Heterodera sacchari

Scientific Name
Heterodera sacchari Luc & Merny, 1963

Synonyms:
None

Common Name
Sugarcane cyst nematode

Type of Pest
Nematode

Taxonomic Position (Siddiqi, 2000)
Class: Secernentea, **Order:** Tylenchida, **Family:** Heteroderidae

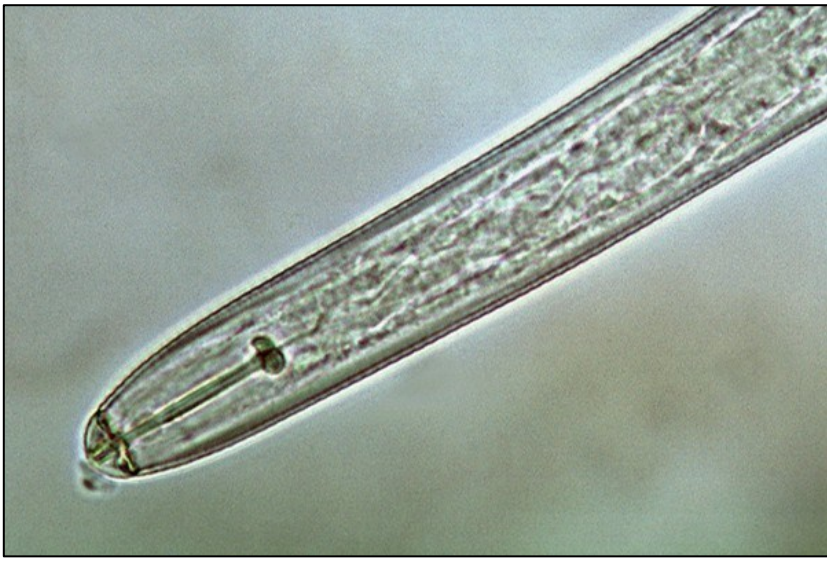


Figure 1. Juvenile of *Heterodera sacchari*, anterior end (Photo courtesy of John Bridge, CABI).

Reason for Inclusion in Manual
CAPS Target: AHP Prioritized Pest List - 2006 through 2011; Cyst Nematode Survey.

Background
The genus *Heterodera* contains at least 80 species, some of which cause serious yield reduction in crops (Subbotin et al., 2010). The protective cyst stage of these nematodes enables them to withstand desiccation and greatly enhances their dispersal and survival (Waeyenberge et al., 2009). There are seven main morphological groups within the genus *Heterodera*: *Afenestrata*, *Avenae*, *Cyperi*, *Goettingiana*, *Humuli*, *Sacchari*, and *Schachtii*. *Heterodera sacchari* is a member of the *Sacchari* group. Its closest known relative is *H. goldeni* (Subbotin et al., 2010).

Pest Description
The original description of this species can be found in Luc and Merny (1963). A detailed description of the life stages can also be found in Luc (1974), Nobbs et al. (1992), Shahina and Maqbool (1995), and Ferris (2005).

Eggs: “112 – 139 (128) µm long, 43 – 45 (44) µm wide; L/W = 2.5 – 3.1 (2.9); retained in body” (Luc, 1974).

