CAPS Datasheets provide pest-specific information to support planning and completing early detection surveys.

Globodera rostochiensis

Scientific Name
Globodera rostochiensis (Wollenweber, 1923) Behrens, 1975

Synonym(s):
Heterodera rostochiensis Wollenweber, 1923
Heterodera schachtii rostochiensis Wollenweber, 1923
Heterodera schachtii solani Zimmermann, 1927

Common Name
Golden nematode, golden potato cyst nematode, yellow potato cyst nematode, potato root eelworm

Type of Pest
Nematode

Taxonomic Position
Class: Chromadorea, **Order:** Rhabditida, **Family:** Heteroderidae (Price et al., 2021)

There are five recognized pathotypes of *G. rostochiensis*, which are characterized by their ability to reproduce on *Solanum* host plants with different genes for resistance (Kort et al., 1977).

Figure 1. Yellow/gold females and brown-colored cysts of *Globodera rostochiensis* on potato roots. Photo courtesy of Xiaohong Wang, Robert W. Holley Center of Agriculture and Health, USDA-ARS, Ithaca, NY.

Pest Recognition
This section describes characteristics of the organism and symptoms that will help surveyors recognize possible infestations/infections in the field, select survey sites, and collect symptomatic material. For morphological descriptions, see the Identification/Diagnostic resources on the AMPS pest page on the CAPS Resource and Collaboration website.

Pest Description

Globodera rostochiensis mature females and cysts (toughened cuticle derived from dead females, containing hundreds of eggs) are just visible to the naked eye and can be seen as minute globes (0.59 mm long by 0.51 mm wide) on the root surface of their host

(Fig. 1) (CERIS, 2023; Faggian et al., 2012; Handoo et al., 2012). Young females are white and as they mature and turn into cysts (dead females), they become yellow or gold and then finally brown (Baldwin and Mundo-Ocampo, 1991).

Figure 2. Potato plants infected with *Globodera rostochiensis*. Photo courtesy of Bonsak Hammeraas, Bioforsk - Norwegian Institute for Agricultural and Environmental Research, http://www.bugwood.org/.

Symptoms

The golden potato cyst nematode (*G. rostochiensis*) can cause patches of poor growth within a field, and plants in these patches may exhibit chlorosis and wilting (Fig. 2) (Mwangi et al., 2015). Infected potato plants may have a reduced root system leading to reduced water and nutrient uptake (Trudgill, 1986). Therefore, symptoms may be mistaken for simple nutrient deficiency or other environmental stressors (Jiménez et al., 2000).

Figure 3. Healthy potato variety Désirée on right compared to infected potato on left. Photo courtesy of Christopher Hogger, Swiss Federal Research Station for Agroecology and Agriculture, http://www.bugwood.org/.

Affected plants suffer yield loss, with reductions in both number and size of tubers (Fig. 3) (Bairwa et al., 2021; Trudgill, 1986; Trudgill and Cotes, 1983b). Yield losses can occur even when symptoms aboveground are not obvious (Brown, 1969).

Symptoms in tomato are similar to those seen in potato. Poor growth and wilting may occur. The leaves of heavily infected tomato plants are purplish and lower leaves may die. During the early stages of attack, roots may slightly swell. This could be confused with galling caused by root-knot nematodes (Spears, 1968).

Easily Mistaken Species

This species can be confused with other *Globodera* species, particularly *G. pallida, G. tabacum,* and *G. ellingtonae*. *Globodera pallida,* a serious pest of potato, has been introduced to the United States and is under official control in parts of Idaho (USDA-APHIS-PPQ, 2022b). *Globodera tabacum* occurs in the United States and primarily infects tobacco (Skantar et al., 2007). Most studies report that *G. tabacum* does not reproduce on potato, although there may be limited exceptions (Baldwin and Mundo-Ocampo, 1991). *Globodera ellingtonae* has been reported to infect potato in Idaho and Oregon (Handoo et al., 2012), but it is not known to cause the severe yield loss in potato that has been observed with *G. rostochiensis* and *G. pallida* (Zasada et al., 2019).

