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Biochemical and molecular characterization of plant-parasitic nematodes

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Summary. Nematologists need correct species identification to carry out research, teaching, extension and other activities. Therefore, nematode taxonomy must be pursued diligently at all levels. The identification of plant-parasitic nematodes is not always easy and that of some species is especially difficult. Most of the information that nematologists use when characterizing and identifying specimens is based on morphological and morphometrical characters. Although these characters are of primary importance, in the last three decades they have been supplemented by biochemical/molecular characters. Biochemical approaches include the separation of proteins (general proteins and isozymes) by one-dimensional gel electrophoresis, isoelectric focusing, two-dimensional gel electrophoresis, and sodium dodecyl sulphate-capillary gel electrophoresis. Serology has also been found effective in the identification and quantification of nematodes, monoclonal antibodies being a more useful immunological tool than polyclonal antibodies. Identification based on the direct examination of DNA is potentially a more powerful method to characterize inter- and intra-specific variability. The development of techniques such as the polymerase chain reaction, restriction fragment length polymorphism, randomly amplified polymorphic DNA, and amplified fragment length polymorphism has increased the accuracy and speed of nematode characterization/identification. Progress continues to be made and more and more nematologists are using molecular techniques for diagnostic purposes and to assess genetic variation.

Key words: biochemistry, DNA, phytoparasitic nematodes, serology

Introduction

The identification of plant-parasitic nematodes is not always easy, particularly in the case of some taxa. Identification is even more complicated when two or more species occur in the same sample. The faulty characterization and identification of species that are economically important may lead to inappropriate control measures being taken. To overcome these problems the characterization and identification of nematodes should be based not only on morphological and morphometrical characters and on host range bioassays, which are of primary importance, but also on protein and nucleic acid profiles.

Biochemical and molecular techniques have been a research priority with nematologists over the past 30 years, and several reviews on the application of such techniques to nematology have

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been published (Hussey, 1979; Platzer, 1981; Fox and Atkinson, 1986; Curran, 1991; Hyman and Powers, 1991; Williamson, 1991; Curran and Robinson, 1993; Hyman, 1996; Jones *et al*., 1997; Powers and Fleming, 1998).

This review attempts to summarize the information available concerning biochemical and molecular markers that have been used in the characterization and identification of plant-parasitic nematodes.

Protein-based characterization

Since the 1960s a wide range of electrophoretic techniques have been developed to detect protein variation: one-dimensional gel electrophoresis for the separation of proteins (general proteins and isozymes); isoelectric focusing (IEF) for protein fractionation (general proteins and isozymes); two-dimensional gel electrophoresis (2-DGE) for electrophoretic resolution of proteins; and sodium dodecyl sulphate-capillary gel electrophoresis (SDS-CGE) for the separation of micro-amounts of proteins and peptides.

One-dimensional gel electrophoresis was the first of these techniques to be applied in nematology, in order to differentiate *Ditylenchus* from *Panagrellus* (Benton and Myers, 1966) and from four *Meloidogyne* species (Dickson *et al*., 1970). Since then, there have been several studies based on proteins, using non-denaturing conditions, to differentiate species, races or pathotypes of: cyst nematodes (mainly *Heterodera avenae, H. glycines, H. schachtii* and *H. trifolii*); *Globodera* (especially the potato cyst nematodes [PCN] *G. pallida* and *G. rostochiensis*); root-knot nematodes (RKN) (especially the four common species, *Meloidogyne arenaria*, *M. hapla*, *M. incognita* and *M. javanica*); and some other plant-parasitic nematodes, *Aphelenchoides, Aphelenchus, Ditylenchus,* and *Radopholus* (Table 1).

One-dimensional SDS gel electrophoresis of proteins has also been used to distinguish species and races of several groups of plant-parasitic nematodes, including cyst nematodes, PCN, RKN, *Aphelenchoides, Ditylenchus, Pratylenchus,* and *Radopholus* (Table 2).

Protein profiles provide a wealth of information but they are often difficult to interpret. Specific enzymes or isozymes can be localized using the appropriate staining procedures and have been effective in discriminating species of several groups of plant-parasitic nematodes (Table 3), including infraspecific groups such as *Heterodera glycines* (Lee *et al*., 1988) and *Radopholus similis* (Huettel *et al*., 1983a, b). Analysis of a number of isozymes: 24 oxidoreductases; 8 transferases; 19 hydrolases; 7 lyases; and 5 isomerases (Table 4) has shown that characteristic isozyme patterns can identify species. Among all these enzymatic systems, the band patterns of carboxylesterase (EC 3.1.1.1), usually referred to as non-specific esterase, are particularly useful to differentiate plant-parasitic nematode species. Other isozymes, such as aspartate transaminase (EC 2.6.1.1), fumarate hydratase (EC 4.2.1.2), glucose-6-phosphate isomerase (EC 5.3.1.9), malate dehydrogenase (EC 1.1.1.37), phosphoglucomutase (EC 5.4.2.2) and superoxide dismutase (EC 1.15.1.1), also distinguish some species.

Esterase phenotypes have been obtained from several populations of 36 species of *Meloidogyne*. The most common esterase phenotypes are designated A2, A3, H1, I1, and J3, according to Esbenshade and Triantaphyllou (1985). These phenotypes are associated with most of the populations in all the four major species, *M. arenaria* (A2, A3), *M. hapla* (H1), *M. incognita* (I1) and *M. javanica* (J3).

Another technique for nematode characterization and identification is isoelectric focusing (IEF), which is a modification of the standard electrophoretic technique. With IEF the proteins are separated on the basis of their charge and resolved into sharp bands. This technique does not register some of the variations observed with other methods, but still provides a large amount of data. IEF of proteins was sensitive enough to identify the two species of potato cyst nematodes. Two species-specific proteins, located at pI 5.7 and pI 5.9, can be used to identify *G. pallida* and *G. rostochiensis*. The intensity of the bands has been shown to be directly proportional to the number of eggs and second-stage juveniles in a sample of cysts. Thus it can be used to indicate the proportions of species present in a field, and potentially to determine the level of infestation in field soils (Fleming and Marks, 1982, 1983). Most IEF protein studies have concentrated on PCN, with oth-

er nematodes receiving less attention (Table 5).

The application of enzyme staining techniques to proteins differentiated by IEF limits the number of bands that are visualised. Several studies have been carried out on plant-parasitic nematodes using isozymes and IEF (Table 6).

