EPPO Datasheet: *Globodera rostochiensis*

Last updated: 2022-10-12

IDENTITY

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Preferred name: *Globodera rostochiensis*
Authority: (Wollenweber) Behrens
Taxonomic position: Animalia: Nematoda: Chromadorea: Rhabditida: Heteroderidae
Other scientific names: *Globodera vulgaris* Xu, Yang, Xie, He, Chen, Pan & Xie, *Heterodera rostochiensis* Wollenweber, *Heterodera schachtii rostochiensis* Wollenweber
Common names: golden nematode, golden potato nematode, potato cyst nematode, yellow potato cyst nematode
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EPPO Categorization: A2 list
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EU Categorization: A2 Quarantine pest (Annex II B)
EPPO Code: HETDRO

Notes on taxonomy and nomenclature

The first report by Kühn (1881) of a cyst nematode associated with potato plants was considered to be *Heterodera schachtii*, the only cyst nematode which was known at this time on potato. Later, when potato cyst nematodes were more widely detected in Europe, many concluded that some *H. schachtii* populations were specialized on potato. Wollenweber (1923) recognized morphological differences between nematodes parasitizing potato and those on sugar beet and described *H. rostochiensis* as a new cyst nematode parasitizing potato (Subbotin *et al.*, 2010). In 1973, a new species of potato cyst nematode (*Heterodera pallida*) was described (Stone, 1973a). Before then, most records and technical data refer to *H. rostochiensis sensu lato*, which included both species, so it is not always possible to determine which species was referred to in earlier publications.

HOSTS

The host range of *Globodera rostochiensis* is limited to plants of the Solanaceae family. Potato (*Solanum tuberosum*) is by far the most important host crop. On tomato (*S. lycopersicum*) and eggplant (*S. melongena*), no economic damage has been reported (EFSA, 2019). Over 130 *Solanum* spp., including their hybrids and weeds, have been identified as potential host plants, as well as a few other species of *Datura, Hyoscyamus, Lycopersicon, Nicotiana, Physalis, Physochlaina, Salpiglossis* and *Saracha*, all belonging to the Solanaceae family (Sullivan *et al*., 2007).

Both *G. rostochiensis* and *G. pallida* have several different pathotypes (Kort, 1974). The pathotypes are characterized by the ability of the population to multiply on certain tuberous *Solanum* clones and hybrids used in breeding, with a mixture of qualitative and quantitative resistances. Some of these pathotypes are recognized by their almost total inability to multiply on specific potato cultivars (single-gene resistance); for example, commonly grown resistant potato cultivars (based on gene H1 deriving from clones of *S. tuberosum* subsp. *andigena*) are resistant to pathotype Ro1 and Ro4 of *G. rostochiensis* only. Other pathotypes show different levels of ability to multiply on different cultivars; the testing of this form of resistance is discussed by Mugniéry *et al*. (1989). In Europe, Kort *et al.* (1977) proposed a scheme with five *G. rostochiensis* pathotypes (Ro1-Ro5) and with three *G. pallida* pathotypes (Pa1-Pa3). In South America, Canto Saenz & de Scurrah (1977) developed another scheme, recognizing more pathotypes.

