Globodera rostochiensis
Globodera pallida

Introduction

For many years the potato cyst nematodes were believed to be restricted in distribution to Europe and were thought to have originated there as a mutation from other cyst species. However, discovery in the 1950s of the nematode on a ship from Peru led to surveys in South America and recognition that potato cyst nematodes occurred on native plants in the Andean region of Peru and adjacent countries. The nematode was likely a pest of pre-Inca potato agriculture, with *G. pallida* still present on *Solanum acaule* in terraces uncultivated since ancient times. Today, it is widely accepted that the potato cyst nematodes, like their potato host, originated in the mountains of South America and that they were introduced into Europe with the potato in the 1600s.

Identity

Authority : Wollenweber 1923

Classification

- Kingdom : Animalia
- Phylum : Nemata
- Class : Secernentea
- Order : Tylenchida
- Family : Heteroderidae
- Genus : *Globodera*
- Species : *rostochiensis*
- Synonyms : *H. schachtii* forma *solani* Zimmerman, 1927; *H. schachtii* subsp. *rosto-chiensis (*Wollenweber*) Kemner, 1929; H. (Globodera) rostochiensis* Wollenweber, 1923 *(Skarbilovich,* 1959); *Globodera rostochiensis* (Wollenweber, 1923) Behrens, 1975. *Globodera palllida* (Stone, 1973) Behrens, 1975.
- Common names: Golden nematode of potato; gold plated nematode; golden nematode;cyst nematode; potato cyst eelworm; potato cyst nematode; potato nematode; potato root eelworm; potato root nematode.

Category

- Role : Pest

Signs & Symptoms

At low levels, potato cyst nematodes do little damage, but after years of repeated potato culture, these cyst nematodes may increase in numbers such as to limit production. In some extreme cases, the yields may be less than the seed pieces planted. Field symptoms of heavy infestations are similar among cyst-forming nematodes; first they induce poor growth in spots, followed by increase in size and number of spots. Damage to the root system is typically associated with wilting of plants and stunting. Tomato plants present symptoms similar to potatoes expect that roots may have slight swellings resembling root-knot nematode nodules.

Morphology Stone (1973)

Female: Long considered as one species, the potato cyst nematode includes in fact two distinct species, ***Globodera rostochiensis*** (Fig.) and ***G. pallida***. Characteristics are, body sub-spherical with projecting neck containing the oesophagus and part of the oesophageal glands. Head small with one or two prominent annules merging into deep irregular annulations on the neck. Cuticle over most of spherical part of body with a pattern of reticulate ridges, no lateral incisures, and with a complex four-layered structure. Hexaradiate head skeleton weakly developed. Anterior part of stylet about 50% of total stylet length and sometimes slightly curved; frequently detached from posterior part of stylet in fixed specimens. Stylet knobs of *G. rostochiensis* rounded with marked posterior slope, but pointed anteriorly for *G. pallida*. Mean length of *G. rostochiensis* stylet typically is longer than that of *G. pallida* (27 vs. 23 μ). Stomal lining forming a tube- shaped stylet guide extending back from basal plate of head skeleton for 75% of stylet length. Median oesophageal bulb large, almost circular with well developed crescentic valvular apparatus. Oesophageal glands in a broad lobe frequently displaced forwards by the massively developed paired ovaries. Excretory pore prominent, near base of neck. Hyaline secretion on body surface in neck region frequently obscuring internal organs. Vulva and tail region not offset from body, opposite neck in a slight almost circular depression, the vulval basin. Vulva a transverse slit lying between finely papillated crescentic areas which occupy most of the vulval basin. Anus outside vulval basin, lying in a direction at right angles to axis of vulval slit. Cuticle surface between vulva and anus thrown into an average 22 ridges for *G. rostochiensis*, and 12 for *G. pallida*. Outside anal-vulval area the ridges change to the reticulate pattern which covers the rest of the body surface except the neck. Irregular fine sub-surface punctations are visible over much of the body and extend into the vulval crescents where they may be confused with surface papillae. Colour white on emergence from root cortex, passing through a four-to-six week golden yellow phase due to a development of internal pigment before the cuticle turns dark brown on death of the female, hence vernacular name "golden nematode".