Two-dimensional gel electrophoresis (2-DGE) is a considerably more informative representation of proteins in a nematode extract, although the preparation and analysis of the gels can be technically demanding. It has been used to examine inter- and intra-specific differences in proteins of *Ditylenchus*, *Globodera, Heterodera* and *Meloidogyne* (Table 7).

SDS-capillary gel electrophoresis (SDS-CGE) differentiates microscopic amounts of proteins and peptides. High-performance capillary electrophoresis is still in a developmental stage. When it was tried out to discriminate populations and pathotypes within *G. rostochiensis* and *G. pallida*, it detected differences in protein profiles between pathotypes Ro1, Ro2, Ro5, Pa1, and Pa2/3 (Hinch *et al*., 1998; Cunha *et al*., 2002). Capillary electrophoresis is simple and more reproducible than 2-DGE and is suitable for the automated analysis of large numbers of samples. This technique will be useful to identify polypeptides of interest for future sequencing and molecular cloning. It should thus lead more quickly to development of probes for species-specific or pathotype-specific components.

Immunological approaches to the nematode diagnostics of *Bursaphelenchus*, *Ditylenchus*, *Globodera*, *Heterodera*, and *Meloidogyne* have included those using polyclonal antibodies (PAbs) which recognize multiple antigenic determinants in nematodes (Webster and Hooper, 1968; Scott and Riggs, 1971; Wharton *et al*., 1983; Davies and Lander, 1992; Lawler and Harmey, 1993; Kennedy *et al*., 1997; Masler, 2002). However, the general cross-reactivity of polyclonal antisera limits their value in species-diagnosis. Problems with PAbs led to the development of tests based on monoclonal antibodies (MAbs), which exhibit greater antigenic specificity and need only small amounts of antigen (50–200 μg) to be produced (Torrance, 1995). Though monospecific, they can be mass-produced and purified, and frozen cell-lines can be stored for long periods of time. However, they have some disadvantages: a long time is required to select useful MAbs, and the cell-lines from which they are produced are not stable.

Species-specific MAbs have been produced against: *H. avenae* and *H. glycines* (Atkinson *et al*., 1988; Curtis *et al*., 1997); *G. rostochiensis* and *G. pallida* (Bakker *et al*., 1988; Schots *et al*., 1989, 1992; Backett *et al*., 1993; Robinson *et al*., 1993; De Boer *et al*., 1996; Cotroneo and Gotta, 1997); *M. incognita* and *M. javanica* (Jones *et al*., 1988; Davies *et al*., 1996; Fujiwara *et al*., 1997). The serodiagnosis of RKN using MAbs appears to be less straightforward than that of PCN, probably because RKN reproduce parthenogenetically. From 281 MAbs produced to females of *M. javanica*, no antibody was found to be species-specific when screened against females of *M. arenaria, M. incognita* and *M. javanica* (Davies and Lander, 1992). In an attempt to differentiate *M. incognita* from *M. javanica*, species-specific esterase bands were purified and MAbs produced; although it is now possible to differentiate these 2 species, the MAbs also cross-react with other RKN (Davies *et al*., 1996; Ibrahim *et al*., 1996).

Immunoassays in the form of an ELISA are an excellent method to quantify plant-parasitic nematodes. MAbs were used to quantify the two species of PCN from clean extracts of cysts and from clean cysts (Schots *et al*., 1992; Robinson *et al*., 1993). Attempts have been made to quantify nematodes, mainly PCN, directly in soil homogenates, although some level of nematode extraction from the soil is necessary here (Davies and Carter, 1995; Evans *et al*., 1995; Davies, 1997; Curtis *et al*., 1998). MAbs that showed species-specific recognition of *H. avenae* and PCN identified and quantified cysts from processed soil samples and from soil samples containing up to 14–20% of organic matter (Curtis *et al*., 1997, 1998). The serological quantification of *Meloidogyne* spp. in roots has also been achieved using MAbs (Robinson, 1989).

DNA-based characterization

The first report of a DNA technique used for taxonomic purposes was probably in 1985 when Curran *et al*. analysed fragments of genomic DNA with restriction enzymes to differentiate

M. arenaria from *M. javanica* and other non-plant-parasitic nematodes. However, this method: 1) was time-consuming; 2) required a substantial amount of DNA; 3) was not sensitive; and 4) exploited only a small proportion of the genetic variation present in the genome. The development of the polymerase chain reaction (PCR) made it possible to discriminate when only minute amounts of material were available, such as, for example, single juveniles of RKN (Powers and Harris, 1993). PCR is characterized by the three Ss: selectivity, sensitivity and speed (Arnheim and Erlich, 1992).

A wide range of DNA-based techniques are available to detect genetic variations that can be exploited or adapted for taxonomic and diagnostic purposes (Curran, 1991; Curran and Robinson, 1993; De Giorgi *et al*., 1994; Vrain and McNamara, 1994; Hyman and Whipple, 1996; Powers and Fleming; 1998).

The amplification of specific genomic regions is a highly effective way of detecting inter- and intra-specific variations between genera and species, and within species. The two most common repeated regions for taxonomic and diagnostic purposes are in ribosomal DNA (rDNA) and in mitochondrial DNA (mtDNA). PCR amplification of the Internal Transcribed Spacer Regions (ITS 1 and ITS 2) combined with restriction enzyme analysis (PCR-RFLP) is a powerful tool for nematode diagnostics. It has been used to characterize several species of Tylenchida, *Longidorus, Paralongidorus, Xiphidorus,* and *Xiphinema* (Table 8).

Another technique, Randomly Amplified Polymorphic DNA (RAPD), extended DNA analysis to characterize a wide range of organisms (Williams *et al*., 1990). The power of RAPD-PCR is in its ability to detect DNA sequence variation without the need for prior DNA sequence information. RAPD-PCR has been used for interspecific, and especially intra-specific discrimination, particularly of *Globodera* and *Meloidogyne* species (Table 9).

Amplified fragment length polymorphism (AFLP) is used to detect and evaluate genetic variation and can screen the whole genome (Vos *et al*., 1995). Qualitative and quantitative analysis has been used to assess genetic relationships mainly among populations of cyst nematodes, PCN and RKN (Xue *et al*., 1993; Folkerstma *et al*., 1996a, b; Jones and Harrower, 1998; Van der Beek *et al*., 1998; Kaplan *et al*., 1999; Semblat *et al*., 1998, 2000; Wang *et al*., 2001; Dautova *et al*., 2002).