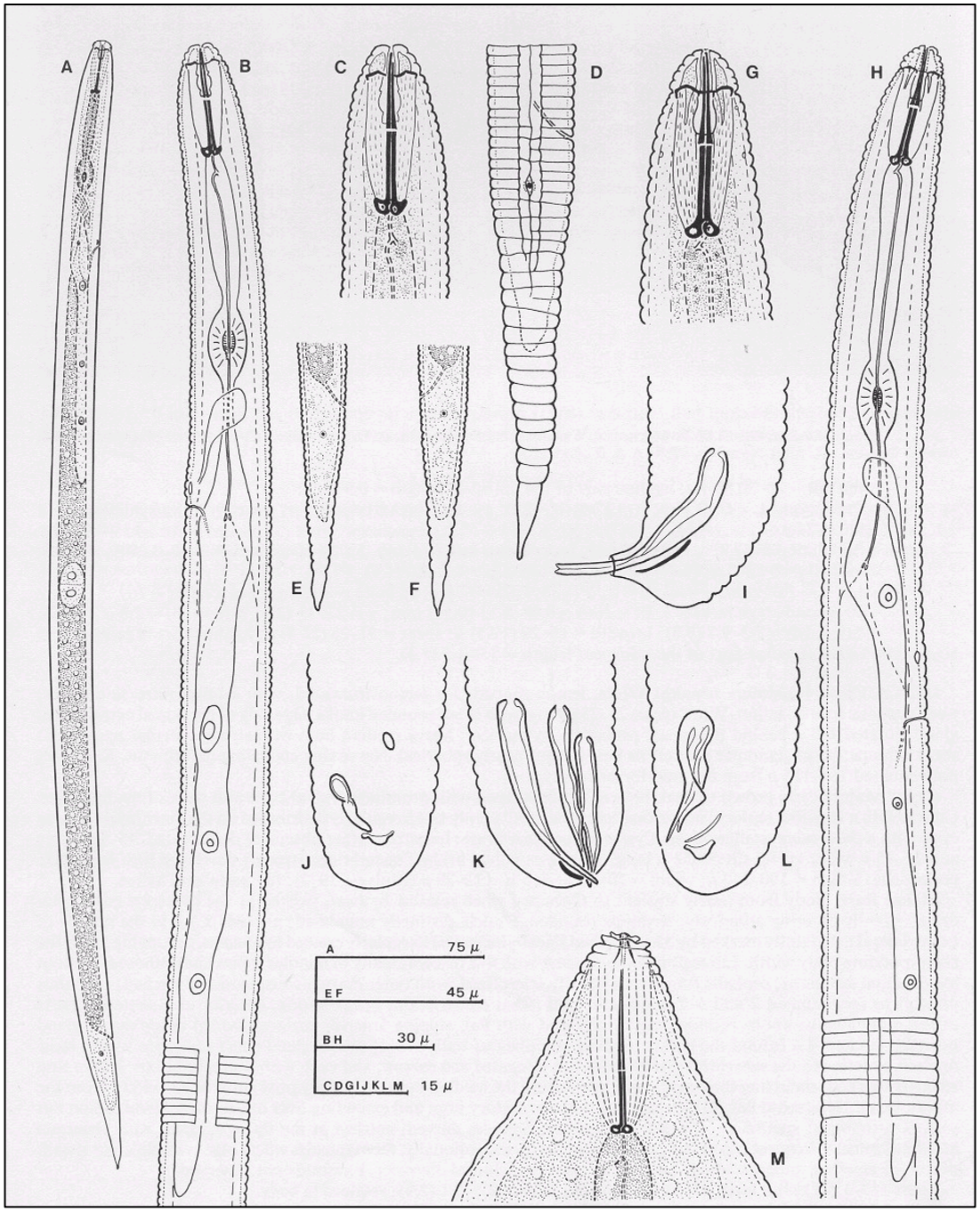


Figure 2. *Heterodera sacchari* Illustration. A-F) Second-stage juveniles. A) Entire larva. B) Oesophageal region. C) Head end. D-F) Tail ends. G-L) Male. G) Head end. H) Oesophageal region. I) Normal tail end, lateral view. J, K, L). Tail ends showing abnormal copulatory apparatus. M) Anterior end of young female. Courtesy of Howard Ferris, UC Davis.

Second-stage juveniles (J2s): "Body straight or slightly ventrally curved when heat-relaxed, slightly tapering at the anterior end, more attenuated at the posterior end (Figs. 1, 2). Cuticle annulated; annules 1.7 µm wide in the middle of body; lateral field

composed of 3 longitudinal lines, not crossed by annules except in the fore-part and at the level of the phasmids. Lip region dome-shaped, with 3 annules; cephalic framework heavily sclerotized. Stylet stong, anterior part slightly shorter than the posterior; knobs well developed, rounded posteriorly, concave anteriorly. Dorsal esophageal gland opening situated 5-8 µm behind the spear. Median esophageal bulb ovoid, with strong valve. Dorsal gland broad, anterior to the subventrals, with a large nucleus. Subventral glands not completely filling the body cavity, each with a small nucleus. Nerve ring well defined, situated immediately behind the median bulb. Excretory pore 104-130 µm from the anterior end. Hemizonid immediately in from of the excretory pore, lenticular, extending over 2 annules. Genital primordium with 2 nuclei, located at the mid-body. Tail elongated, conical, with pointed terminus. Phasmids pore-like, situated 45-47 µm from the posterior end" (Ferris, 2005).

