade potato roots when temperatures were above 10°C. *G. rostochiensis* developed during the winter months at Catania and Bari, where the first generation was completed by the time the potato tubers were harvested. A second generation was started in Bari, but was not completed; only a few J_2s from the newly formed cysts penetrated potato roots, and high late spring temperatures and lack of suitable potato roots prevented their development. At Avezzano, the long growing potato season and lower temperatures provided more favorable conditions for the development of *G. rostochiensis*, which completed two generations: the first by the end of June and the second by the end of August. At Bari the nematode required 126 and 168 cumulative day-degrees, and at Avezzano 275 and 450, to attain the stages of adult female and cyst, respectively.

The golden nematode, *Globodera rostochiensis* (Woll.) Behrens, is widespread worldwide and occurs in both temperate and tropical countries (Brodie, 1984). The life-cycle of this species is generally influenced by temperature and a different number of generations are often reported on potato (*Solanum tuberosum* L.) in various geographical locations.

In temperate regions the nematode usually completes only one generation (Morris, 1971); a second generation may be initiated but not completed (Jones, 1950; Evans, 1969). In subtropical regions an incomplete second generation occurs more frequently (Philis, 1980). In Italy climatic conditions and the time of planting influence the length of the potato growing season. In the coastal areas of southern Italy potatoes are grown as a winter crop from November to March, while in the mid-region of northern-central Italy potatoes are grown as a summer crop from April/May to September/October. *G. rostochiensis* occurs in several of these potato growing areas of Italy (Marinari Palmisano and Cavalli, 1981).

Nematode damage has been observed to be more serious in the temperate areas where the growing season is longer than in the subtropical areas with its shorter growing season (Greco *et al.*, 1982). The duration of the nematode life-cycle and the number of generations per season in potato growing areas of Italy were unknown. This paper reports the results of experiments conducted in 1980-1981 on the duration of the nematode life-cycle and the number of generations in diverse potato growing areas of Italy.

Materials and Methods

The experiments were conducted in Catania, Sicily, in Bari, Apulia (both with subtropical climate) and in Avezzano, Abruzzi (temperate climate).

In Catania, one-hundred 25-cm-diam clay pots were filled with pasteurized volcanic soil (6% clay, 12% silt, 80% sand, 2% OM). Each pot was inoculated with *G. rostochiensis* cysts from a population collected at Cicciano (Avellino) to give a density of 45 eggs/cm³ of soil. Two potato cv. Spunta tubers were planted in each pot on 29 December 1980. Pots were placed outdoors in a trench 30 cm deep. Pots were irrigated and fertilized as necessary. Four plants were harvested at 7 day intervals from potato emergence to tuber harvest. Nematode life stages at each harvest were determined by counting specimens in 10 g aliquots of roots (Coolen, 1979), cysts in 200 g soil by the Fenwick can and the methods of Seinhorst (1974) and Seinhorst and Den Ouden (1966) and J_2s in 100 cm³ soil by Baermann funnels. Air temperature was recorded during this trial.

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At Bari the soil was a sandy loam (35% clay, 16% silt, 49% sand, OM 2.4%) and was inoculated with cysts to give a density of 15 eggs/cm³ of soil. Potatoes cv. Sieglinde were planted in pots on 20 February 1981. Plants were harvested at 7 day intervals and life stages determined as in the first experiment. Soil temperature at 20 cm depth was recorded and the number of accumulated day-degrees required by the nematode to complete its life-cycle determined by assuming the temperature of 10°C as the minimum thermal threshold for nematode development (Philis, 1980).

In the experiment, at Avezzano, pots with a loamy soil (33% clay, 32% silt, 33% sand, 2% OM) were inoculated with cysts to give a density of 30 eggs/cm³ of soil as previously described. Potatoes cv. Majestic were planted on 5 May 1981. The procedures to determine nematode development were the same as in the previous two experiments. Soil temperature at a depth of 20 cm was recorded and cumulative day-degrees required by the nematode calculated as at Bari.

Results

Because soil and root samples were collected at 7 day intervals, overlapping life stages were detected in all experiments.

In the Catania experiment potatoes emerged in early February 1981. The first J_2s were first detected in the roots on 23 February when the air temperature was about 12°C (Fig. 1). Third stage juveniles (J_3), fourth (J_4), adult males and females were found 6, 14, 21 and 28 days respectively after J_2 root penetration (Fig. 2A). Cyst development began 49 days after J_2 penetration and was completed by tuber harvest at the end of April (Fig. 2A).

