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CYST NEMATODES IN EQUATORIAL AND HOT TROPICAL REGIONS

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INTRODUCTION

In the present communication, the term "cyst nematodes in equatorial and tropical regions" is used instead of the usual "tropical cyst nematodes" for two reasons:

- in addition to those species of cyst nematodes that are closely associated with hot tropical crops and areas, there are others that are common in temperate areas which may also be occasionally found in the tropics;

- the topographical meaning of "intertropical" encompasses some mountainous areas, namely in Central and South America, where climate, vegetation and crops are quite similar to those of temperate regions: these are the "cold tropics".

This paper deals only with the "hot tropics", and the term "tropics" and "tropical" refer here only to these climatic regions.

Regarding the earliest records of "*Heterodera*" in equatorial and tropical areas, it must be kept in mind that prior to Chitwood's (1949) resurrection of the ancient generic name *Meloidogyne* Goeldi, 1877, the genus *Heterodera* contained both cyst forming species of Heteroderidae (or *Heterodera* sensu lato) and various root knot species under the name *Heterodera marioni* (Cornu). As most of the early records of "*Heterodera*" in the tropics were given without morphological detail or description of symptoms on the host plant, it is not possible to determine whether the species in question were *Meloidogyne* or cyst-forming species.

Also, there are numerous records of "*Heterodera*-like juveniles" in the literature concerning tropical crops but such juveniles may belong to species of non-cyst forming Heteroderinae genera which also occur in the tropics. For example, in the Ivory Coast *Heterodera*-like juveniles were frequently found in some areas of primary or ancient forests but extensive investigation failed to find cysts. Eventually it was discovered that these juveniles belonged to a non-cyst forming species of Heteroderinae present on some trees and that they represented a new genus and species, subsequently described under the name of *Hylonema ivorense* by Luc et al. (1978). Therefore, records only of "*Heterodera*" juveniles are not considered here.

The first report of a cyst nematode attacking a tropical crop in a tropical area concerns sugar cane in the Hawaiian Islands (Muir and Henderson, 1926). It is clear that there was no confusion with *Meloidogyne* because the authors stated "It is only recently that the two species * [of "*Heterodera*"] have both been recognised in Hawaiian Islands". A description is given of the damage symptoms caused to the host plant by the "two species" and the distinction between *Heterodera* and *Meloidogyne* is clearly stated. Concerning *Heterodera* they say "In sugar cane this nemaode does not show a preference for the tip of roots but attacks them at any point; ... it does not produce a gall on the root". The "brown cyst stage" is also cited.

Muir and Swezey (1926) also recorded "*Heterodera schachtii*" on pine-apple, in the Hawaiian Islands, but here the text is not as clear and doubts remain. These two records are cited again in a later paper by Henderson (1926).

The report of a cyst nematode on sugar cane was not considered seriously by subsequent authors because of the prevailing thought that cyst nematodes were to be found only in temperate areas. For example, in the compilation by Goodey (1956), this record is cited as "*Het. schachtii* = ? *Mel.* sp.".

This "*Heterodera*" has not been reported again in Hawaiian sugar cane plantations and thus the species, and perhaps the genus, remain unknown. However, I consider that it probably was not *H. schachtii*, as sugar cane has been shown to be a non-host for this species (Skarbilovich and Kurramov, 1973).

Thirty five years later, Luc (1961) reported two tropical *Heterodera* species, one parasitising swamp rice in the Ivory Coast and the other sugar cane in the Congo. They were described as *H. oryzae* Luc & Berdon - Brizuela, 1961 and *H. sacchari* Luc & Merny, 1963 and this clearly established that cyst nematodes could occur in the tropics. Subsequently several other species have been described from tropical crops and weeds. Nevertheless, it appears that the cyst-forming nematodes are not as common nor as numerous, and probably not as economically important, in the tropics as they are in temperate areas.

GENUS *HETERODERA* Schmidt, 1871

Heterodera oryzae Luc & Berdon-Brizuela, 1961

H. oryzae was reported from swamp rice fields at Bokakouamekro in the central part of the Ivory Coast (Luc and Berdon-Brizuela, 1981). This species, of the *schachtii* group, is characterised mainly by the presence of a voluminous egg-mass, attached to the cyst, which often contains more eggs than the cyst itself. The original description has been supplemented by Luc and Taylor (1977).