Other DNA-based techniques, such as Microsatellites or Single Sequence Repeats (SSRs), Satellite DNA (satDNA), Sequence Characterized Amplified Regions (SCARs), PCR-Single-Strand Conformational Polymorphism (PCR-SSCP), and DNA microarrays have been used to characterize *Bursaphelenchus*, *Ditylenchus*, *Globodera*, *Heterodera*, and *Meloidogyne* (Table 10).

Concluding remarks

Protein analysis is an effective tool for the characterization and identification of plant-parasitic nematodes; antibody-based systems offer a great potential for the qualitative and quantitative analysis of nematode samples and the direct examination of genetic material or DNA analysis is potentially the most powerful method for nematode diagnosis and the most sensitive means to measure genetic variability. It is expected that more accurate methods of nematode characterization and identification will be developed. For the differentiation of taxa, a multidisciplinary system is probably more appropriate than any single approach.

Table 1. Plant-parasitic nematode species characterized on the basis of proteins, using one-dimensional native gel electrophoresis.

Species	Reference
Aphelenchoides fragariae	Gysels, 1968[a]
A. ritzemabosi	Eriksson and Granberg, 1969
Aphelenchus avenae	Dickson *et al.*, 1970; Evans, 1971
Ditylenchus destructor	Evans, 1971
D. dipsaci	Eriksson and Granberg, 1969; Dickson *et al.*, 1970; Hussey and Krusberg, 1971[b]
D. myceliophagus	Evans, 1971
D. triformis	Benton and Myers, 1966; Dickson *et al.*, 1970; Hussey and Krusberg, 1971[b]
Globodera "mexicana"	Greet, 1972[c]; Greet and Firth, 1977[d]
G. pallida	Greet and Firth, 1977[d]; Franco, 1979[d]; Stegemann *et al.*, 1982[f]
G. rostochiensis	Trudgill and Carpenter, 1971[e]; Greet, 1972[c]; Trudgill, 1972; Trudgill and Parrot, 1972[c]; Greet and Firth, 1977[d]; Franco, 1979[d]; Stegemann *et al.*, 1982[f]
G. solanacearum	Greet, 1972[c]; Greet and Firth, 1977[d]
G. tabacum	" "
G. virginiae	" "
Heterodera avenae	Trudgill and Carpenter, 1971[e]; Stone and Williams, 1974[d]; Shashi *et al.*, 1999
H. cajani	Shashi *et al.*, 1999
H. carotae	Trudgill and Carpenter, 1971[e]
H. glycines	Dickson *et al.*, 1970; Ishibashi, 1970[d]; Pozdol *et al.*, 1981; Pozdol and Noel, 1984[b]; Lee *et al.*, 1988
H. graminis	Shashi *et al.*, 1999
H. lespedezae	Pozdol and Noel, 1984[b]
H. oryzae	Ishibashi, 1970[d]
H. schachtii	Trudgill and Carpenter, 1971[e]; Pozdol and Noel, 1984[b]
H. sorghi	Shashi *et al.*, 1999
H. trifolii	Trudgill and Carpenter, 1971[e]; Pozdol and Noel, 1984[b]
H. zeae	Shashi *et al.*, 1999
Meloidogyne arenaria	Dickson *et al.*, 1970; Hussey *et al.*, 1972[d]; Bergé and Dalmasso, 1975[e]; Dalmasso and Bergé, 1978[f]
M. hapla	Dickson *et al.*, 1970; Ishibashi, 1970[d]; Bergé and Dalmasso, 1975[e], 1976; Dalmasso and Bergé, 1978[f]
M. incognita	Dickson *et al.*, 1970; Ishibashi, 1970[d]; Hussey *et al.*, 1972[d]; Bergé and Dalmasso, 1975[e]; Dalmasso and Bergé, 1978[f]; Castagnone-Sereno *et al.*, 1995b
M. javanica	Dickson *et al.*, 1970; Bergé and Dalmasso, 1975[e]; Dalmasso and Bergé, 1978[f]; Erba and Dickson, 1979
M. mali	Ishibashi, 1970[d]
M. naasi	Dalmasso and Bergé, 1978[f]
Radopholus similis	Huettel *et al.*, 1983b

[a] Cited in Platzer (1981).
[b] Cited inWilliamson (1991).
[c] Cited in Hyman and Powers (1991).
[d] Cited in Fox and Atkinson (1986).
[e] Cited in Jones *et al.* (1997).
[f] Cited in Powers and Fleming (1998).

Table 2. Plant-parasitic nematode species characterized on the basis of proteins, using one-dimensional SDS gel electrophoresis.

Species	Reference
Aphelenchoides arachidis	Ibrahim *et al.*, 1994b
A. besseyi	"
A. bicaudatus	"
A. fragariae	"
A. hamatus	"

(*continued on the next page*)

Table 2. (*continued*)

Species	Reference
Ditylenchus angustus	Ibrahim *et al.*, 1994b
D. dipsaci	Tenente and Evans, 1997
D. myceliophagus	Ibrahim *et al.*, 1994b
Globodera pallida	Den Nijs and Lock, 1990
G. rostochiensis	”
Heterodera glycines	Pozdol and Noel, 1984[a]
H. carotae	Bossis, 1991
H. cruciferae	”
H. lespedezae	Pozdol and Noel, 1984[a]
H. schachtii	”
H. trifolii	”
Pratylenchus coffeae	Jaumot *et al.*, 1997
P. crenatus	Ibrahim *et al.*, 1995
P. fallax	”
P. goodeyi	Jaumot *et al.*, 1997
P. neglectus	Ibrahim *et al.*, 1995
P. penetrans	”
P. pinguicaudatus	”
P. scribneri	Jaumot *et al.*, 1997
P. thornei	Ibrahim *et al.*, 1995; Jaumot *et al.*, 1997
P. vulnus	Jaumot *et al.*, 1997
Radopholus similis	Huettel *et al.*, 1983b; Jaumot *et al.*, 1997

[a] Cited in Williamson (1991).

Table 3. Plant-parasitic nematode species characterized on the basis of isozymes, using one-dimensional native gel electrophoresis.