Globodera rostochiensis and *G. pallida* can be differentiated from each other if the female is at the appropriate stage. As *G. rostochiensis* females mature and die, becoming cysts, they turn from white to yellow/gold and then brown, whereas *G. pallida* changes from white directly to brown (Fig. 4) (Baldwin and Mundo-Ocampo, 1991). Otherwise, distinguishing between *Globodera* species will require detailed morphological or DNA-based analysis.

Figure 4. Comparison of *Globodera rostochiensis* (top) and *Globodera pallida* (bottom). Females of *G. pallida* turn from white/cream directly to brown cysts whereas *G. rostochiensis* females change from white to yellow/gold before they turn brown. Photo courtesy of Ulrich Zunke, University of Hamburg, http://www.bugwood.org/.

Commonly Encountered Non-targets

The approved method to survey for this nematode is soil sampling or root tissue sampling. Due to their morphological similarity, other *Globodera* species that may be captured in the United States using the approved survey method and mistaken for *G. rostochiensis* include *G. ellingtonae, G. pallida*, and *G. tabacum* (Baldwin and Mundo-Ocampo, 1991; CERIS, 2023; Handoo et al., 2012).

Biology and Ecology

Globodera rostochiensis overwinters as embryonated eggs (eggs containing fully developed juveniles/larvae) inside a cyst formed from the toughened cuticle derived from dead females (Fig. 5) (Evans and Stone, 1977). Each cyst contains between 200 and 500 eggs (Evans and Stone, 1977). After host plants emerge, root secretions stimulate the eggs to rapidly hatch into second stage juveniles (J2s), with hatch rates peaking between two and five weeks after plant emergence (Devine and Jones, 2003; Ryan and Devine, 2005). Hatching also occurs in the absence of hosts, but at a much lower level (Devine and Jones, 2003). Optimum hatching temperature is approximately

68°F (Kaczmarek et al., 2014). The first J2s that hatch puncture the posterior end of the cyst with their stylets (a hollow mouth spear), allowing the juveniles to emerge from the cyst (Baldwin and Mundo-Ocampo, 1991). J2s move short distances through the soil searching for host roots and will invade host roots when soil temperatures are at least 50°F (Greco et al., 1988). Infections can occur at temperatures as high as 85°F, but juveniles will die if this temperature is sustained longer than five days (Ferris, 1957). J2s penetrate, move through, and feed on the root. They undergo three molts before reaching the adult stage (Price et al., 2021).

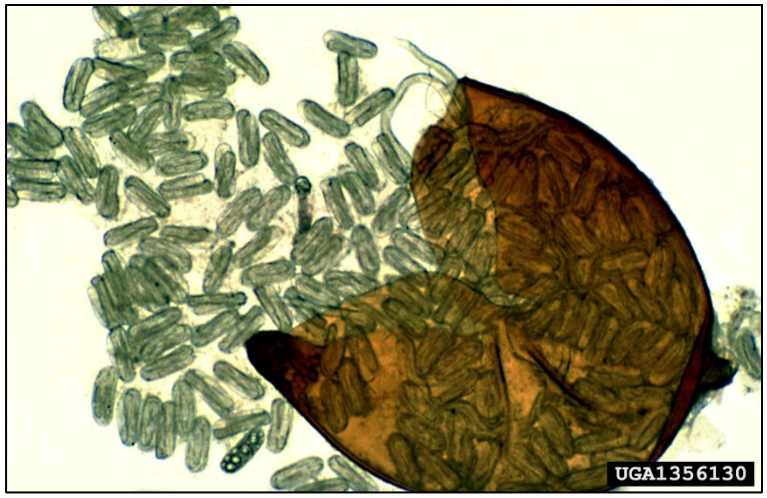

Figure 5. Crushed cyst of *Globodera rostochiensis* with many eggs and juveniles. Photo courtesy of Xiaohong Wang, Robert W. Holley Center of Agriculture and Health, USDA-ARS, Ithaca, NY.

Females establish a permanent feeding site in the root and become sedentary and swollen (Baldwin and Mundo-Ocampo, 1991). Enlarged females burst through the root to expose their posterior body portion, facilitating mating (Baldwin and Mundo-Ocampo, 1991). Adult males are wormlike and leave the roots to find and mate with exposed females in the soil (Price et al., 2021). Mating occurs between 20 and 50 days of J2 root invasion (Evans, 1970). The females retain the fertilized eggs within their bodies and, when they die, become cysts (Baldwin and Mundo-Ocampo, 1991; Evans and Stone, 1977; Jones et al., 2017). Cysts can remain attached to the roots or detach from the root and remain in the soil (Evans and Stone, 1977; Niragire et al., 2020).