*Prior to the beginning of 1928, only two species of "*Heterodera*" were recognised: *H. schachtii* Schmidt (the cyst-forming species) and *H. marioni* (Cornu) (the root knot species). A third species, *H. javanica* Treub, 1885, also existed but as it was described from an exotic host plant (sugar cane) and from a tropical country (Indonesia) little attention was given to it at that time.

The role of the egg-mass in relation to population dynamics has been studied (Merny, 1966; Merny, 1972a, Reversat, 1975d). Juveniles in the egg-mass hatch immediately without need of a stimulation by root exudates and this enables two or three generations to develop on the same rice plant (Merny, 1972a). This ready hatching of egg-masses facilitates the culture of the nematode, even under monoxenic conditions (Reversat, 1975a). Thus *H. oryzae* has been used to examine various aspects of the biology of *Heterodera* such as ovigenesis and reproduction, which does not differ from other amphimictic species of the genus (Netscher, 1969); histopathology of attacked roots (Berdon-Brizuela and Merny, 1964); factors influencing the sex ratio and sex determination (Cadet et al., 1975; Cadet and Merny, 1978a); genetic factors related to the length of juveniles (Netscher and Pernes, 1971); production of artificial mutants (Cadet, 1976); factors influencing penetration by the juveniles (Reversat and Merny, 1973; Cadet and Merny, 1976; Merny and Cadet, 1978); chemical composition of juveniles (Reversat, 1977a); oxygen uptake by juveniles (Reversat, 1975c; 1977b) and their survival (Reversat, 1980), particularly in anaerobic conditions (Reversat, 1975b).

The species is known only from some swamp areas in the Ivory Coast (Merny, 1970), and in Senegal where it parasitises banana trees (Taylor, 1978). Reports of *H. oryzae* from Japan (Hashioka, 1964; Shimizu, 1971, 1972, 1973; Nishizawa et al., 1972) refer to a different species, described by Ohshima (1974) as *H. elachista*. However, the two species appear to be closely related and their relationships require further study.

In addition to rice and banana, few other plants have been shown to be hosts. Maize and *Mariscus umbellatus* are susceptible (Merny and Cadet, 1978) whereas sugar cane, *Sorghum vulgare*, *Pennisetum typhoides* and *Panicum maximum* are not, and large differences between various rice cultivars have been observed (Merny and Cadet, 1978). This relatively narrow host range could explain the limited distribution of the species. It is also limited in flooded rice fields by competition with *H. sacchari*; experiments with juveniles marked with ^{35}S have shown that *H. oryzae* is much less aggressive than *H. sacchari* (Reversat and Bois, 1982).

Heterodera sacchari Luc & Merny, 1963

H. sacchari, of the *schachtii* group, was originally described from sugar cane in the Niari Valley, Congo (Luc and Merny, 1963). It has subsequently been reported from the Ivory Coast where it has frequently been found in flooded rice fields in the northern and central regions (Merny, 1970), in Nigeria on sugar cane (Jerath, 1968) and wild grasses (Odihirin, 1975), in flooded rice fields of Casamance Province, Senegal and in Gambia (Fortuner and Merny, 1973) and on sugar cane in Burkina Faso (Cadet and Merny, 1978b). The species is also reported to have been found on *Saccharum spontaneum* in India (Swarup et al., 1964).

In addition to sugar cane and rice, various wild Graminaceae are considered as hosts by Odihirin (1975): *Paspalum conjugatum*, *Axonopus compressus*, *Mariscus umbellatus*, *Cynodon dactylon*, *Eleusine indica* and *Brachiaria brizantha*. Odihirin (1975) considers that *H. sacchari* is indigenous in Nigeria and whilst I agree I also think that the area of distribution is probably wider than indicated by present reports.

The morphology of *H. sacchari* has been described and the original description was supplemented by Luc (1974). The major diagnostic character of the species is a very dark, strongly developed underbridge

of the female cyst which has finger-like projections. The apparently non-functional male has been described by Netscher et al. (1969). Netscher (1969) has shown that *H. sacchari* is a triploid parthenogenetic species.

The hatching of juveniles from cysts is similar in sugar cane root diffusate and tap water (Garabedian and Hague, 1984) but Riversat (1981) has found potassium permangate to be useful as a hatching agent. Aldicarb, oxamyl and carbofuran prevent hatching from cysts but this effect is decreased by the addition of sugar cane root diffusate (Garabedian and Hague, 1984).