Adults:

Males: "Rare. Body from nearly straight to C-shaped when relaxed by heat, twisted at the posterior end, cylindrical, slightly tapering anteriorly, terminus rounded (Fig. 2). Cuticle distinctly annulated; annules 2.5 µm in the middle of body; lateral field faintly marked by 3 longitudinal lines (=incisures) irregularly crossed by annules, occupying 1/5 of the corresponding body width. Lip region dome-shaped, with 4-5 (exceptionally 6) annules, often anastomosed, without longitudinal striations; cephalic framework heavily sclerotized, with outer margin conspicuously marked; cephalids difficult to see, situated 2 and 6-7 annules behind labial constriction. Spear stong, anterior and posterior parts of the same length; knobs rounded posteriorly and with flat, sloping anterior surface. Dorsal esophageal gland opening situated 4 µm behind the spear. Median esophageal bulb ovoid. Dorsal gland short and wide with a large nucleus, anterior to the subventral glands which are elongated and narrow, and each with a small nucleus. Nerve ring strongly marked, encircling the esophagus just behind the median bulb. Excretory pore situated 137-150 µm from the anterior end. Hemizonid flat, 7-15 µm anterior to the excretory pore and extending over one annule. Hemizonion not seen. Testis single; spermatozoa 4-5 µm in diameter. Spicules curved, notched at the tip; specimens with abnormal atrophied spicules frequent (up to 20% of specimens); exceptionally, three spicules were observed. Spicular sheath present. Lamellate gubernaculum. Tail 1/4 to 1/3 of the cloacal body diameter. Phasmids not observed" (Ferris, 2005).

Females: In *Heterodera* spp. "females become obese and lemon shaped, producing brown cysts when dead varying in size from 0.3 – 1.0 mm in length and 0.2 – 0.8 mm in width, observable with the naked eye" (Bridge and Starr, 2007).

"White, lemon-shaped. Lip region truncated, with 2 offset retrorse annules; weak cephalic sclerotization. Weak stylet, 23-25 µm long, with small, rounded knobs. Opening of the dorsal esophageal gland situated 4-5 µm behind the spear; procorpus cylindrical. Heavy median bulb with strong valve; short isthmus. Basal glandular part of the esophagus nearly spherical. Nerve ring encircling the isthmus. Excretory pore situated 165-175 µm from the anterior extremity" (Ferris, 2005).

Cysts: “large cysts with long vulval slit, rounded semifenestra, bullae present and a well-developed underbridge with "fingerlike" projections. *En face* view of tip region of J2s with submedial lips same width as the labial disc and elongate in the dorsal-ventral axis. Esterase banding pattern show four bands” (Nobbs et al., 1992). “Cysts are persistent tanned sacs derived from the female body and contain the eggs” (Fig. 3) (SON, 2003). The number of eggs in the cyst can vary. Jerath (1968) counted between 36 and 230. Cyst lengths (means 550-735µM) and fenestrae in particular have a wide range in size (Tanha Maafi et al., 2007)

Biology and Ecology

Heterodera sacchari J2s hatch over an extended period of time (reviewed in Coyne and Plowright, 1999a; SON, 2003). This allows the nematode to continually infect available host material (Coyne and Plowright, 2000). Hatching requires the presence of water (CABI, 2012) and is not as dependent on root leachates as other nematodes such as *H. oryzicola* (Ibrahim et al., 1993). After emergence, J2s penetrate host roots to establish a specialized feeding site (called a syncytium) in the stele (SON, 2003). J2s begin feeding and molt through a third and fourth juvenile stage (CABI, 2012). Development to adulthood takes about 30 to 35 days at 24 to 35°C (75.2 to 95°F) (Salawu, 1994). Reproduction is by mitotic parthenogenesis, so most nematodes will develop into females (reviewed in CABI, 2012). Females produce and retain large egg masses in the body (SON, 2003). Females rupture the root cortex, protruding from the root surface. After reproduction, females die and become ovoid brown to dark brown cysts, which are the principle survival structures (SON, 2003). Cysts can dislodge from the roots and be dispersed through soil, wind, or irrigation water (reviewed in CABI, 2012).