Species	Reference
Anguina agrostis	Riley *et al.*, 1988[a]
A. funesta	”
A. tritici	”
Aphelenchoides arachidis	Ibrahim *et al.*, 1994b
A. besseyi	”
A. bicaudatus	”
A. fragariae	”
A. hamatus	”
Aphelenchus avenae	Dickson *et al.*, 1970; Evans, 1971; Ali *et al.*, 1999b
Bursaphelenchus mucronatus	De Guiran *et al.*, 1985
B. xylophilus	”
Ditylenchus angustus	Ibrahim *et al.*, 1994b
D. destructor	Evans, 1971
D. dipsaci	Dickson *et al.*, 1971[b]; Hussey and Krusberg, 1971[a]
D. myceliophagus	Evans, 1971; Ibrahim *et al.*, 1994b
D. triformis	Dickson *et al.*, 1971[b]; Hussey and Krusberg, 1971[a]
Heterodera avenae	Bergé *et al.*, 1981[c]; Dalmasso *et al.*, 1982[c]; Bossis and Rivoal, 1989; Ganguly *et al.*, 1990; Molinari *et al.,* 1996; Romero *et al.*, 1996; Shashi *et al.*, 1999; Mokabli *et al.*, 2001
H. cajani	Ganguly *et al.*, 1990; Meher *et al.*, 1998; Shashi *et al.*, 1998a, b, c, 1999;
H. cruciferae	Molinari *et al.*, 1996
H. elachista	Nobbs *et al.*, 1992
H. filipjevi	Mokabli *et al.*, 2001
H. glycines	Dickson *et al.*, 1971[b]; Lee *et al.*, 1988; Molinari *et al.*, 1996
H. goettingiana	Molinari *et al.*, 1996

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Table 3. (*continued*)

Species	Reference
H. graminis	Meher *et al.*, 1998; Shashi *et al*., 1999
H. latipons	Mokabli *et al*., 2001
H. mani	Mokabli *et al*., 2001
H. oryzae	Nobbs, 1992; Nobbs *et al*., 1992
H. oryzicola	Nobbs *et al*., 1992
H. sacchari	Nobbs, 1992; Nobbs *et al*., 1992
H. schachtii	Molinari *et al*., 1996
H. sorghi	Ganguly *et al*., 1990; Meher *et al*., 1998; Shashi *et al*., 1999
H. trifolii	Molinari *et al*., 1996
H. zeae	Meher *et al.*, 1998; Shashi *et al*., 1998b, c, 1999
Longidorus arthensis	Lamberti *et al*., 2001b
L. elongatus	”
L. helveticus	”
L. macrosoma	”
L. profundorum	”
L. raskii	”
Meloidogyne ardenensis	Karssen and Van Hoenselaar, 1998
M. arenaria	Dickson *et al*., 1971[b]; Hussey *et al*., 1972[c]; Bergé and Dalmasso, 1975[d], 1976; Starr, 1979[i]; Janati *et al*., 1982[c]; Esbenshade and Triantaphyllou, 1985, 1986, 1987[b]; Lopez, 1985; Fargette, 1987b[e], 1988; Pais and Abrantes, 1989[g]; Fargette and Braaksma, 1990[f]; Cenis *et al*., 1992; Ibrahim and Perry, 1993; Davies and Beadle, 1995[e]; Carneiro *et al*., 1996, 2000; Williamson *et al*., 1997[e]; Yaegashi and Toida, 1997; Chen *et al*., 1998; Semblat *et al*., 2000; Navas *et al*., 2001; Castro *et al*., 2003; Cetintas *et al*., 2003
M. artiellia	Karssen and Van Hoenselaar, 1998; Castillo *et al*., 2003
M. baetica	Castillo *et al*., 2003
M. carolinensis	Esbenshade and Triantaphyllou, 1985
M. chitwoodi	Esbenshade and Triantaphyllou, 1985, 1987[b]; Karssen, 1995, 1996[h]; Karssen *et al*., 1995[e]; Van der Beek *et al*., 1997[e]; Williamson *et al*., 1997[e]; Karssen and Van Hoenselaar, 1998; Waeyenberge and Moens, 2001
M. coffeicola	Carneiro *et al*., 2000
M. cruciani	Esbenshade and Triantaphyllou, 1985
M. deconincki	Karssen and Van Hoenselaar, 1998
M. duytsi	Karssen and Van Hoenselaar, 1998; Karssen *et al*., 1998b[h]
M. enterolobii	Esbenshade and Triantaphyllou, 1985; Ibrahim and Perry, 1993
M. exigua	Lopez, 1985; Carneiro *et al*., 1996, 2000
M. fallax	Karssen, 1996[h]; Van der Beek *et al*., 1997[e]; Waeyenberge and Moens, 2001
M. graminicola	Esbenshade and Triantaphyllou, 1985, 1987[b]; Ibrahim and Perry, 1993; Carneiro *et al*.,1996, 2000
M. graminis	Esbenshade and Triantaphyllou, 1987[b]
M. hainanensis	Liao and Feng, 1995
M. hapla	Ishibashi, 1970[c]; Dickson *et al*., 1971[b]; Bergé and Dalmasso, 1975[d], 1976; Dalmasso and Bergé, 1978[e]; Starr, 1979[i]; Esbenshade and Triantaphyllou, 1985, 1986, 1987[b]; Lopez, 1985; Ganguly and Dasgupta, 1989; Pais and Abrantes, 1989[g]; Cenis *et al*., 1992; Ibrahim and Perry, 1993; Karssen *et al*., 1995[e]; Carneiro *et al*., 1996, 2000; Karssen and Van Hoenselaar, 1998; Van der Beek *et al*., 1997[e]; Williamson *et al*., 1997[e]; Chen *et al*., 1998; Molinari, 2001; Navas *et al*., 2001
M. haplanaria	Eisenback *et al.*, 2003
M. hispanica	Janati *et al*., 1982[c]; Esbenshade and Triantaphyllou, 1985; Pais and Abrantes, 1989[g]; Fargette, 1987b[e]
M. incognita	Ishibashi, 1970[c]; Dickson *et al*., 1971[b]; Hussey *et al*., 1972[c]; Hussey and Sasser, 1973[i]; Bergé and Dalmasso, 1975[d]; Dalmasso and Bergé, 1978[e]; Starr, 1979[i]; Janati *et al*., 1982[c]; Esbenshade and Triantaphyllou, 1985, 1986, 1987[b]; Lopez, 1985; Fargette, 1987a[d], b[e], 1988; Ganguly and Dasgupta, 1989; Pais and Abrantes, 1989[g]; Fargette and Braaksma, 1990[f]; Rajasekhar *et al*., 1990; Cenis *et al*., 1992; Ganguly and Sharma, 1992; Ibrahim and Perry, 1993; Davies and Beadle, 1995[e]; Carneiro *et al*., 1996, 2000; Williamson *et al*., 1997[e]; Chen *et al*., 1998; Suchitra and Ganguly, 1999; Semblat *et al*., 2000; Molinari, 2001; Navas *et al*., 2001; Castro *et al*., 2003

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Table 3. (*continued*)