Jerath (1968) observed that infested sugar cane plants are stunted and thin, and secondary roots are less abundant than healthy plants. In sugar cane plantations, cysts of *H. sacchari* may be transported by the water in irrigation canals for at least 5 to 8 km (Odihirin, 1977).

On rice, experiments show (Babatola, 1983a) that infested plants are chlorotic and their growth retarded, roots are necrotic and blackened, tiller numbers are reduced and the grain yield is lower. *H. sacchari* attacks both swamp and upland rice but the latter appears more susceptible to damage (Babatola, 1983b). Rice cultivars react very differently to infestation by the nematode (Babatola, 1983b).

In western areas of Africa, *H. sacchari* may constitute a danger for sugar cane, and both upland and swamp rice. Foliar applications of oxamyl have been shown experimentally to prevent invasion of young sugar cane plants (Garabedian and Hague, 1982) but field trials have not been reported.

H. cyperi Golden, Rau & Cobb, 1963

H. cyperi was first found infesting *Cyperus esculentus* at Sanford, Florida, USA, and was described by Golden et al. (1963). No other host was known and its distribution was thought to be limited to two countries in Florida and one in Georgia (Mulvey and Golden, 1983). Recently, however, Kumar (1980) recorded it on *Cynodon dactylon* and *Bambusa* sp. in a coffee estate, in Karnataka, India. Eroshenko and Kazachenko (1972) considered it to be a species inquirenda, but there does not seem sufficient reason for this.

Heterodera mothi Khan & Husain, 1965

H. mothi, found on *Cyperus rotundus*, was the first cyst nematode described from India (Khan and Husain, 1965). Cysts of this species, which is of the *goettingiana* group, are characterised by the thinness of their cuticle, the prominence of the anal area, and the slenderness of the vulval bridge. Mulvey (1972) emphasised the fact that the underbridge is rarely present. An egg-sac has been observed (Khan and Jairajpuri, 1975).

Sharma and Swarup (1984) state that this species reproduces only on the type host whereas other records are from *Chrysanthemum carinatum* and *Hibiscus syriacus* in India (Yaqoob and Khan, 1969); *Cyperus esculentus*, *Glycine max*, *Gossypium hirsutum*, in Georgia, USA (Minton et al., 1973); in soil from sugar-beet fields in Iran (Talatschian and Achyani, 1976); sugar cane (Maqbool, 1981) and onion (Maqbool et al., 1983) in Pakistan; and cysts in soil at Viti Levu, Fiji Islands (Kirby et al., 1978).

Sharma and Swarup (1984) gave information on the morphometrics and life cycle of *H. mothi* but nothing is known about its pathogenicity.

H. indocyperi Husain & Khan in Khan et al., 1964 (cited by Hesling, 1978) is considered by Hesling to be a nomen nudum and a synonym of *H. mothi*.

Heterodera cajani Koshy, 1967 (= *H. vigni* Edward & Misra, 1968)

This species, of the *schachtii* group, was first reported under the name of *H. trifolii* in a pigeon-pea field of the IARI at New Delhi, India (Swarup et al., 1964). It was described later as *H. cajani* by Koshy (1967). *H. vigni* described from roots of *Vigna unguiculata* by Edward and Misra (1968) has been recognised (Kalha and Edward, 1979) as a junior synonym of *H. cajani*.

H. cajani is the most widespread cyst-forming nematode in India and has been reported in the states of Andhra Pradesh, Bihar, Delhi, Haryana, Rajasthan, Tamil Nadu and Uttar Pradesh (Sharma and Swarup, 1984). The species has also been reported on cowpea in Egypt (Aboul-Eid and Ghorab, 1974).