The numbers of J_2s in the soil were highest at the time of plant emergence but decreased when adult females were abundant in the roots, and then increased moderately when cysts were formed (Fig. 2B). Because new J_2s appeared only at harvest of the potatoes, they were not able to start a second generation. Cysts were present in the soil throughout the experiment because the initial inoculum consisted of cysts. The numbers of cysts and eggs in the soil did not change substantially during the first three months after J_2 penetration, but increased when new cysts were formed in the roots, and reached a peak at potato harvest. At this time the egg densities were 226/g soil with an average of 196 eggs/cyst (Fig. 2B).

At Bari the first J_2 were observed in the roots in March when potatoes emerged from the soil, a month after planting. Temperatures during this period ranged from 10 to 13°C (Fig. 1). The J_3s and J_4s reached their peak numbers 14 and 21 days, respectively, after J_2 invasion (Fig. 3A). Adult males and females reached their peak 28 and 35 days, respectively, after J_2 invasion, at the end of April (Fig. 3A). The first cysts appeared 29 days after J_2 invasion, just before harvest. Cysts represented 84% of the nematode life-stages (eggs excluded) 63 days after J_2 penetration (Fig. 3A). Heat units required by the first generation to reach adult and cyst stages with embryonated eggs were 126 and 275 cumulative day-degrees, respectively.

The J_2 densities in the soil decreased when adult females appeared in the roots but increased when new cysts were formed (Fig. 3B). The cyst and egg densities in the soil increased at the end of May when the new cysts were abundant in the roots, as observed at Catania (Fig. 3B). The maximum egg density averaged 165/g soil at tuber harvest (Fig. 3B).

In this experiment, the potato tubers were almost mature when the new cysts were formed, and there were few roots suitable for infection by the new J_2s to initiate a second generation. However, to ascertain the occurrence of a second generation, potatoes were planted in 28 pots containing non infested soil on 4 May and plants were infested with 2000 newly formed cysts from the first generation on 19 May. In these pots a few J_2s were found in the roots 7 and 30 days after soil infestation. The J_2s in the roots were not able to reach maturity 40 days after soil infestation because of the high soil temperatures (25°C), which prevailed in Bari during this period.

In the Avezzano experiment J_2s were abundant in potato roots on 21 May, when the potatoes emerged. J_3s and J_4s, females and adult males peaked 10, 18 and 30 days, respectively, after root invasion (Fig. 4A). The numbers of J_2s in the roots decreased when adult fe-

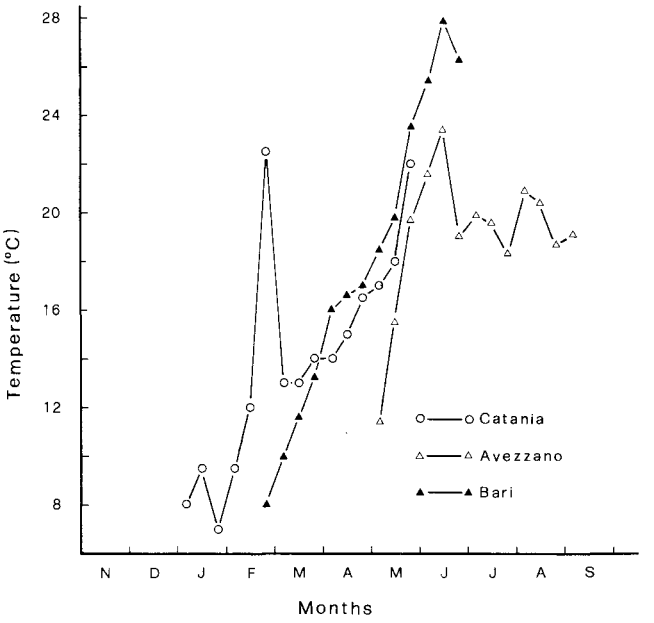

Fig. 1 - Soil temperatures at 20 cm depth recorded at Avezzano and Bari and air temperature at Catania.

