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Data Sheets on Quarantine Pests

Radopholus citrophilus and *Radopholus similis*

IDENTITY

Taxonomic position: Nematoda: Tylenchida: Pratylenchidae
Notes on taxonomy and nomenclature: *R. similis* is an original member of the EPPO A2 quarantine list. Reported from several EPPO countries, it is locally established in a few. It has now been divided into two species (Esser *et al.*, 1984; Huettel *et al.*, 1984): *R. similis sensu stricto*, formerly the banana race, attacking bananas but not citrus, corresponding to the original A2 list entry, and *R. citrophilus*, formerly the citrus race, attacking bananas and citrus. The latter is absent from Europe and so is now considered a member of the A1 list. It may be noted that the separation of the two sibling species is not universally accepted (Esser *et el.*, 1988).

- ***Radopholus citrophilus***
  Name: *Radopholus citrophilus* Huettel *et al.*
  Synonyms: *Radopholus similis* citrus race
  Common names: Citrus spreading decline nematode (English)
  Bayer computer code: RADOCI
  EPPO A1 list: No. 161
  EU Annex designation: II/A1
- ***Radopholus similis***
  Name: *Radopholus similis* (Cobb) Thorne
  Synonyms: *Tylenchus similis* Cobb (synonym of *R. similis sensu lato*)
  Radopholus similis banana race (synonym of *R. similis sensu stricto*)
  Common names: Burrowing nematode, banana toppling disease nematode (English)
  Anguillule mineuse du bananier (French)
  Nemátodo coco, nematodo barrenador (Spanish)
  Bayer computer code: RADOSI
  EPPO A2 list: No. 126
  EU Annex designation: II/A2

HOSTS

Both species have a wide host range, attacking monocotyledonous plants: Musaceae (bananas, *Strelitzia*), Araceae (*Philodendron, Anthurium*), Marantaceae (*Calathea*), and some dicotyledons (e.g. *Piper nigrum*). Over 200 plants have been recorded as hosts of *R. similis sensu lato*, but mostly incidentally (in the vicinity of infested banana plots) or by artificial inoculation (see also Pest significance). So far as is known, this wide range of secondary hosts applies to both the sibling species. *R. citrophilus* is distinguished by its specific ability, in addition, to attack and damage citrus. Most of these species are important ornamental crops for the EPPO region and citrus is highly significant for the Mediterranean area.

GEOGRAPHICAL DISTRIBUTION

- ***Radopholus citrophilus***

EPPO region: Absent.
Africa: Côte d'Ivoire.
North America: Present only in the USA (in Florida, where it was recorded for the first time in 1953 (Suit & Du Charme, 1953), Hawaii).
Central America and Caribbean: Cuba, Dominican Republic, Puerto Rico.
South America: Guyana.
EU: Absent.

- ***Radopholus similis***

Widespread in most banana-growing regions of the world and present in glasshouses in temperate areas (Orton Williams & Siddiqi, 1973; O'Bannon, 1977).
EPPO region: Locally established on ornamental plants in glasshouses in Belgium, France, Germany, Italy and Netherlands; locally established in Portugal (Madeira). Present in Egypt, Lebanon. It has also been reported from Denmark but is now eradicated.
Asia: Brunei Darussalam, India (Arunachal Pradesh, Goa, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu), Indonesia (Sumatra), Japan (unconfirmed), Lebanon, Malaysia (Peninsular), Oman, Pakistan, Philippines, Sri Lanka, Thailand, Yemen.
Africa: Burundi, Cameroon, Central African Republic, Congo, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Réunion, Senegal, Seychelles, Somalia, South Africa, Sudan, Tanzania, Zambia, Zimbabwe (IAPSC, 1985).
North America: Canada (in glasshouses in British Columbia; few reports), USA (Arizona, California, Florida, Louisiana, Texas).
Central America and Caribbean: Barbados, Belize, Costa Rica, Cuba, Dominica, Dominican Republic, Guadeloupe, Guatemala, Honduras, Jamaica, Martinique, Panama, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, Trinidad and Tobago, United States Virgin Islands.
South America: Brazil (widespread), Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela.
Oceania: Australia (New South Wales, Northern Territory, Queensland, South Australia, Western Australia), Fiji, French Polynesia, Guinea, Palau, Papua New Guinea, Samoa, Tonga.
EU: Present.

BIOLOGY

Both species are migratory, endoparasitic nematodes, all stages of which develop within the host tissue, although in adverse conditions the nematodes may emerge from the roots.

