

EPPO Datasheet: *Globodera pallida*

Last updated: 2022-10-12

IDENTITY

Preferred name: *Globodera pallida*

Authority: (Stone) Behrens

Taxonomic position: Animalia: Nematoda: Chromadorea: Rhabditida: Heteroderidae

Other scientific names: *Heterodera pallida* Stone

Common names: pale potato cyst nematode, white potato cyst nematode

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EPPO Categorization: A2 list

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EU Categorization: Quarantine pest ((EU) 2019/2072 Annex II B)

EPPO Code: HETDPA



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Notes on taxonomy and nomenclature

In 1973, a new potato cyst nematode (PCN) species, *Heterodera pallida*, was described from potato in Lincolnshire, England (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. To accommodate the potato cyst nematodes and related species which have round cysts, Skarbilovich (1959) erected the subgenus *Globodera* which was later elevated to generic status by Behrens (1975) (see also Mulvey & Stone, 1976).

Recently, distinct genetic differences among *Globodera pallida* populations spanning Europe and other regions, and those found in South America were revealed by Subbotin *et al.* (2020). Picard *et al.* (2007) also discovered that populations from South America have a greater genetic diversity. Two groups of South American *G. pallida* populations with large genetic diversity including the 'pallida Chilean type' were identified, suggesting this may be a cryptic species within a possible *G. pallida* complex. Further integrative taxonomical research, including high throughput sequencing (HTS), morphological and behavioral studies are required in order to clarify this (Thevenoux *et al.*, 2019).

HOSTS

The host range of *G. pallida* 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, can be potential host plants as well as a few other species of *Datura*, *Hyoscyamus*, *Lycopersicon*, *Physalis*, *Physochlaina*, *Salpiglossis* and *Saracha*, all belonging to the Solanaceae family (Sullivan *et al.*, 2007).

Both *G. pallida* and *G. rostochiensis* 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; this method is discussed by Mugniéry *et al.* (1989). In Europe Kort *et al.* (1977) proposed a scheme with three *G. pallida* pathotypes (Pa1-Pa3) and with five *G. rostochiensis* pathotypes (Ro1- Ro5). In South America Canto Saenz & de Scurrall (1977) developed another scheme, recognizing more pathotypes.

Despite general acceptance, both pathotype schemes are considered insufficient for testing potato varieties for

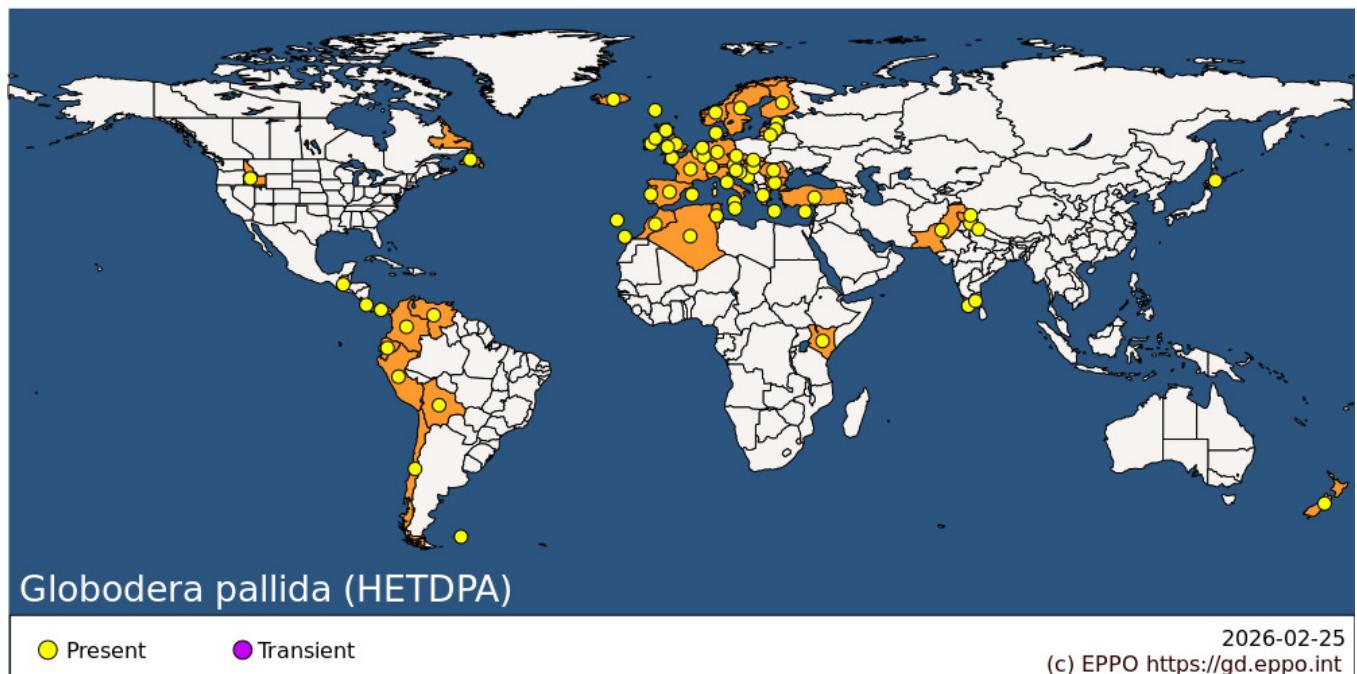
resistance to potato cyst nematodes. Variation in virulence in many European *G. pallida* populations with respect to quantitative resistance derived from *S. vernei* and other selected sources of *Solanum* species cause problems. Due to the extensive heterogeneity of some populations and environmental influences these populations could not be reliably described as pathotypes (Phillips and Trudgill, 1998; Turner and Subbotin, 2013). 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 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 mitochondrial sequences and microsatellite markers identified the more precise origin of western European *G. pallida* which is located in southern Peru, between Lake Titicaca and the city of Cusco (Plantard *et al.*, 2008). Analysis of the mtDNA haplotype distribution of PCN populations from all over the world (Subbotin *et al.*, 2020) confirmed this, and for each of the two species, *G. pallida* and *G. rostochiensis*, a different centre of origin was suggested in the Andes.