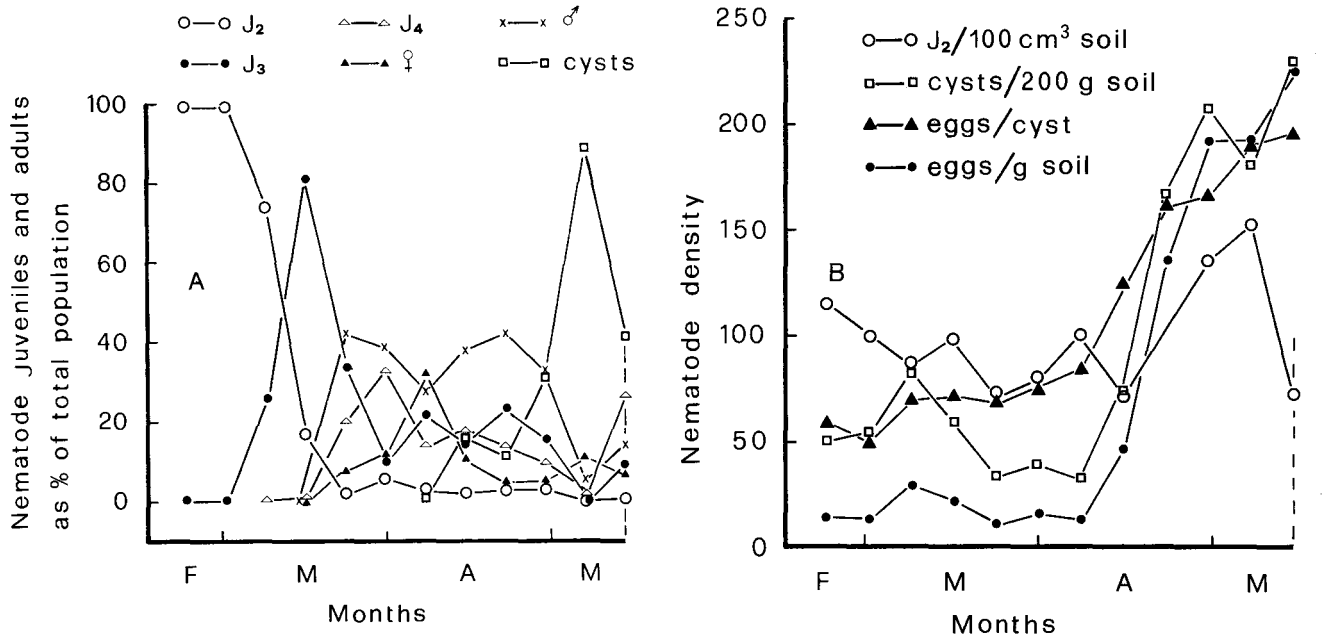

Fig. 2 - *Globodera rostochiensis* life stages detected in cv. Spunta early potato at Catania: root (A) and soil (B) in pots. Dashed line on the abscissa indicates potato harvest time.