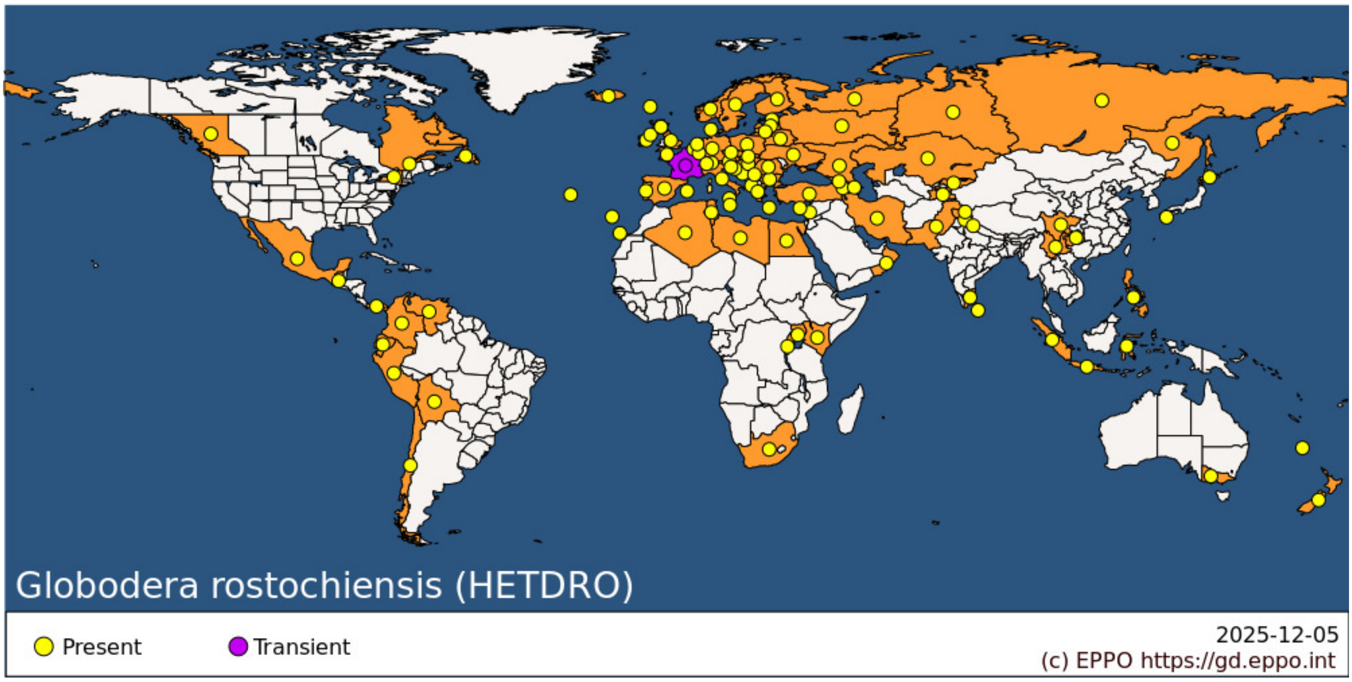
Despite general acceptance, both pathotype schemes are considered insufficient for testing potato varieties for resistance to potato cyst nematodes. In Europe, it is generally accepted that only Pa1 and Ro1 are clearly separable pathotypes and the others are seen as overlapping populations. Nevertheless, the ‘European’ scheme is still used in many countries as it is the only available tool for the selection and assessment of PCN resistant potato cultivars as for example in EPPO Standard PM 3/68 (3) *Testing of potato varieties to assess resistance to* Globodera rostochiensis *and* Globodera pallida (2021). In practice, field populations often contain mixtures of species which makes separation or characterization very difficult.

Host list: *Solanum demissum*, *Solanum lycopersicum*, *Solanum melongena*, *Solanum tuberosum*

GEOGRAPHICAL DISTRIBUTION

The area of origin of the two species *G. pallida* and *G. rostochiensis* is in the Andes Mountains in South America from where they were introduced to Europe with potatoes, probably in the mid-19th century. From there, they were spread with seed potatoes to other areas. The present distribution covers temperate zones down to sea level and in the tropics at higher altitudes. In these areas, distribution is linked with that of the potato crop.

Research on microsatellite markers consistently observed high genetic diversity in Bolivian *G. rostochiensis* populations, the postulated region of origin (Boucher *et al.*, 2013). Analysis of the mtDNA haplotype distribution of PCN populations from all over the world (Subbotin *et al*., 2020) confirmed this, and for each two species, *G. pallida* and *G. rostochiensis*, a different centre of origin was suggested in the Andes.



EPPO Region: Albania, Algeria, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France (mainland), Georgia, Germany, Greece (mainland, Kriti), Hungary, Ireland, Italy (mainland, Sicilia), Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal (mainland, Azores, Madeira), Romania, Russian Federation (the) (Central Russia, Eastern Siberia, Far East, Northern Russia, Southern Russia, Western Siberia), Serbia, Slovakia, Slovenia, Spain (mainland, Islas Baleares, Islas Canárias), Sweden, Switzerland, Tunisia, Türkiye, Ukraine, United Kingdom (Channel Islands, England, Northern Ireland, Scotland)
Africa: Algeria, Egypt, Kenya, Libya, Rwanda, South Africa, Tunisia, Uganda
Asia: China (Guizhou, Sichuan, Yunnan), India (Himachal Pradesh, Jammu & Kashmir, Tamil Nadu, Uttarakhand), Indonesia (Java, Sulawesi, Sumatra), Iran, Islamic Republic of, Japan (Hokkaido, Kyushu), Kazakhstan, Kyrgyzstan, Lebanon, Oman, Pakistan, Philippines, Sri Lanka, Tajikistan
North America: Canada (British Columbia, Newfoundland, Québec), Mexico, United States of America (New York)
Central America and Caribbean: Guatemala, Panama
South America: Bolivia, Chile, Colombia, Ecuador, Peru, Venezuela
Oceania: Australia (Victoria), New Zealand, Norfolk Island