On the basis of field observations and experiments by various authors (Koshy, 1967; Koshy and Swarup, 1972; Bhatti and Gupta, 1973; Janarthanan, 1972; Verma and Yadav, 1975; Gaur and Sing, 1977) the following host plants have been established: *Cajanus cajan, Cicer arietinum, Cyamopsis tetragonoloba, Dolichos biflorus, D. lablab, Glycine max, Phaseolus atropurpureus, P. aureus, P. calcaratus, P. lathyroides, P. lunatus, P. mungo, P. vulgaris, Pisum sativum, Sesamum indicum, S. orientale, Vivia narabenesis* cv. *sativa, Vigna sinensis* and *Zea mays*. With the exception of the last species, all these host plants belong to Leguminosae or Pedaliaceae. Koshy and Swarup (1972) established that 82 crop and weed species were non-hosts including *Cyamopsis tetragonoloba, Glycine max, Phaseolus calcaratus, Pisum sativum* cv. Early Wisconsin and several *Vicia* species. The original description of the species has been supplemented by Koshy et al. (1971) and Sharma and Swarup (1984). The biology of *H. cajani* is similar to other *Heterodera* species. Host reactions have been described by Aboul-Eid and Ghorab (1974) and the life cycle by Koshy and Swarup (1971a). More than nine generations per year have been reported (Koshy and Swarup, 1971b). The hatching of juveniles from cysts and egg-masses is optimal at 29°C; root leachates of *Cajanus cajan* and *Dolichos lablab* have a positive effect; hatching of juveniles from egg-masses at 20 days is 100 per cent in contrast to only 16 per cent from brown cysts (Koshy and Swarup, 1971d). The presence of egg-masses, and the rapid hatching of juveniles, explains the high number of generations observed. It has also been observed that *H. cajani* may attack the aerial parts of young seedlings of pigeon-pea (Koshy and Swarup, 1971e).

Although there is no precise data on the damage to crop plants caused by *H. cajani*, it must be considered a dangerous species. Its presence in Egypt shows that it could become established in tropical, subtropical and even Mediterranean countries.

Heterodera graminis Stynes, 1971

H. graminis was described from roots of *Cynodon dactylon* on a bowling green at New Castle, New South Wales, Australia (Stynes, 1971). The species has recently been recorded on undetermined species of grasses on

a golf course at Delhi, Rajasthan, India (Sharma and Swarup, 1984) and has been found in soil at Vanua Levu, Fiji Islands (Kirby et al. 1978) and on *Cynodon dactylon* in a sugar cane plantation in Trinidad (Stone, in litt.).

H. graminis is of the *goettingiana* group, and appears to be closely related to *H. cyperi*.

In pot experiments *H. graminis* reproduced on *Setaria italica, Secale cereale* and maize (Sharma and Swarup, 1984). Nothing is known about its pathogenicity but host plants were described as yellowish and stunted (Kirby et al., 1978; Sharma and Swarup, 1984). Data on the life cycle are given by Sharma and Swarup (1984).

Heterodera zeae Koshy, Swarup & Sethi, 1971

This species of the *schachtii* group was described from specimens found in association with maize at Chapli, Rajasthan, India (Koshy et al., 1971). Surveys showed that *H. zeae* is widely distributed throughout India and in the following states: Andhra Pradesh, Bihar, Delhi, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh (Koshy and Swarup, 1971c) and Karnataka (Narayanaswamy, et al., 1982). Subsequently it was recorded in Pakistan (Maqbool, 1981), in Egypt (Oteifa, unpublished report, 1978), and in the USA (Sardanelli et al., 1981). *H. zeae* is considered to be one of the most economically important nematodes attacking cereals in India (Sharma and Swarup, 1984).

In addition to the original description, data on morphology and morphometrics have been reported from Indian populations by Sharma and Swarup (1984) and for American populations by Golden and Mulvey (1983). Hutzell (1984) has recently described the male. Sharma and Swarup (1984) provide some information on the biology of the species but there has been no published information on pathogenicity. Hosts recorded for *H. zeae* include several cultivars of *Zea mays*, (Misra et al., 1977), *Echinochloa colona, Panicum* spp., *Setaria italica* and *Triticum aestivum*. Experimentally (Srivastava and Swarup, 1975; Sharma and Swarup, 1984) the following plants have been found susceptible to *H. zeae: Oryza sativa, Secale cereale, Sorghum vulgare, Zea mexicana, Avena sativa* and *Hordeum vulgare*. *Sorghum vulgare* was, however, considered resistant by Srivastava and Swarup (1975) as were *Paspalum* spp. and *Pennisetum typhoideum*. Maqbool (1981) reported non-graminaceous crops (gram, citrus, pear, garlic) as hosts, but it is not clear if cysts were found on the roots of these plants or in the surrounding soil.