Fig. 1: Globodera rostochiensis
Genome sequencing Center
Nematode.net
http://www.dreamwater.com/biz/mactode

Cyst: Sub-spherical with protruding neck, no protruding vulval cone, circumfenestrate. Vulval region may be intact in new cysts but in older specimens all or part of the vulval basin is lost, forming a single circular fenestra. Vulval bridge, underbridge and other remains of internal genitalia absent. Abullate but small irregular areas of darker pigmentation or local thickening may be present in the vulval region of some cysts, called " vulval bodies" by some authorities. Cuticular pattern of cyst resembles female but may be accentuated. Anus at apex of a V-shaped sub-surface mark in cuticle in some specimens. Sub-crystalline layer absent.

Male: Vermiform with short bluntly rounded tail of variable shape. Body strongly curved on heat relaxation with posterior part twisted 90 to180^0 about longitudinal axis, giving a C or S shape. Cuticle with regular annulations, four incisures in lateral field terminating on tail. Annules cross but not inner incisures. Cuticle has typical tylenchid structure. Head rounded, offset with six to seven annules, large oral disc surrounded by

six small lips, the lateral lips bearing amphid apertures. Head skeleton hexaradiate, heavily sclerotised. Anterior and posterior cephalids at 2nd to 4th and 6th to 9th body annules, respectively. Stylet well developed, with backward sloping basal knobs, anterior portion 45% of total stylet length. Stomal lining forming a tubular lyre-shaped stylet guide extending from basal plate of head skeleton 70% of stylet length. Median oesophageal bulb ellipsoid, with prominent crecentic valvular apparatus. Broad nerve ring encircling oesphagus mid-way between median bulb and intestine; no obvious oesophago-intestinal valve. Oesophageal glands in narrow, ventrally situated lobe terminating near excretory pore, which lies approximately 15% of body length from head. Dorsal gland nucleus prominent, sub-ventral gland nuclei posterior and obscure. Hemizonid two annules long, two to three annules anterior to excretory pore. Hemizonion one annule long, nine to 12 annules posterior to excretory pore. Testis single, about 50% of body length commencing with single cap cell, tapering posteriorly to vas deferens with narrow lumen and glandular walls. Cloacal aperture small with raised lip. Stout arcuate spicules terminating distally in single pointed tips. Small unornamented gubernaculum present, dorsal to spicules about 2 μ thick.

Second-stage larva: Folded four times in egg. Vermiform, tail tapering uniformly to finely rounded terminus. Posterior 1/2 to 2/3rd of tail hyaline. Cuticular annulations distinct, lateral field with four incisures, beginning and terminating with three incisures, and with occasional areolations. Cuticles thicker for first seven to eight body annules, with typical tylenchid structure. Head slightly offset, rounded, with four to six annules. Oral disc ovate surrounded by lateral lips bearing amphid apertures and a pair of narrow sub-median lips dorsally and ventrally, the lips in one or both sub-median pairs sometimes fused. Contours of oral disc and lips oval. Head skeleton heavily sclerotised, hexaradiate, tips of dorsal and ventral radii appearing bifurcate in some specimens. Anterior cephalid at 2nd or 3rd and posterior at 6th to 8th body annules. Stylet well developed with anterior part less than 50% total stylet length. Stylet knobs rounded with slight backward slope for *G. rostocheinsis* and forward projection for *G. pallida.* General arrangement of stoma, oesophagus, median bulb, nerve ring and oesophageal glands as in male. Oesophgeal gland lobe extending ventrally beyond excretory pore for about 35% of body length. Excretory pore approximately 20% of body length behind head. Hemizonid two annules wide one annule anterior to excretory pore. Hemizonian less than one annule wide five to six annules posterior to excretory pore. Four-celled gonadial primordium at approximately 60% body length. Caudalids not reported; a pair of phasmids visible halfway along tail of some specimens. *Globodera* spp. are characterized by round cysts distinguishing them from *Heterodera* spp. which have lemon-shaped cysts with projecting vulval regions. Of the round cyst species *G. pallida* is very similar in both morphology and host range to *G. rostocheinsis*.