Figure 3: *Heterodera glycines* cysts on host plant roots. These cysts are very similar in appearance to cysts of *H. sacchari*. Courtesy of Elizabeth Bush, Virginia Polytechnic Institute and State University, Bugwood.org

Although *H. sacchari* can reproduce on both upland rice and lowland (swamp) rice cultivars, this species does better on upland rice cultivars (Babatola, 1983b). This species is more abundant in sandy soils than in clay soils (Jerath, 1968). Although this species is common in hydromorphic and flooded rice environments that are intermittently submerged (CABI, 2012), *H. sacchari* generally cannot withstand extended flooding (Bridge and Starr, 2007).

Cysts can persist in the soil for many years (SON, 2003). They are more numerous in soil during the dry season; this coincides with the time that sugarcane matures (Jerath, 1968; reviewed in Luc, 1974). Jerath (1968) determined that eggs were viable under laboratory conditions for up to one year.

Symptoms and Signs

Aboveground symptoms are not species-specific. Symptoms are similar to ones caused by other *Heterodera* species. Symptoms include: severely stunted and chlorotic plants with less tillers produced, reduction in root growth, and black or brown roots. The reduced roots may appear to have smaller roots that are stimulated by nematode feeding. Seedlings may be killed in heavily infested soils (Bridge and Starr, 2007). Proliferation of lateral roots at infection points is characteristic of *H. sacchari* infections (Babatola, 1983). In Côte d'Ivoire, this nematode causes symptoms of physiological drought in upland rice fields (Audebert et al., 2000) (leaf folding is a typical drought symptom) (CABI, 2012).

In damaged sugarcane, secondary roots are fewer. Roots are sometimes gathered forming patches of decaying root material in which cysts may be found (Jerath, 1968). Salawu (1992) reported that infected sugarcane had reduced shoot weight and caused severe root necrosis, while Jerath (1968) reported infected sugarcane plants were between a third and a half the height of uninfected plants (1-1.5 m (3-5 ft) vs. 3-3.5 m (10-12 ft)).

One of the most obvious sign is the presence of lemon-shaped, swollen, white females (about 0.25 mm in diameter) about 30-35 days after the initial invasion of J2s (reviewed in CABI, 2012). Females rupture the root cortex and can be seen protruding from the root surface.

Pest Importance

Evans and Rowe (1998) state that *H. sacchari* is one of the most economically important cyst nematode species in the hot tropics, while Lamberti et al. (2007) state that this species is of local importance in Western Africa.

This species is considered a pest of rice in West Africa and Trinidad (Bridge and Starr, 2007). Audebert et al. (2000) state that this species is emerging as a potentially serious pest of upland rice in West Africa. They also found that the presence of *H. sacchari* increased the effects of drought and drought related losses (Audebert et al., 2000). Infection by nematodes can decrease water use efficiency, increase suction pressure in roots, and reduce water consumption (reviewed in Audebert et al., 2000). In South Africa, this species causes stunting and chlorosis of upland rice (Coyne and Plowright, 1999a). Nematode populations can rapidly increase over a single season (USDA, 2012).

The presence of *H. sacchari* is linked to suppression of emerging seedlings, reduced leaf and root weight, and reduced tiller number of susceptible upland rice. This may affect the host's ability to cope with additional stresses like weeds and drought. This

could exacerbate losses (Coyne and Plowright, 1999a). Yield losses on rice can be up to 50%. Populations of this species can increase rapidly due to intensive wet season rice cropping (reviewed in Plowright et al., 1999). Coyne and Plowright (2000) have also recorded severely reduced grain yield in upland rice (*Oryza sativa* cv. IDSA6) in Côte d'Ivoire. Babatola (1983a) states that symptoms of infection are more severe in upland conditions; this has also been observed in sugarcane infested by *H. sacchari*.

USDA (2012) states that this species can reduce yields in rice and sugarcane and would likely prompt regulatory actions by other countries. Although there is a lack of field experimentation, it is believed that this pest could be a potentially serious pest of sugarcane (reviewed in SON, 2003). Sugarcane is widely cultivated in the United States. It was planted on 905,000 acres during the 2013/14 growing season (USDA-ERS, 2014).