The life cycle takes a minimum of 38 to 48 days, from embryonated egg to embryonated egg (Chitwood and Buhrer, 1946). In the absence of a host, eggs within a cyst can remain viable in the soil as a dormant stage (diapaused embryonated eggs in a cyst) for over 25 years (Grainger, 1964; Greco et al., 1988; Mimee et al., 2015; Turner, 1996). *Globodera rostochiensis* produces one generation per crop/year in New York (USDA-APHIS-PPQ, 2008).

Known Hosts

The most important agricultural host of *G. rostochiensis* is *Solanum tuberosum* (potato) (Baldwin and Mundo-Ocampo, 1991), although it also infects *S. lycopersicum* (tomato) (Vovlas and Grammatikaki, 1989).

The host list below includes cultivated and wild plants that 1) are infected or infested by the pest under natural conditions, 2) are frequently described as major, primary, or preferred hosts, and 3) have primary evidence for feeding and damage documented in *the literature. Plants are highlighted in bold if they are commercially produced and the pest causes economically significant damage.*

<u>Preferred hosts</u>
Solanum tuberosum **(potato)[*] (Greco et al., 1993)**

Other members of Solanaceae can allow multiplication of *G. rostochiensis* and may be found as weeds in agricultural fields (Mimee et al., 2014). These may be a target for survey.

Pest Importance

The golden nematode, *G. rostochiensis*, is considered one of the most important nematode pests of potato where it occurs (Sun et al., 2007). Yield losses have been estimated at 90% or more where soils are heavily contaminated with this species (Greco and Moreno L., 1992b).The amount of damage (especially reduced tuber weight) caused by *G. rostochiensis* is correlated to the number of nematode eggs per soil unit (Seinhorst, 1982) and yields may be reduced even when no symptoms are seen aboveground (Brown, 1969). Yield loss estimates range from .81 to 3.2 tons/acre for every 567 eggs/oz of soil (Brown, 1969; Brown and Sykes, 1983; Philis, 1991; Whitehead et al., 1984). Yield losses are also dependent on potato cultivar, environmental conditions, and agronomic practices (Bélair et al., 2016; Kaczmarek et al., 2014; Trudgill and Cotes, 1983a). Twining et al., (2009) reports that 4% of potato yield for processing and fresh market has been lost annually in the United Kingdom, resulting in losses of ~$33 million per year. In Kenya, potato yield losses due to cyst nematodes were estimated at $127 million annually in 2016 and 2017 (Mburu et al., 2020).

Globodera rostochiensis poses a serious threat to American domestic and international trade in potatoes and any agricultural commodity shipped from the regulated areas that carries soil, such as nursery, turf, root and tuber crops (Dandurand et al., 2019; Hodda and Cook, 2009; Prasad, 2008). Approximately 20 percent of potatoes grown in the United States are exported, with a value of $1.88 billion in 2021 (Knudson and Miller, 2023). Some of the largest export markets of U.S. potatoes are Canada, Mexico, and Japan, and *G. rostochiensis* is considered a quarantine pest in these countries (DOF, 2017; Government of Canada, 2023; Knudson and Miller, 2023; Plant Protection Station, 2023). The National Potato Council estimates that farm production of potatoes in the U.S. was valued at $10.8 billion in 2021 (Knudson and Miller, 2023).

Globodera rostochiensis is a PPQ program pest and is under official control with regulations to prevent its spread (USDA-APHIS-PPQ, 2023) and is considered a pest of concern on the EPPO A2 list (EPPO, 2022).

Known Vectors (or associated insects)

[*] Hosts with known U.S. distribution

This species is not a known vector, is not known to be vectored, and does not have any associated organisms. However, this species was recently indicated to be associated with a RNA virus (Ruark et al., 2018). Moreover, injury from nematode feeding can increase infections and disease severity caused by fungi such as *Rhizoctonia solani* and *Verticillium dahliae* (Back et al., 2006; Evans, 1987).