BIOLOGY

G. rostochiensis is a sedentary endoparasite. Second-stage juveniles (J2) hatch from eggs within cysts in the soil, under stimulus from host root exudates of Solanaceae, and penetrate the root behind the growing root tip and move into the cortical region. Reaching the pericycle, the J2 penetrates a single cell and injects secretions which induce the formation of a large, multinucleate feeding structure, a syncytium, formed by dissolution of adjacent cell walls. The nematode remains here for the rest of its development, as it passes through two more juvenile stages to become either male or female. Females swell and break through the root surface but remain attached. The vermiform males leave the root and are attracted to females that exude sex pheromones. Many males may surround each female and multiple matings occur. Males live only a few days. After copulation the females remain on the roots while 200-500 eggs develop within them. Females are white when they protrude from the root surface, but later pass through a golden yellow phase lasting 4-6 weeks. When they die and mature into cysts, their skin hardens and turns brown to become a protective cover around the eggs within. At this point they generally drop from the surface of the root into the soil. In temperate climate regions, *G. rostochiensis* usually has one generation per year, however, several studies also describe the occurrence of a second generation, without the ‘obligatory’ diapause, such as Mwangi *et al.* (2021) in Kenya. The life cycle is completed in 40-60 days (Stelter, 1971; Stone, 1973b; Jones & Jones, 1974, Subbotin *et al.*, 2010).

Soil temperature has an influence on the development of *G. rostochiensis*. It is adapted to develop at warmer temperatures than *G. pallida*. Optimum hatching of the J2 from the eggs occurs between 15-27°C, hatching starts at 11°C (Kaczmarek *et al.*, 2014), and optimum reproduction is between 17.5-22.5°C (Jones *et al.*, 2017). *G. rostochiensis* hatches faster than *G. pallida*, over a shorter period and has overall a lower amount of hatching than *G. pallida* (Den Nijs and Lock, 1992; Kaczmarek *et al.*, 2014).

Cysts can remain dormant for many years (20 years or more) in the absence of solanaceous hosts, whereas second-stage juveniles have a much shorter survival time (weeks) when no hosts are present. For many years, a natural decline of 30-35% per year was assumed. Recently, it has become known that the type of soil affects this decrease: In sandy and peaty soils, the average decline in the first year after potato cultivation is much higher than in marine clay and loamy soils (69% vs 26%). In marine clay and loamy soils *G. rostochiensis* populations also declined slower than *G. pallida* (Been *et al.*, 2019).

DETECTION AND IDENTIFICATION

Symptoms

The symptoms caused by *G. rostochiensis* are not specific. Patches of poor growth occur generally in the crop, sometimes with stunting, yellowing, wilting or death of the foliage. The tuber size of infested plants can be reduced, even with minor symptoms on the foliage. Roots display extensive branching, causing more adherence of the soil to the root system. In case of heavy infestation, the crop dies prematurely.

Morphology

Second-stage juveniles are vermiform and motile, 468 (425 – 505) µm long, having a well-developed stylet 21.8 (19-23) µm with small and rounded knobs of 3-4 µm width sometimes a bit anteriorly flattened and a pointed tail. Males are similar in general appearance, on average about 1200 µm long with a short and bluntly rounded tail terminus. Females are white or creamy coloured and spherical with a projecting neck, diameter approximately 445 µm (Stone, 1973a; 1973b, Brzeski, 1998). The cysts are smoothly rounded, no terminal cone, with a tanned skin. Vulval region consists of a single circumfenestration. The number of cuticular ridges between anus and vulva ranges from 16 - 31, generally higher than 14. Granek’s ratio is 1.3 - 9.5, generally higher than 3 (Golden & Ellington, 1972; Baldwin & Mundo-Ocampo, 1991; Flemming and Powers, 1998).