Species	Reference
M. javanica	Dickson *et al*., 1971[b]; Bergé and Dalmasso, 1975[d]; Dalmasso and Bergé, 1978[e]; Starr, 1979[i]; Janati *et al*., 1982[c]; Esbenshade and Triantaphyllou, 1985, 1986, 1987[b]; Fargette, 1987b[e], 1988; Ganguly and Dasgupta, 1989; Pais and Abrantes, 1989[g]; Fargette and Baarksma, 1990[f]; Rajasekhar *et al*., 1990; Cenis *et al*., 1992; Ibrahim and Perry, 1993; Tomaszewski *et al*., 1994; Abrantes *et al*., 1995; Davies and Beadle, 1995[e]; Carneiro *et al*., 1996, 2000; Williamson *et al*., 1997[e]; Yaegashi and Toida, 1997; Chen *et al*., 1998; Molinari, 2001; Castro *et al*., 2003; Cetintas *et al*., 2003
M. konaensis	Carneiro *et al*., 2000
M. kralli	Karssen and Van Hoenselaar, 1998; Karssen and Grunder, 2002
M. lusitanica	Pais and Abrantes, 1989[g]; Abrantes and Santos, 1991[h]
M. mali	Ishibashi, 1970[c]
M. maritima	Karssen and Van Hoenselaar, 1998; Karssen *et al*., 1998a[h]
M. mayaguensis	Carneiro *et al*., 2000, 2001
M. megadora	Abrantes *et al*., 1995
M. microcephala	Esbenshade and Triantaphyllou, 1985, 1986, 1987[b]
M. microtyla	Esbenshade and Triantaphyllou, 1985, 1987[b]
M. naasi	Dalmasso and Bergé, 1978[e]; Esbenshade and Triantaphyllou, 1985, 1987[b]; Karssen and Van Hoenselaar, 1998
M. oryzae	Esbenshade and Triantaphyllou, 1985; Carneiro *et al*., 2000
M. paranaensis	Carneiro *et al*., 2000; Castro *et al.,* 2003
M. platani	Esbenshade and Triantaphyllou, 1985
M. querciana	Esbenshade and Triantaphyllou, 1985
M. salasi	Lopez, 1985
Nacobbus aberrans	Baldwin and Cap, 1992; Doucet and Gardenal, 1992; Jatala *et al*., 1993; Doucet *et al*., 2002
Pratylenchus crenatus	Ibrahim *et al*., 1995
P. fallax	”
P. neglectus	”
P. penetrans	”
P. pinguicaudatus	”
P. thornei	”
Radopholus similis	Huettel *et al*., 1983a; Sarah, 1997
Rotylenchulus reniformis	Rao *et al*., 1998

[a] Cited in Williamson (1991).
[b] Cited in Hyman and Powers (1991).
[c] Cited in Fox and Atkinson (1986).
[d] Cited in Jones *et al*. (1997).
[e] Cited in Powers and Fleming (1998).
[f] Cited in Hyman (1996).
[g] Cited in Curran and Robinson (1993).
[h] Cited in Karssen and van Hoenselaar (1998).
[i] Cited in Platzer (1981).

Table 4. Enzymes used in the electrophoretic analysis of plant-parasitic nematodes.

Enzyme	EC Number[a]
Oxidoreductases	
Alcohol dehydrogenase	1.1.1.1
Amine oxidase (flavin-containing) (= monoamine oxidase)	1.4.3.4
Catalase	1.11.1.6
Cytochrome-*c* oxidase	1.9.3.1
Cytochrome-*b* 5-reductase (= diaphorase)	1.6.2.2

(*continued on the next page*)

Table 4. (*continued*)

Enzyme	EC Number[a]
D-Aspartate oxidase	1.4.3.1
Dihydrolipoyl dehydrogenase (= lipoamide dehydrogenase)	1.8.1.4
Galactose 1-dehydrogenase	1.1.1.48
Glucose-6-phosphate 1-dehydrogenase	1.1.1.49
Glucose oxidase	1.1.3.4
Glutamate dehydrogenase	1.4.1.2
Glyceraldehyde-3-phosphate dehydrogenase(phosphorylating)	1.2.1.12
Glycerol-3-phosphate dehydrogenase (NAD^+) (= α-glycerophosphate dehydrogenase)	1.1.1.8
Isocitrate dehydrogenase ($NADP^+$)	1.1.1.42
L-Iditol 2-dehydrogenase (= sorbitol dehydrogenase)	1.1.1.14
L-Lactate dehydrogenase	1.1.1.27
Leucine dehydrogenase	1.4.1.9
Malate dehydrogenase	1.1.1.37
Malate dehydrogenase (oxaloacetate-decarboxylating) ($NADP^+$) (= malic enzyme)	1.1.1.40
Peroxidase	1.11.1.7
Phosphogluconate dehydrogenase (decarboxylating)	1.1.1.44
Succinate dehydrogenase (ubiquinone)	1.3.5.1
Superoxide dismutase	1.15.1.1
Xanthine dehydrogenase	1.1.1.204
Transferases	
Adenylate kinase	2.7.4.3
Alanine transaminase (= alanine aminotransferase = glutamate pyruvate transaminase)	2.6.1.2
Aspartate transaminase (= aspartate aminotransferase = glutamate-oxaloacetate transaminase)	2.6.1.1
Creatine kinase	2.7.3.2
Hexokinase	2.7.1.1
Nucleoside triphosphate adenylate kinase	2.7.4.10
Phosphoglycerate kinase	2.7.2.3
Pyruvate kinase	2.7.1.40
Enzyme	EC Number[a]
Hydrolases	
β-*N*-Acetylhexosaminidase (= β-*N*-acetylglucosaminidase)	3.2.1.52
Acid phosphatase	3.1.3.2
Adenosine deaminase	3.5.4.4
Alkaline phosphatase	3.1.3.1
α-Amylase	3.2.1.1
Carboxylesterase (= esterase)	3.1.1.1
Cellulose 1,4-β-cellobiosidase	3.2.1.91
Cholinesterase	3.1.1.8
Fructose-biphosphatase (D-fructose-1,6-diphosphatase)	3.1.3.11
α-L-Fucosidase	3.2.1.51
α-Galactosidase	3.2.1.22
β-Galactosidase	3.2.1.23
α-Glucosidase	3.2.1.20
β-Glucosidase	3.2.1.21
β-Glucuronidase	3.2.1.31
Hydroxyacylglutathione hydrolase (= glyoxalase II)	3.1.2.6
α-Mannosidase	3.2.1.24
β-Mannosidase	3.1.2.25
Urease	3.5.1.5
Lyases	
Aconitate hydratase	4.2.1.3
Fructose-bisphosphate aldolase	4.1.2.13
Fumarate hydratase	4.2.1.2
4-Hydroxy-2-oxoglutarate aldolase (= aldolase)	4.1.3.16
Lactoylglutathione lyase (= glyoxalase I)	4.4.1.5