Significantly higher population densities for *H. sacchari* have been observed in weed free rice plots versus rice plots with weeds, suggesting reduced interspecific competition facilitated increased nematode populations (Coyne et al., 1999). Work has been carried out to develop and study plant resistance to this pathogen (Lorieux et al., 2003; Amoussou et al., 2004; Williamson and Kumar, 2006). Crosses between *Oryza glaberrima* and *O. sativa* are resistant to the nematode (Plowright et al., 1999). Other controls can be used to help control the nematode, including crop rotation with non-host plants and chemical control. Control of this nematode has led to yield increases of over 60% (Bridge and Starr, 2007). It has been found that soil fauna can have an effect on plant tolerance to parasites, specifically the presence of earthworms which can decrease the number of infested plants by *H. sacchari* (Blouin et al., 2005).

Rice, the primary staple for more than half the world's population, is produced worldwide. The United States is a major exporter, and the global market accounts for nearly half the annual sales volume of U.S.-produced rice. During the 2012/2013 growing season, rice was planted on approximately 2.7 million acres in the United States (USDA-ERS, 2014).

Heterodera sacchari is listed as a harmful organism in Brazil, Indonesia, Japan, Taiwan, and Timor-Leste (USDA-PCIT, 2014). There may be trade implications with these countries if this nematode becomes established in the United States.

Known Hosts

Major hosts

Oryza sativa (rice) and *Saccharum officinarum* (sugarcane) (CABI, 2012).

A detailed list of cultivars of *Oryza sativa* and *Saccharum officinarum* attacked by this species can be found in Nemaplex (n.d.). Affected rice cultivars can also be found in Babatola (1983b).

Wild hosts
Axonopus compressus (carpet grass), *Brachiaria brizantha, Cynodon dactylon* (Bermuda grass), *Echinochloa colona* (jungle rice), *Eleusine indica* (goose grass), *Paspalum conjugatum* (sour grass), *Saccharum spontaneum* (wild sugarcane), and *Urochloa brizantha* (palisadegrass) (SON, 2003; CABI, 2012).

This species also attacks a number of indigenous Cyperaceae and Gramineae (reviewed in Lamberti et al., 2007). Coyne and Playwright (1999b) state that some cereal crops are susceptible to *Heterodera sacchari* infection, including maize, millet, and sorghum.

Pathogen or Associated Organisms Vectored
This species is not known to vector any pathogens or other associated organisms.

Known Distribution
Asia: India, Pakistan, and Thailand; **Africa:** Benin, Burkina Faso, Chad, Congo, Côte d'Ivoire, Gambia, Ghana, Liberia, Nigeria, and Senegal; **Caribbean:** Jamaica (Ferris, 2005; CABI, 2012).

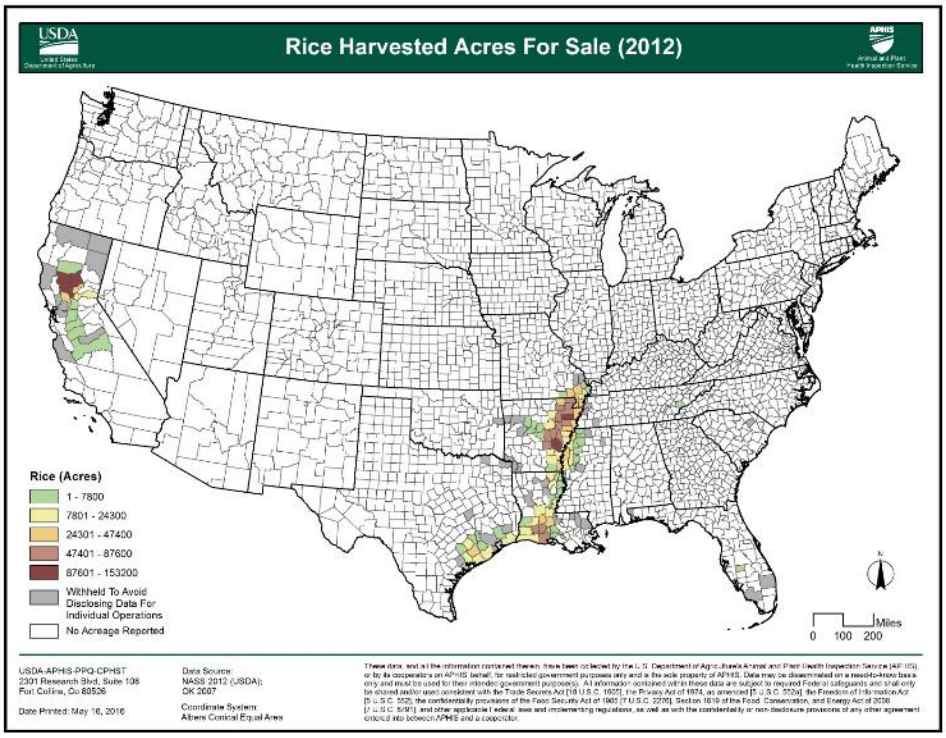
Some sources state that this species is found in Trinidad and Tobago (SON, 2003). However, CABI (2012) states that this record is unreliable.