R. similis is reported to take up to 5 years to die out in soil if no banana crops are grown during this period, presumably because of alternative weed hosts. Longevity of *R. citrophilus* in host-free soil is not precisely known, but is certainly more than 6 weeks, and possibly as long as for *R. similis*. Spread of both species is by rooted planting material, by soil as such, and, within a plot, by root contact or near contact, by irrigation water, cultivation machinery, etc.; spread within a plot is estimated at 3-6 m on bananas in Central America and at 15 m annually on citrus in Florida.

All larval stages and adult females are infective and capable of penetrating roots at any point, but, entry is usually by the root tip. The nematode feeds on and burrows in the cortex, forming extensive cavities. *R. citrophilus* enters the stele and accumulates in the phloem and the cambium; *R. similis* does not. *R. citrophilus* has been found in roots at depths of 3 m in citrus groves in Florida.

Fertilization is the norm, but reproduction by parthenogenesis does take place. The life cycle is completed in about 21 days at 25°C, and each female lays an average of four to five eggs each day for 2 weeks. A ten-fold population increase can occur in 45 days under favourable conditions. In soil, populations may reach about 3000 individuals per kg soil, while in the root they may exceed 100 000 per 100 g root. Both species interact with various soil-inhabiting fungi, generally increasing the incidence of disease caused by these pathogens.

DETECTION AND IDENTIFICATION

Symptoms

On *Calathea*

Infestation results in restricted root systems, and hence reduced production. A decrease in leaf size and colour alterations lead to a reduction in quality of saleable plants (Hamlen & Conover, 1977).

On citrus

Declining trees have fewer and smaller leaves and more dead twigs than healthy trees. There is a tendency to wilt, seasonal growth flushes are weak, fruit set poor and yields low, but death does not usually occur.

Roots have extensive cavities and the phloem and cambium may be completely destroyed, leaving nematode-filled spaces separating the remains of the stele from the cortex. External cracks may appear over the lesion.

Morphology

- ***Radopholus similis***

Microscopic observation of the nematode is necessary for correct diagnosis (Orton Williams & Siddiqi, 1973).

Juveniles are 315-400 µm in length, with spears 13-14 µm long and the tail tapering to a bluntly rounded terminus.

Adults are 520-880 µm in length (average 670 µm). Females have a spear about 18 µm long, with well developed, round basal knobs, spherical spermathecae (usually with rod-shaped sperms and an elongate-conoid tail. In males, the head is knob-like, due to the elevated lip region, the oesophagus and spear are degenerate, the bursa coarsely crenate, enveloping about two-thirds of the tail, and the spicules strongly cephalated, 18-22 µm long, with pointed distal ends.

- ***Radopholus citrophilus***

Morphologically, *R. citrophilus* is nearly indistinguishable from *R. similis* (Du Charme & Birchfield, 1956). However, SEM observations revealed several diagnostic differences (Huettel & Yaegashi, 1988). The cloaco-spicular orifice on males of *R. citrophilus* has three to seven genital papillae, whereas on males of *R. similis* it is either smooth or it has one or two shorter genital papillae. Females of *R. citrophilus* have four annules in the region of the vulval opening, but *R. similis* have five.

Detection and inspection methods

Besides their host range, the species differ in the following biological characteristics:

(1) The chromosome number is n=5 for *R. citrophilus* and n=4 for *R. similis* (Huettel & Dickson, 1981; Huettel *et al.*, 1983a).

(2) Comparisons of the non-enzymatic proteins by polyacrylamide slab gels show a major protein band difference in *R. citrophilus* (Huettel *et al.*, 1983b).

(3) In interspecific attraction studies, males of *R. similis* are attracted to but do not copulate with females of *R. citrophilus*. This behavioural difference may be caused by different sex pheromones in the two species (Huettel *et al.*, 1982).

MEANS OF MOVEMENT AND DISPERSAL

The nematodes have a limited capacity for natural spread. In international trade, they are very likely to be carried on underground parts of citrus, bananas and ornamental plants, and in accompanying soil. *R. similis* was introduced into France on ornamentals from the USA. *R. citrophilus*, which mainly presents a risk to citrus, could be introduced on other hosts, such as *Anthurium* spp.

PEST SIGNIFICANCE

Economic impact

- ***Radopholus citrophilus***

In Florida, *R. citrophilus* causes spreading decline of citrus, an important disease since about 1928. Yields are reduced by 40-70% (oranges) and 50-80% (grapefruits). After a 10-year comparison of healthy and infested groves, crop production was 1338 and 62 boxes per ha, respectively. Regulatory measures (a site approval programme) have much reduced the impact of the pest (Esser *et al.*, 1988).