Heterodera gaembiensis Merny & Netscher, 1976

Heterodera gambiensis, belonging to the *schachtii* group, has been reported on *Sorghum vulgare* and *Pennisetum typhoideum* in various locations in Gambia, West Africa (Merny and Netscher, 1976). Surprisingly, in the Senegalese regions surrounding Gambia, extensive surveys failed to locate this species. It has, however, recently been recorded on *Eleusine caracana* in Karnataka, India (Narayaswamy et al., 1982). There is no information on the biology, host range or pathogenicity of the species.

Heterodera oryzicola Rao & Jayaprakash, 1978

This species of the *schachtii* group is known only from upland rice in Kerala State, India (Rao and Jayaprakash, 1978). Although it has been observed to penetrate the roots of several graminaceous plants, according

to Sharma and Swarup (1984) cysts are produced only on rice, mainly on the cultivars Jaya, Ratna and T (N)-1.

H. oryzicola causes stunting and chlorosis of leaves (Rao and Jayaprakash, 1977) and field experiments indicate yield losses of 21-42 per cent (Usha and Kurien, 1981).

Morphologically *H. oryzicola* is very close to *H. oryzae*, from which it differs mainly in various measurements of the stylet and spicules, and length of the hyaline terminal part of tail of the second stage juvenile (Rao and Jayaprakash, 1978). Sharma and Swarup (1984) provide additional morphometric data and information on the life cycle.

Heterodera delvii Jairajpuri, Khan, Setty & Govindu, 1979

This species, belonging to the *goettingiana* group, was described from "ragi" (*Eleusine coracana*) in Bangalore, Karnataka, India (Jairajpuri, 1979). Other hosts reported by Krishna Prasad et al. (1980) include various *Echinochloa* species, *Sorghum vulgare*, maize, pearl millet, finger millet, *Setaria italica*, wheat and *Panicum miliaceum*.

H. delvii is close to *H. cyperi*, *H. mothi* and *H. graminis*, but differs mainly in the structure of the underbridge which shows a subcircular mass attached to its centre; this is absent in the other species. No information is available on the biology and the pathogenicity of this species. It is not known outside the type location, and attempts to find it again at this site have been unsuccessful (Sharma and Swarup, 1984).

Heterodera sorghi Jain, Sethi, Swarup & Srivastava, 1982

This species, of the *schachtii* group, has been found on *Sorghum vulgare* at Raispur, Utah Pradesh, India (Jain et al., 1982); it has also been recorded, without indication of host, at Hayatpur, Haryana State (Dhawan et al., 1983). In pot experiments *H. sorghi* reproduced on *Echinocloa colona*, *Eleusine caracana*, *Setaria italica*, *Paspalum scrobiculatum*. *Zea mays*, *Cyperus rotundus* and *Pennisetum typhoides* (Sharma and Swarup, 1984).

H. sorghi is characterised by a very thick, prominent and dark brown underbridge. Data on morphometrics and life cycle have been provided by Sharma and Swarup (1984) but nothing is known about its pathogenicity.

Heterodera raskii Basnet & Jayaprakash, 1984

H. raskii was recently described from Hyderabad, India, on *Cyperus bulbosus* Vab., which is presently the only known host (Basnet and Jayaprakash, 1984). It is in the *goettingiana* group and considered to be close to *H. cyperi* Golden et al., 1962. Cysts are very elongated, somewhat resembling those of *Dolichodera* Mulvey & Ebsary, 1980. Nothing is known about pathogenicity or host-parasite relationships.

Other *Heterodera* species

Heterodera schachtii Schmidt, 1871: This typically temperate species has been recorded in Western Tropical Africa in two locations close to each other. In Senegal, *H. schachtii* was found in a small vegetable garden in the centre of Dakar, where it caused damage to beets and cabbage (Luc and Netscher, 1974); extensive surveys in the surrounding area were negative.

It was recorded later in Banjul, Gambia, also on beets (Bridge and Manser, 1980). In both cases, *H. schachtii* was probably introduced from Europe with rooted plants and is not considered to present a danger to crops in Senegal and Gambia.