Pathway
This species can disperse through running water, including rain, irrigation, and run-off, like other nematodes. It can also disperse through human-assisted movement of seed, soil, or equipment (reviewed in USDA, 2012).

Cysts can easily be moved to new areas (Bridge and Starr, 2007) and can persist for years in soil. They can be dispersed by soil or plant material (SON, 2003). Odihirin (1977) found that cysts could be carried 5 to 8 km in irrigation canals.

On February 10, 2000, a live nematode cyst was intercepted at the U.S.-Mexico border crossing in El Paso, Texas, and verified to be *Heterodera sacchari* at the USDA Nematology Laboratory in Beltsville, Maryland. The cyst was found on *Solanum stoloniferum* plant material in the automobile of a border crosser (AQAS, 2014). The geographic origin of this intercepted cyst is unknown. To date, *H. sacchari* is not confirmed to be present in Mexico, nor has *S. stoloniferum* been confirmed as a host of this cyst nematode.

There have been shipments of *Oryza sativa* propagative material from the following host countries since 2004: India (172), Pakistan (105), Thailand (29), Benin (6), Burkina Faso (1), and Ghana (4). There have also been shipments of *Saccharum* spp. propagative material from the following host countries since 2004: Pakistan (2), and Thailand (1) (AQAS, 2014). There were also interceptions of *Saccharum officinarum* propagative material from the following host countries since 2004: Jamaica (25), Nigeria (10), India (5), and Ghana (1) (AQAS, 2014).



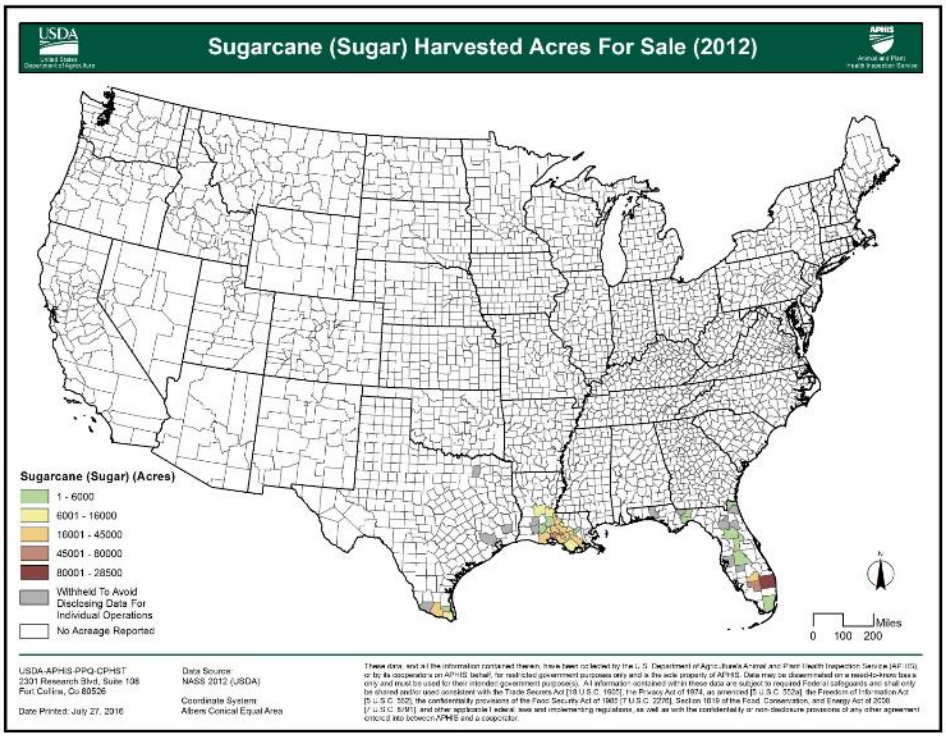


Figure 4. Rice and sugar commodity acreage. Map courtesy of USDA-APHIS-PPQ-CPHST.