- ***Radopholus similis***

The burrowing nematode is of great economic importance in the banana-growing areas of Australia, Central and South America, Africa and the Pacific and Caribbean Islands, causing what is variously called root rot, blackhead, toppling disease and decline, and predisposing trees to fungal infection.

R. similis has also been recovered from the roots of a number of crops planted close to infested bananas in tropical Africa. It is an important pest on turmeric, cardamoms, and (in Fiji) ginger. Severe damage has been reported in inoculation trials on soyabeans, sorghum, maize and sugarcane, and moderate damage on roots of aubergines, coffee, tomatoes and potatoes. *R. similis* was responsible for the yellows disease of *Piper nigrum*, which, by 1953, had destroyed 90% of this crop in Indonesia.

Glasshouse infestations of *R. similis* have been reported from Europe, Japan and Canada as well as from Arizona, California, Louisiana and Texas in the USA. The infestations of *Calathea* may pose a serious problem during commercial production, especially in ground-bed stock cultivation, resulting in infested propagation units being used for container production.

Control

Nematicides have been used to control *R. similis* and increase banana yields. In an experiment in the Côte d'Ivoire, banana yield increased by 22 t/ha (101% increase) by use of dibromochloropropane, 24.4 t/ha by ethoprophos and 30.6 t/ha by phenamiphos. In another trial, prophos increased yield in the first fruit cycle by 188% and phenamiphos by 211%, while yield increases during the second fruit cycle were even more dramatic, 300% and 411%, respectively (Vilardebo, 1974). From this, it can be deduced that *R. similis* caused a yield reduction of 80%. However, this figure is probably inflated, since the total biological and physiological effects of the nematicides are not completely known.

For control in *Calathea* production, use of nematode-free propagating stock, soil solarization, raised benches and strict sanitation procedures are advised. Single applications of certain nematicides (ethoprophos and oxamyl) as soil drenches are reported to control *R. similis* populations in *C. makoyana* and *C. lancifolia*.

Phytosanitary risk

EPPO (OEPP/EPPO, 1988) has listed *R. citrophilus* as an A1 quarantine pest and it is also of quarantine significance for APPPC; EPPO has listed *R. similis* as an A2 quarantine pest. *R. similis* presents a danger to glasshouse ornamentals (especially monocotyledons) throughout the EPPO region and also to bananas and avocados in the limited areas where these crops are cultivated in the region (southern Spain, Morocco, Israel, etc.). There are a number of citrus-growing areas in the Mediterranean where climatic and cultural conditions would favour establishment and development of *R. citrophilus* in the field. In addition, throughout the EPPO region, there are numerous glasshouses which also offer a favourable environment for this nematode. It is not yet clear whether *R. citrophilus* differs from *R. similis* in its damage potential in glasshouses.

PHYTOSANITARY MEASURES

Careful pre-export and post-entry inspection of rooted host plants is essential for material from infested countries, but there is no technique currently available to distinguish between *R. similis* and *R. citrophilus* in quarantine laboratories. Normal quarantine samples are wholly inadequate for laboratory analysis procedures to determine chromosome number, behavioural studies, host testing or other physiological determinations. Accordingly, more stringent measures may be needed for material from countries (or regions) where *R. citrophilus* occurs.

Treatment in transit may be possible. Paring discoloured tissues and subsequent dipping in a dibromochloropropane mixture controls the nematode on banana sets, but is not entirely satisfactory (Peachey & Hooper, 1963). Besides, this product has been withdrawn in many countries. Hot water treatment of banana sets, at 55°C for 20-25 min, is effective but requires costly equipment and may cause phytotoxicity. These methods remain to be tested on other hosts.

Concerning *R. citrophilus*, EPPO recommends (OEPP/EPPO, 1990) that importations of plants for planting of citrus, *Fortunella* and *Poncirus* from countries where the pest occurs should be prohibited; other host plants can also be prohibited. Plants with roots (and growing medium attached) of Araceae, citrus, *Fortunella*, Marantaceae, Musaceae, *Persea*, *Poncirus* and Strelitziaceae from non-EPPO countries should come from a place of production which has been inspected and found free from the nematode.

For *R. similis*, importations of plants with roots of Araceae, Marantaceae, Musaceae, *Persea* and Strelitziaceae from non-EPPO countries where the pest occurs may be prohibited. Countries may also require that consignments of host plants (with roots) should come from a place of production inspected (by examining root and soil samples for non-EPPO countries) and found free from the nematode.

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