Heterodera graminophila Golden & Birchfield, 1972: Although found by Golden and Birchfield (1972) outside of a strictly tropical area (Louisiana, USA), *H. graminophila* is cited here as Birchfield (1973) stated that the species "may not be native to the USA since the host plant, *Echinochloa colona* and other closely related forms, are cultivated in tropical Asia and Africa for food". Other hosts are rice and *Sorghum halepense*. *H. graminophila* was said by Birchfield (1973) to be atypical of the genus because of the absence of giant cells at the feeding point within the host root: the females feed in the pericycle and phloem tissues of the host; no galling of root tissues and no foliage symptoms occurred. Birchfield (1973) considered it an example of a well-balanced host-parasite system, possibly indicative of a very old parasite relationship.

H. graminophila belongs to the *goettingiana* group, and is close to *H. cyperi* and *H. graminis*.

Heterodera avenae Wollenweber, 1924: This is a cosmopolitan species present in some warm parts of the world. It has been associated with severe diseases in India known as "molya". Many Indian publications refer to *H. avenae* but it occurs only on temperate cereals such as barley and wheat. On the contrary, tropical cereals such as *Echinochloa colona, Sorghum vulgare, Eleusine coracana, Oryza sativa, Setaria italica, Zea mays* are non-hosts (Gill and Swarup, 1971; Sharma and Swarup, 1984). Thus strictly *H. avenae* does not qualify as a tropical cyst nematode.

Heterodera chaubattia Gupta & Edward, 1973: This species was found in the soil of an orchard at Chaubattia, Uttah Pradesh, India (Gupta and Edward, 1973). This is the only report and Sharma and Swarup (1984) failed to rediscover the nematode at the type locality. Moreover types are apparently not available for study and thus taking into account the discrepancies and lack of information in the original description, Sharma and Swarup (1984) considered *H. chaubattia* to be a species inquirenda.

GENUS *CACTODERA* Krall & Krall, 1979

Cactodera cacti (Filipj. & Sch. Stekh. , 1941) Krall & Krall, 1979

This species was reported on *Echinopsis* spp. in Mysore, India (Kumar, 1964); the nematode could have been introduced with the host plant, which is an ornamental.

Cactodera amaranthi (Stoyanov, 1972) Krall & Krall, 1969

This species was described by Stoyanov (1972) as *Heterodera amaranthi* from roots of *Amaranthus viridis* growing in experimental fields at Santiago de las Vegas, near Hayana, Cuba. Heavy infestation of the host was reported. It was found earlier in Florida by G. J. Rau (unpublished report, 1957). Details of this and subsequent finding are given by Golden and Raski (1978) who also studied the different stages of the nematode.

Hosts are limited to species of *Amaranthus (A. viridis, A. spinosus, A. retroflexus)*. The distribution includes Cuba, Mexico, and the USA

(Florida, Colorado, Illinois, Kansas, Missouri, Tennessee) according to Mulvey and Golden (1983). However, Reis (1982) reported a cyst forming species "closely resembling" *G. amaranthi* and heavily parasitising *Amaranthus patulus* in a citrus orchard near Maputo, Mozambique. Thus, the distribution of this species may be rather wide.

GENUS *GLOBODERA* Skarbilovich, 1959

Globodera rostochiensis (Wollenweber, 1923) Behrens, 1975; *Globodera pallida* (Stone, 1973) Behrens, 1975

The potato cyst nematodes have been reported in tropical countries but only on rare occasions. The first report is that of Tiago (1956) in Mozambique; but at that time the report was considered questionable. In India, *G. rostochiensis* and/or *G. pallida* are considered to be serious pests of potatoes in the Nilgiris region, which is a hilly part of Madras State and does not have a tropical climate (Seshadri and Sivakumar, 1962; Prasad and Chawla, 1965; Logisvaran and Menon, 1969). Sharma and Swarup (1983) report the presence of both species in Tamil Nadu State, the southernmost state of India and tropical. *G. rostochiensis* had also been recorded in South Africa, where its distribution appears to be restricted to the Transvaal (Kleynhans, personal communication).

Apparently, *G. rostochiensis* and *G. pallida* are not adapted to the tropics; they may survive in some locations (as does *H. schachtii*) but they do not pose as severe a threat to potato crops in hot tropical areas as do various root-knot nematode species.