Biology & Ecology

Tanned cysts, often with about 500 eggs, are especially persistent in soil; eggs within cysts may survive 28 years where soil type and temperature are ideal, but even under these conditions the percentage of hatch decreases steadily over time. Hatching of freshly developed eggs apparently can occur in water, but, for eggs in diapause, hatching is stimulated by host root diffusates. Root diffusates from both susceptible and resistant cultivars elicit similar responses from eggs and larvae, but the effectiveness of diffusates depends on temperature. Some substances, such as exudates of the fungus, *Rhizoctonia solani*, inhibit hatching of one or sometimes both nematode species. *G. pallida* and *G. rostocheinsis* differ in their response to various hatching agents and their

concentrations. Furthermore, *G. pallida* hatches less freely and is less persistent at high temperatures than *G. rostochiensis*. The importance of root diffusates to hatching and completion of the life cycle of the potato cyst nematodes has generated speculation on possible control measures that would interfere with the role of diffusates.

Hatched second-stage juveniles are attracted to penetrate the hosts just behind the root tip or lateral root. They move through the root and feed on the pericycle, cortex or endodermis, and become sedentary, inducing formation of a large syncytial transfer cell at the feeding site. In resistant reactions, the host response typically involves localized necrosis and thickening of the syncytial walls, perhaps in response to accumulation of lignin which might act as a barrier to the flow of nutrients. Development from hatching to adults takes 38-45 days and females mate within 50 days of root invasion. As the sedentary female enlarges, the tail end bursts through the root, becoming exposed for mating. Whereas females of *Globodera* produce little if any gelatinous matrix, they nevertheless exude a pheromone which attracts males for copulation. Males are motile and develop from sedentary saccate juvenile stages; some suggest that males are more abundant under environmental conditions which may be stressful to the population. Males do not feed; they live up to 10 days inseminating up to 10 females, and each may be inseminated by more than one male. A degree of mating compatibility is conserved between *G. rostochiensis*, *G. pallida*, and many cyst nematodes, so that under laboratory conditions males of one species may inseminate females of another and in many cases hybrids are produced. The possible occurrence of such hybrids in nature may account for the high variability in morphology and host specificity within some species. The potato cyst nematode is amphimitic.

Eggs are retained within the boy of the female and the second-stage juvenile develops within the eggs. Upon death, the body of the female becomes a cyst, changing in colour from white to brown, also passing through a golden or orange phase in *G. rostochiensis*. Juveniles may hatch so that so that more than one generation is completed per year on a crop if temperatures remain favourable or, in the absence of favourable conditions, including a suitable host, they may persist within the cyst for years.

Dispersal/vectors

Movement of infested material through commerce on vehicles and seed material.

Management

Cultural Control

It has been noted that closely related wild forms of potato- *S. tuberosum andeginea, S. vernei*, *S.sucrense*- provide sources of resistance to potato cyst nematodes which have been incorporated into agricultural cultivars. Although resistant cultivars stimulate hatching, roots respond to infection by necrosis and hypersensitive reaction. In resistant cultivars, juveniles often fail to mature to females, whereas production of males apparently is unrestrained. Resistance is based on dominant gene, but females that are homozygously recessive for the virulence gene are capable of reproduction on resistant plants. The effectiveness of resistant cultivars is confounded by pathotypes which overcome resistance, and more such pathotypes may be selected by repeated use of resistant cultivars. Resistant cultivars are primarily useful as a means to maintain an already low population density of potato cyst nematodes below damaging levels, when the cultivars meet other commercial requirements. However, resistant cultivars are not

available for every purpose, and there are not many that are resistant to a range of pathotypes.