Potential Distribution within the United States

According to commodity acreage maps, southern states, Florida, and California are most vulnerable to *H. sacchari* based on host presence (Fig. 4). In addition, the climatic zones in the countries where this species is found correspond to U.S. Plant Hardiness Zones 8-11 (USDA, 2012), so areas within these climate zones would be most vulnerable, and areas in colder zones are less vulnerable. Surveys should be focused in areas where rice and/or sugarcane are grown.

Survey

CAPS-Approved Method*:

Use soil sampling, collection of host roots, or of a combination of both methods.

Soil sample: Send sample to a nematology diagnostic lab where nematodes will be extracted from the soil and identified (preferred method). Laboratory methods that are acceptable for cyst extraction include sugar centrifugation, USDA cyst extractor, Fenwick can sieving, wet sieving, and elutriation. Cobb's sieving technique has been used regularly to extract second stage juveniles from the soil.

Collect host roots: Send sample to nematology diagnostic lab where nematodes will be extracted and identified.

Signs to look for include the presence of numerous lemon-shaped, swollen, white females (approximately 0.25 mm in diameter) that are visible along the roots 30 to 35 days after the initial invasion of J2s.

Symptoms to look for include infected root systems are likely to be stunted and more so if significant invasion occurs early in the growth of the crop. Infected plants will be stunted and in rice, plants will produce fewer tillers. In upland conditions, rice plants can exhibit leaf folding typical of drought stress. In severe infections rice plants can be killed. Infected sugarcane is stunted with reduced shoot weight, fewer secondary roots, and root necrosis.

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Literature-Based Methods:

Visual survey/soil sampling: "Look for lemon-shaped, swollen, white females (~0.25mm in diameter) which are visible along the roots from ~30 days after planting or emergence. White females will not be seen before this time but severe stunting of roots and a proliferation of secondary roots could indicate infection. This could be confirmed by extracting cysts from the organic fraction of soil (Shepherd, 1986)" (CABI, 2012).

Key Diagnostics/Identification

CAPS-Approved Method*:

Morphological:

Mulvey (1972) provides a key to 39 species of *Heterodera*, including *H. sacchari*, based on characteristics of cysts.

Sharma and Swarup (1983) provide morphological keys, based on cyst, cone top structures, and second-stage larvae, to cyst nematode species occurring in India, including *H. sacchari*.

A key to cyst nematodes found in Pakistan (including *H. oryzae*, *Globodera pallida*, and *G. rostochiensis*) can be found in Shahina and Maqbool (1995).

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Literature-based Methods:

Biochemical: Nobbs *et al.* (1992) use morphology coupled with esterase banding patterns to separate *H. sacchari, H. elachista, H. oryzicola*, and *H. oryzae*.

Molecular: *Heterodera* species can be identified by sequencing the ITS–rRNA genes and by PCR-RFLP profiles; these tools remain the best available for identifying cyst-forming nematodes (Waeyenberge et al., 2009). Tahna Maafi et al. (2003, 2007) use RFLP of ITS-rRNA and/or sequencing of ITS-rDNA to distinguish cyst nematodes from Iran.

Easily Confused Species

There are four cyst nematode species that infect rice roots: *H. elachista*, *H. oryzae*, *H. oryzicola*, and *H. sacchari* (Handoo, 2008). *Heterodera sacchari* is morphologically similar to *H. elachista*, *H. oryzae*, and *H. oryzicola*. Separation by morphology alone can be difficult. Species are determined by morphology and biochemical characters of diagnostic value (Nobbs et al., 1992).

Tanha Maafi et al. (2007) state that *H. sacchari* is similar morphologically to *H. goldeni* and *H. leuceilyma* (the last of which is found in the United States) and provides morphological information to help distinguish them. All three species have “distinct finger-like projections in the strongly developed underbridge in the vulval cone of the cysts”. All of these species have grasses and other Poaceae as hosts (Tanha Maafi et al., 2007).

Shurtleff and Averre (2000) state that the genera *Cactodera*, *Globodera*, *Punctodera*, and *Sarisodera* all resemble *Heterodera*.

CABI (2012) states that aboveground symptoms caused by this cyst nematode could be confused with nitrogen deficiency or drought stress. Diagnosis should be based on root examination.

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Draft Log

July 26, 2016: Updated mapping information, 'Potential Distribution' section.