(*continued on the next page*)

Table 4. (*continued*)

Enzyme	EC Number[a]
Phosphoenolpyruvate carboxylase	4.1.1.31
Phosphopyruvate hidratase (= enolase)	4.2.1.11
Isomerases	
Glucose-6-phosphate isomerase (= phosphoglucose isomerase)	5.3.1.9
Mannose-6-phosphate isomerase (= phosphomannose isomerase)	5.3.1.8
Phosphoglucomutase	5.4.2.2
Phosphoglycerate mutase	5.4.2.1
Triose-phosphate isomerase	5.3.1.1

[a] Enzyme classification number recommended by the Nomenclature Committee of the International Union of Biochemistry and Molecular Biology.

Table 5. Plant-parasitic nematode species characterized on the basis of proteins, using isoelectric focusing.

Species	Reference
Globodera achilleae	Doneghan and McKenzie, 1987
G. hypolysi	Sumiya *et al.*, 2002
G. pallida	Fleming and Marks, 1982, 1983; Ohms and Heinicke, 1983[a]; Fox and Atkinson, 1984a[b]; Marks and Fleming, 1985[b]; Fleming and Dolan, 1986[a]; Doneghan and McKenzie, 1987; Santos *et al.*, 1989, 1995; Jatala and Gavilano, 1991; Karssen *et al.*, 1995[a]; Zaheer *et al.*, 1996a; Ibrahim *et al.*, 2001
G. rostochiensis	Fleming and Marks, 1982, 1983; Ohms and Heinicke, 1983[a]; Fox and Atkinson, 1984a[b]; Marks and Fleming, 1985[b]; Fleming and Dolan, 1986[a]; Doneghan and McKenzie, 1987; Santos *et al.*, 1989, 1995; Jatala and Gavilano, 1991; Karssen *et al.*, 1995[a]; Zaheer *et al.*, 1996a; Subbotin *et al.*, 1999a; Ibrahim *et al.*, 2001; Sumiya *et al.*, 2002
G. tabacum	Sumiya *et al.*, 2002
Heterodera australis	Subbotin *et al.*, 2002
H. avenae	Rumpenhorst, 1985; Fleming and Dolan, 1986[a]; Subbotin *et al.*, 1996; Subbotin *et al.*, 2002
H. bifenestra	Rumpenhorst, 1985
H. carotae	Fleming and Dolan, 1986[a]
H. fici	Trindade *et al.*, 1992
H. filipjevi	Subbotin *et al.*, 1996
H. glycines	Lawson *et al.*, 1984
H. goettingiana	Trindade *et al.*, 1992
H. hordecalis	Rumpenhorst, 1985
H. humuli	Fleming and Dolan, 1986[a]
H. latipons	Rumpenhorst, 1985
H. mani	Rumpenhorst, 1985; Fleming and Dolan, 1986[a]; Subbotin *et al.*, 1996
H. schachtii	Fleming and Dolan, 1986[a]; Trindade *et al.*, 1992
Hoplolaimus columbus	Lawson *et al.*, 1984
Meloidogyne arenaria	Lawson *et al.*, 1984
M. exigua	Rodrigues and Abrantes, 1992
M. hapla	Lawson *et al.*, 1984
M. hispanica	Rodrigues and Abrantes, 1992
M. incognita	Lawson *et al.*, 1984; Rodrigues and Abrantes, 1992
M. javanica	" "
Punctodera punctata	Rumpenhorst, 1985; Fleming and Dolan, 1986[a]

[a] Cited in Powers and Fleming (1998).
[b] Cited in Jones *et al.* (1997).

Table 6. Plant-parasitic nematodes species characterized on the basis of enzymes, using isoelectric focusing.

Species	Reference
Ditylenchus dipsaci	Ibrahim, 1991
Globodera pallida	Fleming and Marks, 1983; Wharton *et al*., 1983; Fox and Atkinson, 1984a[a], b[b], 1985[c],
G. rostochiensis	1988[d]; Marks and Fleming, 1985[a]; Fox *et al*., 1986[b]; Ibrahim, 1991; Zaheer *et al*., 1992, 1996a, b
Heterodera avenae	Bergé *et al*., 1981[b]; Rumpenhorst, 1985; Bossis and Rivoal, 1989; Molinari *et al*., 1996; Andrés *et al*., 2001
H. bifenestra	Rumpenhorst, 1985
H. cruciferae	Molinari *et al*., 1996
H. glycines	Huettel, 1986; Esbenshade and Triantaphyllou, 1988; Radice *et al*., 1988[d]; Noel and Stanger, 1991; Molinari *et al*., 1996; Noel and Liu, 1998
H. goettingiana	Molinari *et al*., 1996
H. filipjevi	Andrés *et al*., 2001
H. hordecalis	Rumpenhorst, 1985
H. latipons	Rumpenhorst, 1985; Andrés *et al*., 2001
H. mani	” ”
H. schachtii	Molinari *et al*., 1996
H. trifolii	”
Longidorus arthensis	Lamberti *et al*., 2001b
L. elongatus	Lamberti *et al*., 1999b, 2001b
L. helveticus	Lamberti *et al*., 2001b
L. latocephalus	Molinari *et al*., 1997
L. macrosoma	Lamberti *et al*., 2001b
L. pauli	Lamberti *et al*., 1999b
L. profundorum	Lamberti *et al*., 2001b
L. raskii	”
Meloidogyne arenaria	Venkatachari *et al*., 1991[e]
M. exigua	Rodrigues and Abrantes, 1992
M. hapla	Venkatachari *et al*., 1991[e]
M. hispanica	Rodrigues and Abrantes, 1992
M. incognita	Ibrahim, 1991; Venkatachari *et al*., 1991[e]; Rodrigues and Abrantes, 1992
M. javanica	Ibrahim, 1991; Venkatachari *et al*., 1991[e]; Rodrigues and Abrantes, 1992; Abrantes *et al*., 1995
M. megadora	Abrantes *et al*., 1995
Nacobbus aberrans	Ibrahim *et al*., 1997[c]
Paralongidorus halepensis	Lamberti *et al*., 1999b
Pratylenchus agilis	Andrés *et al*., 2000
P. brachyurus	Payan and Dickson, 1990
P. coffeae	Andrés *et al*., 2000
P. goodeyi	”
P. penetrans	”
P. scribneri	Payan and Dickson, 1990; Andrés *et al*., 2000
P. thornei	Andrés *et al*., 2000
P. vulnus	”
Punctodera punctata	Rumpenhorst, 1985
Radopholus similis	Fallas *et al*., 1996; Kaplan and Opperman, 1997; Andrés *et al*., 2000
Xiphidorus minor	Lamberti *et al*., 1999a
Xiphinema chambersi	Lamberti *et al*., 2002a
X. citricolum	Lamberti *et al*., 2002b
X. diversicaudatum	Lamberti *et al*., 1999c
X. floridae	Lamberti *et al*., 2002b
X. georgianum	Molinari *et al*., 1997
X. index	”