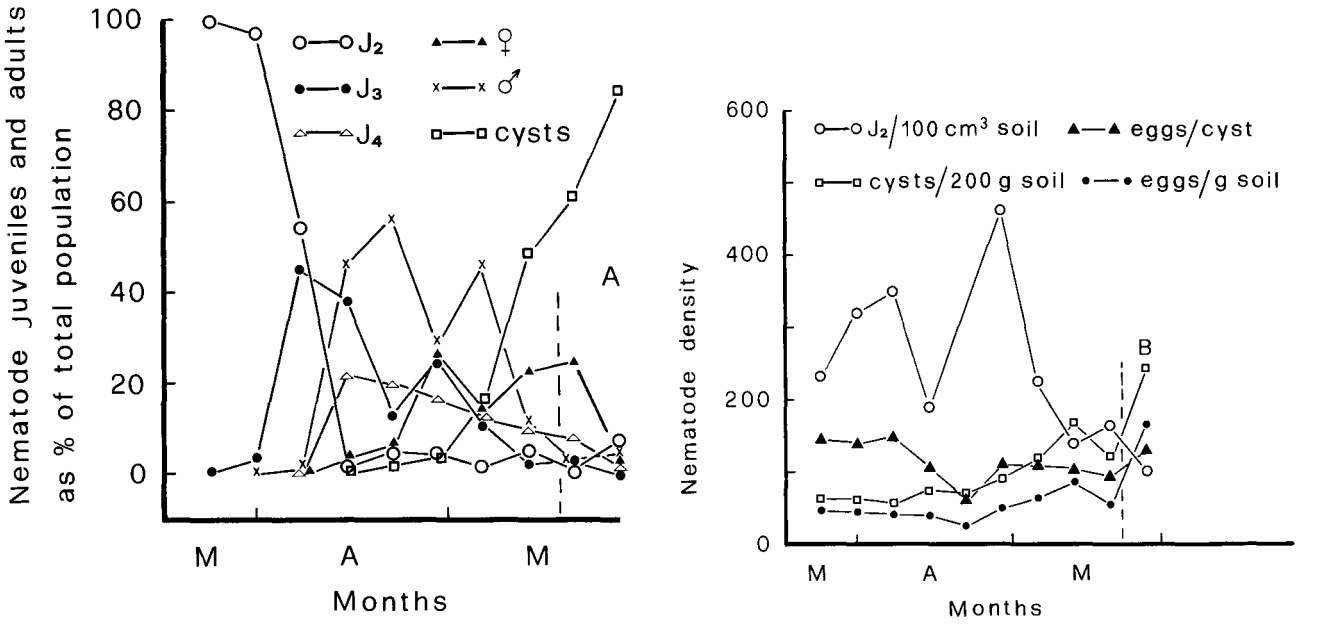

Fig. 3 - *Globodera rostochiensis* life stages detected in cv. Sieglinde early potato at Bari: roots (A) and soil (B) in pots. Dashed line on the abscissa indicates potato harvest time.

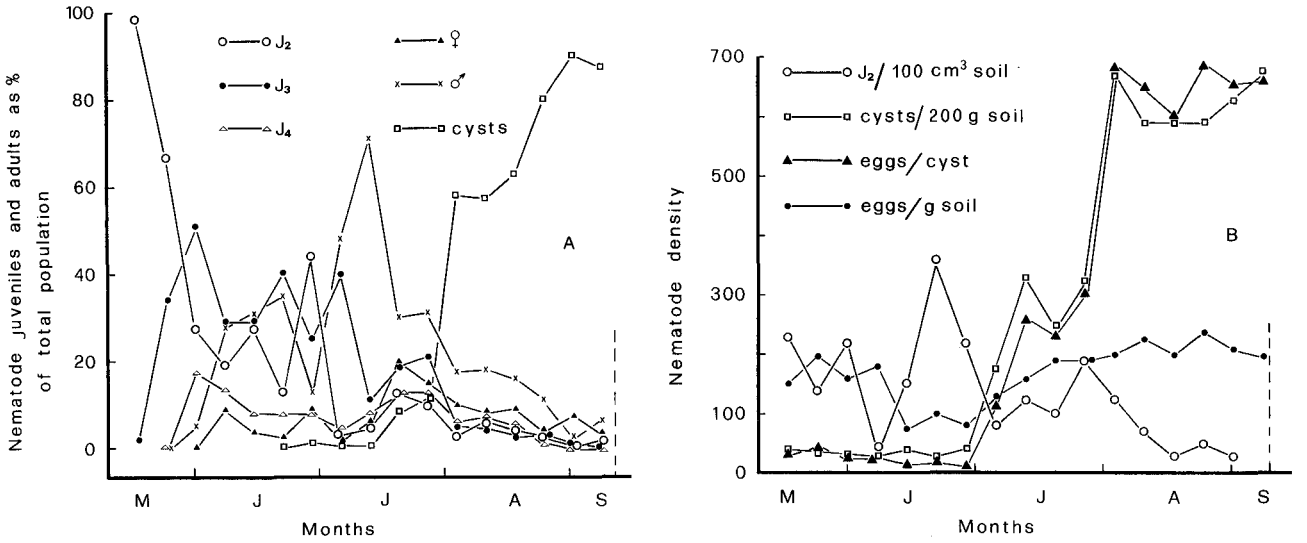

Fig. 4 - *Globodera rostochiensis* life stages of first and second generation detected in cv. Majestic late potato at Avezzano: roots (A) and soil (B) in pots. Dashed line on the abscissa indicates potato harvest time.