Known Distribution

Globodera rostochiensis is native to the Andes mountains and has since spread to most of the potato-producing regions throughout the world (Greco and Moreno L., 1992b).

Africa: Algeria, Egypt, Kenya, Rwanda, South Africa, Tunisia, and Uganda; **Asia:** China, India, Indonesia, Japan, Philippines, Sri Lanka, Tajikistan, and Turkey; **Central America:** Panama; **Europe:** Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece (including Crete), Hungary, Iceland, Ireland, Italy (including Sicily), Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal (including Azores and Madeira), Romania, Russia, Serbia, Spain (including Balearic Islands and Canary Islands), Slovakia, Slovenia, Sweden, Switzerland, Ukraine, and United Kingdom (England, Northern Ireland, Scotland, Channel Islands, and Falkland Islands); **Middle East:** Armenia; Lebanon, Iran, Oman, Pakistan; **North America:** United States (New York), Canada, and Mexico; **Oceania:** Australia and New Zealand; **South America:** Bolivia, Chile, Colombia, Ecuador, Peru, and Venezuela (Andrés et al., 2006; Bačić, 2012; Baeza, 1972; Bélair et al., 2016; Bendezu et al., 1998a; Bendezu et al., 1998b; Brodie, 1995; Cortada et al., 2020; Da Cunha et al., 2004; Dao and González, 1971; Desgarennes et al., 2018; Devine et al., 1999; Douda et al., 2014; Eglitis and Kaktynya, 1980; Elekes-Kaminszky et al., 2004; Enneli and Ozturk, 1995; EPPO, 2023a, 2023b, 2023c, 2023d; Eyres et al., 2005; Gitty and Maafi, 2009; Gonzalez and Phillips, 1996; Gorgadze et al., 2019; Greco et al., 1993; Greco and Moreno L., 1992b; Grubišić et al., 2007; Heikkilä and Tiilikkala, 1992; Hlaoua et al., 2008; Ibrahim et al., 2017; Inácio et al., 2020; Indarti et al., 2004; IPPC, 2013; Iskandaryan and Arutyunyan, 1990; Jogaitė et al., 2007; Jovani, 1994; Knoetze et al., 2006; Koliopanos, 1976; Koppel and Tsahkna, 1998; Lamberti et al., 1987; Lombardo et al., 2011; Manduric and Andersson, 2003; Mani et al., 1993; Marshall, 1993; More no da Cunha et al., 2000; Morgan-Jones and Rodríguez-Kábana, 1986; Munir et al., 2004; Mwangi et al., 2015; Niragire et al., 2020; Oro et al., 2014; Ostojic et al., 2011; Oydvin, 1978; Pedroche et al., 2013; Peng et al., 2022; Philis, 1991; Ponin et al., 1978; Potoček et al., 1991; Przetakiewicz, 2013; Pylypenko et al., 2005; Rohini, 1990; Ruthes and Dahlin, 2022; Salazar and Ritter, 1992; Širca and Urek, 2004; Subbotin et al., 1999; Tarte, 1968; Tirchi et al., 2016; Trifonova, 2000; Vovlas and Grammatikaki, 1989; Yamada et al., 1972; Yu and Coosemans, 1998; Zaheer et al., 1993).

Globodera rostochiensis has been previously eradicated from Israel (EPPO, 1987) and in Delaware in the United States (USDA-APHIS-PPQ, 2008). There are also miscellaneous records from Libya, Faroe Islands, and Norfolk Island, but we could not access primary data.

Status of infestation in the United States (October 2022)

Globodera rostochiensis was discovered in 1941 on Long Island, New York. It was later confirmed in the New York counties of Cayuga, Livingston, Nassau, Orleans, Seneca, Steuben, Suffolk, and Wayne, and it is under official control in these counties (USDA-APHIS-PPQ, 2008, 2022a). *Globodera rostochiensis* was also found in New Castle County, Delaware in 1968, but no cysts were recovered in subsequent surveys (CDFA, 2021; Spears, 1969). It was eradicated and removed from quarantine in 1970 (USDA-APHIS-PPQ, 2008). The primary population of *G. rostochiensis* in New York is pathotype Ro1. A virulent pathotype, Ro2, that can reproduce on potato varieties that are resistant to Ro1, has also been found in a few fields in New York since 1995 (Dandurand et al., 2019; USDA-APHIS-PPQ, 2008; Wang et al., 2021). Quarantine measures and crop rotations with non-hosts and resistant potato varieties have successfully controlled and contained *G. rostochiensis* where it occurs in New York. Therefore, there are no current impacts to interstate or international trade, except for survey and certification requirements (USDA-APHIS-PPQ, 2023).