(*continued on the next page*)

Table 6. (*continued*)

Species	Reference
X. italiae	Lamberti *et al*., 1999c
X. laevistriatum	Lamberti *et al*., 2002b
X. naturale	Lamberti *et al*., 2002a
X. pachtaicum	Lamberti *et al*., 1999c
X. santos	Molinari *et al*., 1997
X. simile	Lamberti *et al*., 1999c
X. taylori	Molinari *et al*., 1997; Lamberti *et al*., 1999c
X. vuittenezi	" "
X. vulgare	Lamberti *et al*., 2001a

[a] Cited in Jones *et al*. (1997).
[b] Cited in Fox and Atkinson (1986).
[c] Cited in Powers and Fleming (1998).
[d] Cited in Williamson (1991).
[e] Cited in Curran and Robinson (1993).

Table 7. Plant-parasitic nematodes species characterized on the basis of proteins, using two-dimensional gel electrophoresis.

Species	Reference
Ditylenchus dipsaci	Bossis *et al*., 1998
Globodera pallida	Bakker and Gommers, 1982[a]; Stegemann *et al*., 1982[b]; Bakker and Bouwman-Smits, 1988b[c]; Bakker *et al*., 1992[b]; De Boer *et al*., 1992b; Bossis and Mugniéry, 1993[b]; Fullaondo *et al*., 1997[b], 2001; Cunha *et al*., 2000; Folkertsma *et al*., 1996a
G. "mexicana"	Bossis and Mugniéry, 1993[b]
G. rostochiensis	Bakker and Gommers, 1982[a]; Stegemann *et al*., 1982[b]; Ohms and Heinicke, 1985; Bakker and Bouwman-Smits, 1988a[c], b[c]; De Boer *et al*., 1992a; Bossis and Mugniéry, 1993[b]; Fullaondo *et al*., 1997[b]; Cunha *et al*., 2000
G. solanacearum	Bossis and Mugniéry, 1993[b]
G. tabacum	"
G. virginiae	"
Heterodera avenae	Ferris *et al*., 1989[b], 1994[d]; Bossis and Rivoal, 1996; Romero *et al*., 1996
H. glycines	Ferris *et al*., 1985[c], 1986; Bakker and Bouwman-Smits, 1988b[c]
H. schachtii	Bakker and Bouwman-Smits, 1988b[c]; Bossis *et al*., 1997
H. trifolii f. sp. *beta*	Bossis *et al*., 1997
Meloidogyne arenaria	Premachandran *et al*., 1984[e]; Van der Beek *et al*., 1998; Tastet *et al*., 2000
M. chitwoodi	Van der Beek *et al*., 1997[b], 1998; Tastet *et al*., 1999
M. fallax	" "
M. hapla	Van der Beek *et al*., 1997[b], 1998
M. incognita	Premachandran *et al*., 1984[e]; Dalmasso *et al*., 1991; Castagnone-Sereno *et al*., 1995b; Van der Beek *et al*., 1998; Tastet *et al*., 2000
M. javanica	Premachandran *et al*., 1984; Van der Beek *et al*., 1998; Tastet *et al*., 2000
M. mayaguensis	Tastet *et al*., 2000
M. naasi	Van der Beek *et al*., 1998

[a] Cited in Jones *et al*. (1997).
[b] Cited in Powers and Fleming (1998).
[c] Cited in Hyman and Powers (1991).
[d] Cited in Hyman and Whipple (1996).
[e] Cited in Williamson (1991).

Table 8. Plant-parasitic nematodes characterized by PCR-RFLP of ITS regions.

Species	Reference
Anguina agropyronifloris	Powers *et al*., 2001
A. agrostis	”
A. funesta	”
A. graminis	”
A. pacificae	”
A. microlaenae	”
A. tritici	”
A. wevelli	”
Aphelenchoides arachidis	Ibrahim *et al*., 1994a
A. besseyi	Ibrahim *et al*., 1994a; Iwahori *et al*., 1998
A. bicaudatus	Ibrahim *et al*., 1994a
A. composticola	”
A. fragariae	Ibrahim *et al*., 1994a; Iwahori *et al*., 1998
A. hamatus	Ibrahim *et al*., 1994a
A. nechaleos	”
A. paranechaleos	”
Aphelenchus avenae	Ali *et al*., 1999a; Iwahori *et al*., 1998
Belonolaimus longicaudatus	Cherry *et al*., 1997
Bursaphelenchus abietinus	Braasch and Burgermeister, 2002
B. borealis	Braasch *et al*., 1999
B. eggersi	”
B. fraudulentus	Hoyer *et al*., 1998; Braasch *et al*., 1999
B. fungivorus	Braasch *et al*., 1999
B. hellenicus	Braasch *et al*., 1999; Braasch and Burgermeister, 2002
B. hofmani	Braasch *et al*., 1999
B. hyalobianum	Braasch *et al*., 1999; Braasch and Burgermeister, 2002
B. leoni	Hoyer *et al*., 1998; Braasch *et al*., 1999
B. mucronatus	Hoyer *et al*., 1998; Iwahori *et al*., 1998, 1999; Braasch *et al*., 1999; Mota *et al*., 1999; Liao *et al*., 2000, 2001; Abelleira *et al*., 2003; Zheng *et al*., 2003
B. poligraphi	Braasch *et al*., 1999
B. rainulfi	Braasch *et al*., 1999; Braasch and Burgermeister, 2002
B. sexdentati	Hoyer *et al*., 1998; Braasch *et al*., 1999
B. xylophilus	Hoyer *et al*., 1998; Iwahori *et al*., 1998, 1999; Braasch *et al*., 1999; Mota *et al*., 1999; Liao *et al*., 2000, 2001; Zheng *et al*., 2003
Cactodera cacti	Maafi *et al*., 2003
C. estonica	Subbotin *et al*., 2000b
Ditylenchus africanus	Wendt *et al*., 1995
D. angustus	Ibrahim *et al*., 1994a
D. destructor	Wendt *et al*., 1993[a], 1995
D. dipsaci	Wendt *et al*., 1993[a], 1995; Zouhar *et al*., 2002
D. myceliophagus	Wendt *et al*., 1993[a], 1995
Globodera pallida	Thiéry and Mugniéry, 1996[a]; Gonzalez *et al*., 1997; Subbotin *et al*., 1999a, 2000a; Fleming *et al*., 2000; Grenier *et al*., 2001
G. “mexicana”	Thiéry and Mugniéry, 1996[a]
G. rostochiensis	Gonzalez *et al*., 1997; Orui, 1997; Subbotin *et al*., 1999a, 2000a; Fleming *et al*., 2000; Grenier *et al*., 2001; Radivojevic *et al*., 2001
G. tabacum	Thiéry and Mugniéry, 1996[a]; Fleming *et al*., 2000; Subbotin *et al*., 2000a
Heterodera arenaria	Subbotin *et al*., 1999b, 2000b
H. aucklandica	”
H. australis	Subbotin *et al*., 2002
H. avenae	Bekal *et al*., 1997; Subbotin *et al*., 1999b, 2000b, 2002; Peng *et al*., 2000; Zheng *et al*., 2000; Maafi *et al*., 2003
H. betae	Wouts *et al*., 2001; Saïd *et al*., 2002
H. cajani	Subbotin *et al*., 2000b
H. carotae	Fleming *et al*., 2000; Subbotin *et al*., 2000b
H. ciceri i	Subbotin *et al*., 2000b
H. cruciferae	”
H. cyper	”