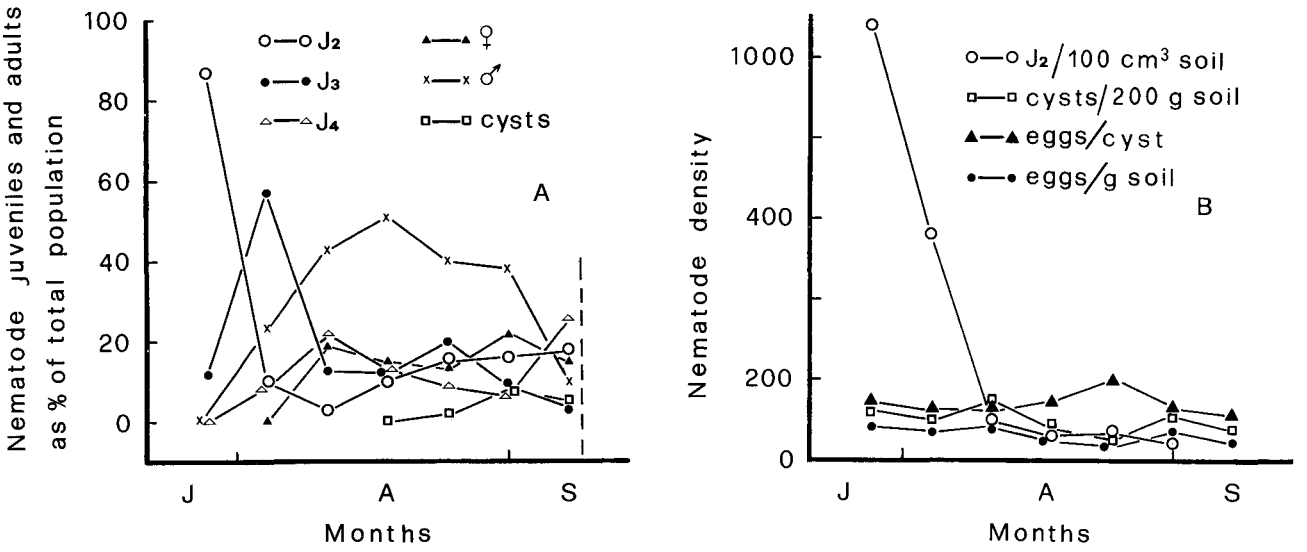

Fig. 5 - *Globodera rostochiensis* life stages of second generation only detected on potato cv. Majestic at Avezzano: roots (A) and soil (B) in pots. Dashed line on the abscissa indicates potato harvest time.

males were formed at the beginning of June and increased slightly when cysts appeared at the end of June (Fig. 4/A). Potato tubers at Avezzano were not yet mature and roots were still receptive to invasion by new J_2s and thus were able to support a second generation. J_3s and J_4s of the second generation increased during the first 10 days of July, while adult males and females of the second generation reached their peak during the second half of July (Fig. 4A). The numbers of second generation cysts peaked in late August/early September (Fig. 4A). First and second generation were present in the roots from July to September. The density of J_2s in the soil was greater than at Bari and Catania, when the new cysts were present in the roots, indicating that egg hatch had occurred in the new cysts (Fig. 4B). Twenty-eight pots with potato plants were infested with 3800 new cysts on 15 July. In these pots the population dynamics differed fron Bari and Catania, as high J_2 densities were observed in the roots 12 days after soil infestation; and only a few J_3s, J_4s and adult males were found at this time (Fig. 5A). Adult females appeared 7 days later and peaked on 10 August, about 26 days after soil infestation and 14 days after J_2 invasion (Fig. 5A). Cysts appeared a week later when tubers were still immature (Fig. 5A).

Twelve days after soil infestation the number of second generation J_2s in the soil of these pots was high, indicating that a large number of eggs hatched in the presence of suitable potato roots (Fig. 5B). However, the J_2 density decreased about 26 days after soil infestation and remained low until the end of the experiment.

In the first generation, 168 cumulative day-degrees were required to reach the stage of adult female and 450 were required to attain the cyst stage with embryonated eggs. In the second generation 200 and 342 cumulative day-degrees, respectively, were required by the nematode to reach these life-stages.

Discussion

Globodera rostochiensis J_2s were able to invade potato roots at approximately 10°C. In Catania and Bari, which had a shorter potato growing season than Avezzano, a second generation was not started because suitable roots were not available. In Avezzano, slower root maturation resulted in a second generation being completed and a large increase in final nematode densities. The high soil temperatures (above 25°C) which occur in southern Italy, may have an adverse effect on nematode development. Similar results were reported in Cyprus (Philis, 1980) where a second generation was started but not completed. The Italian population of *G. rostochiensis* appears to be adversely affected by high temperatures. In some areas of southern Italy potatoes are also grown as a summer crop (July-December). In these crops *G. rostochiensis* would not be able to attack the roots until autumn, when the temperature drops below 25°C, and therefore no substantial damage would be expected and the nematode would be unable to complete its life-cycle. However *G. rostochiensis* populations have been reported to reproduce on potato at temperatures > 27°C in other areas (Meredith, 1976).

At Avezzano, lower temperatures allowed a longer potato growing season than at Bari (and in southern Italy). In these conditions *G. rostochiensis* produced a large number of cysts when the potato tubers were still immature. Under the cooler temperatures of Avezzano J_2s emerged from newly formed cysts, infested potato roots and developed a second generation, thus leading to a higher reproduction rate of the nematode. These findings are in contrast with reports from England where the nematode was not able to complete a second generation (Jones, 1950; Evans, 1969).

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