Pathway

The J2s of potato cyst nematodes (*G. rostochiensis* and *G. pallida*) do not move long distances by themselves in the soil. However, all life stages can be dispersed through passive transport via agricultural tools, workers, animals, wind, soil, irrigation water, and propagative material (Picard et al., 2004; Schomaker and Been, 1999). In the absence of a suitable host, cysts remaining in infested soil for over 25 years still contained viable eggs (Grainger, 1964; Turner, 1996).

It is thought that potato cyst nematodes were introduced to Europe along with potato tubers from South America. From Europe, they were further spread to potato-growing regions in over 50 countries through infected seed pieces and contaminated machinery (Baldwin and Mundo-Ocampo, 1991; Brodie and Mai, 1989).

Use the PPQ Commodity Import and Export manuals listed below to determine 1) if host plants or material are allowed to enter the United States from countries where the organism is present and 2) what phytosanitary measures (e.g., inspections, phytosanitary certificates, post entry quarantines, mandatory treatments) are in use. These manuals are updated regularly.

Agricultural Commodity Import Requirements(ACIR) manual: ACIR provides a single source to search for and retrieve entry requirements for imported commodities. https://acir.aphis.usda.gov/s/

Plants for Planting Manual: This manual is a resource for regulating imported plants or plant parts for propagation, including buds, bulbs, corms, cuttings, layers, pollen, scions, seeds, tissue, tubers, and like structures.
https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/plants_for_planting.pdf

Treatment Manual: This manual provides information about treatments applied to imported and domestic commodities to limit the movement of agricultural pests into or within the United States.
https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

Potential Distribution within the United States

Based on where *G. rostochiensis* is known to occur in the world and comparing those climates with Global Plant Hardiness Zones, we expect that *G. rostochiensis* could establish in plant hardiness zones 3-10 (Bolsheshapova et al., 2014; Greco and Moreno L., 1992a; Takeuchi et al., 2018). As of 2023 in the United States, *Globodera rostochiensis* is only found in certain counties of New York, specifically Cayuga, Livingston, Nassau, Orleans, Seneca, Steuben, Suffolk, and Wayne (USDA-APHIS-PPQ, 2022a). It is not considered widely distributed throughout the United States (USDA-APHIS-PPQ, 2023).

The states with the highest potato production are most likely to be impacted by *G. rostochiensis*. As measured in US dollars, the largest producers of potatoes are as follows: Idaho, Washington, Wisconsin, Colorado, California, North Dakota, Oregon, Maine, Minnesota, Michigan, Nebraska, Florida, and Texas (NASS, 2023). However, potatoes are cultivated in every state, and there are known experimental hosts of *G. rostochiensis* throughout the United States, so this nematode could establish in any state. State surveyors should determine the suitability of a survey for *G. rostochiensis* in their local areas.

Survey and Key Diagnostics

Approved Methods for Pest Surveillance*:

For the current approved methods and guidance for survey and identification, see Approved Methods for Pest Surveillance (AMPS) pest page on the CAPS Resource and Collaboration website, at https://approvedmethods.ceris.purdue.edu/.

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Versions

2011: Datasheet completed (Version 1)

July, 2014: Added additional references that were recommended by Andrea Skantar. Updated the **Key Diagnostic** and **Easily Confused Species** sections to reflect these new references (Version 2).

August, 2015: Added Kenya to **Known Distribution** section (Version 2.1).

April, 2024: Converted to new template with comprehensive revision of all sections. Updated class and order in **Taxonomic Position**. Changed references to cite available primary data and reworded information accordingly. Reduced technical language. Added Rwanda, Uganda, China, Georgia, Italy (including Sicily), Azores, Slovenia, Northern Ireland, Scotland, and Falkland Islands to **Known Distribution** and removed Sierra Leone and Liechtenstein. Updated statistics and information throughout the document where applicable. (Version 3)

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