GENUS *AFENESTRATA* Baldwin & Bell, 1985

Afenestrata africana (Luc, Germani & Netscher, 1973) Baldwin & Bell, 1985)

A. africana was described by Luc et al. (1973) as the second species of *Sarisodera* Wouts & Sher, 1971, as the two species apparently shared several important characters including the presence of cysts devoid of fenestra and a peculiar vulval cone formed by the hypertrophied and very protuberant vulval lips. Restudy of the type species, *Sarisodera hydrophila* Wouts & Sher, 1971, by Baldwin and Bell (1985) led these authors to consider that the females do not transform into cysts; consequently, they erected the genus *Afenestrata* (with cysts), distinct from *Sarisodera* (without cysts).

Morphology, caryology (n = 9, as in many Heteroderinae) and histology of the syncytium produced by *A. africana* are well documented (Luc et al., 1973; Taylor and Luc, 1979; Baldwin and Bell, 1985). The only reported host is Guinea grass *Panicum maximum*, and the only location is the type locality - Experimental Fields, ORSTOM Centre, Adiopodoume near Abidjan, Ivory Coast. However, *A. africana* came from Kenya, East Africa and the location in the Experimental Fields where the nematode was found had been planted with rooted seedlings of Guinea grass obtained by plant breeders during an expedition in Kenya.

Because of this no further investigations of *A. africana* have been undertaken and the original field was treated with a nematicide, then planted with a non-graminaceous crop. A population of *A. africana* was transferred to a greenhouse at the Nematology Laboratory, ORSTOM Centre, to be used only for taxonomic or anatomical studies.

CONCLUSION

This paper somewhat resembles a catalogue and it is difficult to separate into sections. Nevertheless, the following tentative collective conclusions can be made:

- with a few exceptions, among the genera of cyst-forming Heteroderinae found in temperate climates, only species pertaining to the genus *Heterodera* have been reported in the hot tropical climates;

- the twelve *Heterodera* species considered herein as tropical belong to only two groups of the genus: the *schachtii* group (*oryzae, sacchari, cajani, zeae, gamgiensis, oryzicola* and *sorghi*), and the *goettingiana* group (*cyperi, mothi, graminis, delvii* and *raskii*);

- all these species with the exception of *H. mothi* and *H. cajani* show a clear host preference for graminaceous plants; several of them have been described from, or experimentally raised on, rice but it must be kept in mind that rice is the most cultivated cereal in the tropics, and consequently the most frequently sampled;

- these species, with a few exceptions, have been reported only in West Africa and in India but this could not be considered conclusive in relation to geographical distribution because there are no negative reports from other tropical parts of the world;

- currently, only the genus *Afenestrata* can be considered as strictly tropical;

- with the limited information on the biology of these species, it can be stated that the optimal temperature for hatching is rather high, and there are several generations per year, this being correlated in several species with the presence of a voluminous egg-mass attached to the cyst;

- as far as present research observations permit, it may be assumed that only *H. cajani, H. oryzicola, H. zeae* and to some extent *H. sacchari* are dangerous species;

- cyst forming Heteroderinae appear less important in tropical climates than in temperate areas but research on the group should not be neglected because of their presence on various important crops, particularly cereals.

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DISCUSSION

Noel stated that, according to data of Dr W. Hadisoeganda, *H. glycines* is present in Indonesia as are other species of the genus and he asked in what way *H. glycines* is related to *H. cajani*. Golden responded that although the two species are closely related they are distinct, largely on the basis of structure of the cyst wall. Stone stated that populations of *H. oryzicola* he is studying with Dr A. K. Koshy are very close, if not identical, to *H. oryzae;* they attack both rice and banana-trees, as does *H. oryzae*. Stone also stated that *H. chaubattia* is probably a junior synonym of *Globodera mali*.

B'Chir reported that cyst nematodes are not economically important in Tunisia, as compared with *Meloidogyne* or *Pratylenchus*, reflecting the general situation in the tropics, but *Globodera* species can be a problem when potatoes are grown continuously. This led to a discussion about the effect of temperature on the behaviour of potato cyst nematodes from which it was concluded that, based on observations in various countries e.g. New Zealand, Tunisia, Pakistan, they become inactive when soil temperatures exceed 30°C but they may nevertheless constitute a problem in cooler seasons.

Edongali stated that the *H. trifolii* reported in Libya does not attack subterranean clover and in response to a question by Luc he said that *H. latipons* has not yet been recorded in Libya, whereas it is present in Tunisia.