Morphological identification of the three similar PCN species; *G. pallida*, *G. rostochiensis* and *G. ellingtonae* can only be done by well-trained persons, considering the high intraspecific variation and overlap between the species. Morphological as well as morphometric characteristics, including the number of cuticular ridges between anus and fenestra, Granek’s ratio, stylet length and shape of stylet knobs, need to be examined. *G. rostochiensis* differs from *G. pallida* as it has yellow coloured rather than white females, a shorter J2 stylet length (22 vs 24 µm), narrower stylet knob (3-4 vs. 4-5 µm wide) and a different stylet knob shape (small and rounded rather than robust and square-hooked).

Detection and inspection methods

Specific guidance on the sampling of soil and potato tubers is given in the EPPO Standards PM 9/26 *National regulatory control system for* Globodera pallida *and* Globodera rostochiensis (EPPO, 2018), PM 3/71 *General crop inspection procedure for potatoes* (EPPO, 2007) and PM 3/75 Globodera rostochiensis *and* Globodera pallida: *sampling soil attached to ware potato tubers for detection prior to export and at import* (EPPO, 2014). Detection of the young cysts by lifting potato plants is only possible for a short period when females mature into cysts. When inspected too late, cysts can easily fall off when lifting the plants. Females and young cysts are just visible to the naked eye and look like tiny yellow or brown pin-heads on the root surface. Low-level infestations are very difficult to detect visually, they cause no patchy growth of the potato crop. Sufficient soil sampling in a systematic manner is necessary to ensure that no infestation is present in the field. In addition, for detection or surveys, sampling of tare soil or the soil brushed off from the potatoes can also be done (Viaene *et al*., 2016).

Nematode extraction (Southey, 1986) and identification should be carried out according to EPPO Standards PM 7/119 (EPPO, 2013) and PM 7/40 *Diagnostic protocol for* Globodera rostochiensis *and* G. pallida (EPPO, 2022) providing all relevant morphological information and molecular methods for an accurate identification. Combining morphological and molecular methods is highly recommended, especially when new introductions are suspected. Molecular methods as PCR, real-time PCR, HTS or Sanger sequencing must be used intelligently, taking into account the distinctive features of the test or method. For high-throughput diagnosis it is possible to use the real-time PCR method of Reid *et al.* (2015) based on detection and identification of floats from the extraction machine. DNA-based methods do not discriminate between dead or live eggs and juveniles. Molecular determination of the viability combined with identification can be done with the RNA-specific real-time PCR of Beniers *et al.* (2014).

PATHWAYS FOR MOVEMENT

G. rostochiensis has limited potential for natural movement; second-stage juveniles can move short distances in the soil when attracted towards roots, at most only 1m per year and dry cyst can be dispersed to adjoining fields by wind or water. The main routes of spread are infested seed potatoes; movement of contaminated soil on non-host plants such as plants for planting, nursery stock and flower bulbs; farm machinery, ware potatoes or any other plant parts intended for consumption or processing. The latter are only important if there is a risk of them being planted or if care is not taken with disposal of waste soil. Soil as such and tare soil is also a pathway (EPPO, 2018).

PEST SIGNIFICANCE

Economic impact

Potato cyst nematodes are major pests of the potato crop in cool and temperate areas, losses have been estimated within Europe at 9% of total potato production; and in other potato growing areas where less or no control strategies are used, almost total losses can occur (Turner and Subbotin, 2013). The amount of damage, particularly in relation to the weight of tubers produced, is closely related to the number of nematode eggs per unit of soil. It has been estimated that approximately 2 tonnes/ha of potatoes are lost for every 20 eggs/g soil (Brown, 1969). Up to 80% of the crop can be lost when nematode populations increase to very high levels due to repeated cultivation of potatoes. The damage threshold can be as low as 1-2 eggs/g soil, depending on environmental conditions and level of tolerance of the grown cultivar. In addition to yield loss, there is also an indirect impact due to costs for control and phytosanitary measures. Online decision tools as ‘Nemadecide’ were developed to help growers to keep PCN at low, economically acceptable density levels (Been *et al.*, 2006).