EPPO Region: Algeria, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France (mainland), Germany, Greece (mainland, Kriti), Hungary, Ireland, Italy (mainland, Sicilia), Latvia, Lithuania, Luxembourg, Malta, Morocco, Netherlands, Norway, Portugal (mainland, Madeira), Romania, Slovakia, Slovenia, Spain (mainland, Islas Baleares, Islas Canárias), Sweden, Switzerland, Tunisia, Türkiye, United Kingdom (Channel Islands, England, Northern Ireland, Scotland, Wales)

Africa: Algeria, Kenya, Morocco, Tunisia

Asia: India (Himachal Pradesh, Jammu & Kashmir, Kerala, Tamil Nadu, Uttarakhand), Japan (Hokkaido), Pakistan

North America: Canada (Newfoundland), United States of America (Idaho)

Central America and Caribbean: Costa Rica, Guatemala, Panama

South America: Bolivia, Chile, Colombia, Ecuador, Falkland Islands, Peru, Venezuela

Oceania:

BIOLOGY

G. pallida is a sedentary endoparasite. Second-stage juveniles (J2) hatch from eggs within cysts in the soil, under stimulus from 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 and white. 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. When the females 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. pallida* usually has one generation per year. 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. pallida*. It is adapted to develop at colder temperatures than *G. rostochiensis*. Optimum hatching of the J2 from the eggs occurs between 13-25°C, hatching starts at 5°C (Kaczmarek *et al.*, 2014). Above 17.5°C, however, reproduction, number of females per plant and their fecundity, decreases (Jones *et al.*, 2017). *G. pallida* hatches more slowly than *G. rostochiensis*, over a longer period and has overall a higher number of eggs which hatch successfully compared to *G. rostochiensis* (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. pallida* populations also declined faster than *G. rostochiensis* populations (Been *et al.*, 2019).

DETECTION AND IDENTIFICATION

Symptoms

The symptoms caused by *G. pallida* 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, 484 (440 – 525) µm long, having a well-developed stylet 23.8 (22-24) µm with robust and hooked knobs of 4-5 µm width with distinct forward projections 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 450 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 8 - 20, generally lower than 14. Granek's ratio is 1.2 - 3.5, generally lower than 3 (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. pallida* differs from *G. rostochiensis* as it has white rather than yellow-coloured females, a longer J2 stylet length (24 vs 22 µm) and a robust and square-hooked stylet knob (rather than small and rounded).

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 white or brown pin-heads on the root surface. Low-level infestations in the field 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 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, 2021b) 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 such 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. pallida has limited potential for natural movement; second-stage juveniles can move short distances in the soil when attracted towards roots, at most only 1 m per year and dry cysts can be dispersed to adjoining fields by wind or water. The main routes of spread are infested seed potatoes and 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 these 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). This is particularly the case when, because of the pathotypes present, only a few resistant cultivars are commercially available for planting. Most popular cultivars have no resistance against *G. pallida*.

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 despite the fact that identification of a single major resistance gene is very difficult due to the high genetic diversity of the European *G. pallida* populations. No single gene offers complete resistance, (unlike the H1 for *G. rostochiensis*). A small number of partially or high resistant potato cultivars such as Innovator, Arsenal and Ivetta are currently on the market. However, Innovator is intolerant, not growing well when higher populations densities are present. Innovator and Arsenal are limited to the processing market, but Ivetta is also suitable for cooking.

Control in tomato crops is chiefly by soil fumigants.

Phytosanitary risk

In the EPPO region *G. pallida* is already established in most areas that are important for the cultivation of ware and starch potatoes; and regular attention to control is needed in such areas. *G. pallida* is still absent from some areas or EPPO countries; in particular in some seed potato production areas, which should be kept as free as possible from this nematode. New introductions would have a high probability of establishing a viable population in areas where potatoes are grown (EFSA, 2012).

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. pallida*. 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 (EFSA, 2020). The German population 'Oberlangen' showed a higher reproduction and fitness than 'Chavornay', the standard Pa3 reference population. The resistance response of potato cultivar 'Seresta', restricting the development of a syncytium, only imposed a partial effect on the Oberlangen population, evident by the number of juveniles developing into females (Mwangi *et al.*, 2019).

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 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. pallida* 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. pallida* 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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