Crop rotation might be a promising method of control for nematodes with a narrow host range, such as potato cyst nematodes, except that the infective state is so persistent in the absence of a host. In most of Europe, where populations decrease only about 35%/ year in the absence of a host, a five-to-seven year rotation is needed to minimize damage, but in warmer climates, such as the Mediterranean area, decline is apparently faster and shorter rotations may be effective. Volunteer plants and weed hosts can interfere with effective rotations.

Trap crops, if implemented with caution and careful timing, are a promising method of reducing cyst nematode populations. Sprouted small tubers (with only a small reserve of nutrients) of a susceptible late cultivar are planted and invaded by juveniles. The plants are carefully sampled so that they can be destroyed just before the females produce eggs. Optimally this method can result in a 75% decrease in populations and, combined with chemical treatment of soil, reduction of 90% has been achieved.

Chemical control

Chemical control has the disadvantages of environmental hazard and high cost, but is often effective in managing the potato cyst nematodes, particularly when integrated with other strategies. The withdrawal of DBCP and EDB from general use might have discouraged investment in discovery and registration of new nematicides, yet these are likely to be needed for potato production in the foreseeable future. In some cases, as in the Netherlands, chemical treatment of the soil may be required by the government to keep nematode infestations at low levels nationally and thus to protect the international trade of seed potatoes.

Biological control

The potential for biological control of potato cyst nematodes has been investigated. The Andes area, the putative origin of the potato and the nematodes, is deemed a possible source of natural enemies to the nematodes, and several associated fungi were found in Peru.

Phytosanitary measures

Importation of potatoes is widely regulated by quarantine laws as a first line of defense in managing potato cyst nematodes. In the USA the potato cyst nematodes have successfully been limited to small areas, but under different regulatory conditions containment has been more difficult. For example, in Mexico the potato cyst nematode seems to be a relatively new introduction and spread within the mountainous regions of the country was rapid. Quarantine is confounded by a number of undescribed wild *Globodera* forms on weed hosts; these are morphologically similar to *G. rostocheinsis* and *G. pallida*, but do not reproduce on potato.

Host Notes

The potato cyst nematodes parasitize about 90 species of the large genus, *Solanum*. Many hosts are wild species of South America including close relatives of potato, *S. tuberosum*, with varying levels of resistance, *S. tuberosum andigena*, *S. vernei*, and *S. sucrense*. However, other weed hosts such as *S. sarachoides*, *S. dulcamara*, and *Datura stramonium* in Europe may exacerbate persistence of these nematodes in certain agricultural areas. Although the potato cyst nematodes are not typically found on tobacco, exceptions have been noticed. *Solanum tuberosum* is by far the most important agricultural host of potato cyst nematodes; other agricultural hosts are *S. melongena* (eggplant) and *Lycopersicon esculentum* (tomato).

Distribution

The potato cyst nematode is widespread and is found on farms in Europe, Asia, America, and perhaps New Zealand. The range of the potato cyst nematodes on weed hosts prior to movement by commerce is unknown and commerce may not entirely account for their recent distribution. It is suggested that containment or restricted spread in some regions, such as warmer climates and the USA, probably cannot be wholly attributed to successful quarantine, but rather adverse conditions in areas of introduction. Similarly, *G, rostocheinsis* in northern Mexico probably has not moved into Texas on vehicles and become established in the potato-growing region of Texas, perhaps because of the high soil temperatures. In many regions *G. rostochiensis* and *G.pallida* occur together, but often temperature seems to restrict distribution of one or the other species. In cooler areas such as north of 15.6S, *G. pallida* occurs exclusively, whereas the range of *G. rostochiensis* extends into regions with slightly warmer climates than tolerated by *G. pallida*.

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