Control

Control is traditionally by crop rotation, as it is recognized that after several years in the absence of potato cultivation the population of nematodes will be reduced to below the damage and detection thresholds; 6-7 years without potatoes is a common recommendation. Other more recent field management practices for limiting the population are; use of resistant potato crops and trap crops as sticky nightshade (*S. sisymbriifolium)*, biofumigation techniques, inundation or early destruction of susceptible potato crops before the life cycle has completed. In addition, good farm hygiene, including cleaning equipment and machinery, and reduction of growth of volunteer potato plants in the field is necessary (EPPO, 2020), in combination with regular testing for the presence of PCN and the use of suitable potato cultivars for effective deployment of the resistance (Molendijk and de Jongh, 2018).

In the last decade great progress had been made in the breeding of resistant potato varieties. Resistance to *G. rostochiensis* has been attributed to a number of genes, which confer partial *(Gro1.2, Gro1.3, Gro1.4, Grp1)* or near absolute *(H1, Gro1, GroVI)* resistance (Finkers-Tomzcak *et al.,* 2011). The H1 gene has been widely introgressed into many commercial cultivars.

Control in tomato crops is chiefly by soil fumigants.

Phytosanitary risk

G. rostochiensis is already established in the EPPO region and new introductions would have a high probability of establishing a viable population in areas where potatoes are grown (EFSA, 2012). *G. rostochiensis* still seems to be the dominant species throughout Europe, but its incidence is decreasing due to the use of resistant potato cultivars (Den Nijs *et al.,* 2019; Camacho *et al.,* 2020). It is still essential that areas of seed potato production are kept as free as possible from this nematode.

Additionally, the introduction of new virulent populations by import of non-European populations, particularly South American populations, would pose a threat to the use of resistant cultivars as major tool in controlling *G. rostochiensis*. The inability to precisely link genetic variability to the virulence characteristics of a specific nematode population, and quickly identify the virulence status of intercepted populations for inspection purposes, strengthens the need to prevent their introduction (Hockland *et al.,* 2012). New virulent populations can also arise from selection pressure as effect of intensive cropping presents risks, as recently occurred in Germany and the Netherlands for the closely related species *G. pallida* (EFSA, 2020). There are also indications of virulent *G. rostochiensis* populations occurring in the Netherlands, which is being further investigated within the Dutch project ‘Rostofit’.

In contrast to plants for planting, soil associated with potatoes, as tare soil, and root crops for packing or processing is mostly not regulated or only rarely regulated. Combined with the increasing use of the same machinery on multiple farms e.g. between sugar beet and potato farms and the renting of land that belongs to different farms increases the risk of the spread of *G. pallida*. Recommendations are available in the new EPPO Standard PM 3/92 *Management of phytosanitary risks for potato crops resulting from movement of soil associated with root crops and potatoes* (EPPO, 2021) to better address the risk associated with this pathway.

PHYTOSANITARY MEASURES

Measures to prevent the introduction *of G. rostochiensis* to areas where it is not already established include soil sampling surveys and regulations concerning movement of seed potatoes, nursery stock, flower bulbs and soil. These apply nationally as well as internationally.

Specific requirements are recommended in EPPO Standard PM 8/1 *Commodity-specific phytosanitary measures for Potato* (EPPO, 2017) for seed potatoes (except micropropagative material and minitubers) and ware potatoes to be imported from third countries. In this Standard, seed potatoes should come from fields free from viable cysts of *G. rostochiensis* and *G. pallida* according to PM 9/26. Ware potatoes from non-EPPO countries where *G. pallida* or *G. rostochiensis* occur should come, under transitional arrangements, from a pest free area and origin from a pest-free potato production and distribution system for the respective pests according to EPPO Standard PM 3/61 (EPPO, 2019), and confirmation by inspection or testing of tubers on import that the respective pest(s) does not occur.

For several EPPO countries, seed potatoes, the major pathway for entry, is already closed. For example, in the EU, the implementation regulation 2019/2072 prohibits import of seed potatoes and plants for planting of stolon- or tuber-forming species of *Solanum* L. or their hybrids.

Additional safeguards during transit of consignments could be washing of tubers and flower bulbs to remove soil, although it should be noted that cysts can remain embedded in tubers, especially in the eyes.

Measures to contain or eradicate *G. rostochiensis* are described in the national regulatory control system PM 9/26 (EPPO, 2017). The regulatory control system was developed for potato but can be applied to other crops as well, with possible slight modifications depending on the crops.

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