(*continued on the next page*)

Table 8. (*continued*)

Species	Reference
H. elachista	Orui, 1997; Maafi *et al*., 2003
H. fici	Subbotin *et al*., 1997, 2000b; Maafi *et al*., 2003
H. filipjevi	Bekal *et al*., 1997; Subbotin *et al*., 1999b, 2000b; Fleming *et al*., 2000; Maafi *et al*., 2003
H. glycines	Orui, 1997; Szalanski *et al*., 1997; Fleming *et al*., 2000; Subbotin *et al*., 2000b; Zheng *et al*., 2000; Maafi *et al*., 2003
H. goettingiana	Szalanski *et al*., 1997; Fleming *et al*., 2000; Subbotin *et al*., 2000b; Maafi *et al*., 2003
H. hordecalis	Subbotin *et al*., 1999b, 2000b; Maafi *et al*., 2003
H. humuli	Subbotin *et al*., 1997, 2000b; Eroshenko *et al*., 2001; Maafi *et al*., 2003
H. iri	Subbotin *et al*., 2000b
H. latipons	Bekal *et al*., 1997; Subbotin *et al*., 1999b, 2000b; Maafi *et al*., 2003
H. litoralis	Subbotin *et al*., 1999b, 2000b
H. mani	Bekal *et al*., 1997; Fleming *et al*., 2000
H. medicaginis	Subbotin *et al*., 2000b; Saïd *et al*., 2002
H. mothi	Maafi *et al*., 2003
H. oryzicola	Subbotin *et al*., 2000b
H. riparia	Subbotin *et al*., 1997, 2000b; Eroshenko *et al*., 2001
H. salixophila	Subbotin *et al*., 2000b
H. schachtii	Szalanski *et al*., 1997; Subbotin *et al*., 1999b, 2000b; Fleming *et al*., 2000; Saïd *et al*., 2002; Maafi *et al*., 2003
H. trifolii	Orui, 1997; Szalanski *et al*., 1997; Subbotin *et al*., 2000b; Wouts *et al*., 2001; Saïd *et al*., 2002; Maafi *et al*., 2003
H. turcomanica	Maafi *et al*., 2003
H. urticae	Subbotin *et al*., 2000b
H. vallicola	Eroshenko *et al*., 2001
H. zeae	Szalanski *et al*., 1997
Longidorus arthensis	Lamberti *et al*., 2001b
L. elongatus	Lamberti *et al*., 1999b, 2001b
L. helveticus	Lamberti *et al*., 2001b
L. macrosoma	”
L. pauli	Lamberti *et al*., 1999b
L. profundorum	Lamberti *et al*., 2001b
L. raskii	”
Meloidodera alni	Subbotin *et al*., 2000b
Meloidogyne arenaria	Orui, 1998
M. camelliae	”
M. chitwoodi	Zijlstra *et al*., 1995, 1997; Schmitz *et al*., 1998; Waeyenberge and Moens, 2001
M. fallax	” ” ”
M. hapla	Zijlstra *et al*., 1995, 1997; Orui, 1998; Schmitz *et al*., 1998
M. incognita	” ” ”
M. javanica	Zijlstra *et al*., 1995; Orui, 1998; Schmitz *et al*., 1998
M. mali	Orui, 1998
M. marylandi	”
M. naasi	Schmitz *et al*., 1998
M. suginamiensis	Orui, 1998
Nacobbus aberrans	Ibrahim *et al*., 1997[a]; Reid *et al*., 2003
Paralongidorus halepensis	Lamberti *et al*., 1999b
Pratylenchus agilis	Waeyenberge *et al*., 2000
P. bolivianus	”
P. brachyurus	Orui and Mizukubo, 1999c; Waeyenberge *et al*., 2000
P. coffeae	Orui, 1996; Orui and Mizukubo, 1999a, c; Pourjame *et al*., 1999; Waeyenberge *et al*., 2000
P. crenatus	Orui and Mizukubo, 1999b, c; Waeyenberge *et al*., 2000
P. fallax	Waeyenberge *et al*., 2000
P. goodeyi	”
P. japonicus	Mizukubo *et al*., 1997
P. loosi	Pourjame *et al*., 1999; Waeyenberge *et al*., 2000
P. macrostylus	Mizukubo *et al*., 1997
P. mediterraneus	Waeyenberge *et al*., 2000

(*continued on the next page*)

Table 8. (*continued*)

Species	Reference
P. negletus	Hafez *et al*., 1999; Orui and Mizukubo, 1999a, b, c; Waeyenberge *et al*., 2000
P. penetrans	Orui, 1996; Orui and Mizukubo, 1999a, b, c; Waeyenberge *et al*., 2000
P. pratensis	Waeyenberge *et al*., 2000
P. pseudocoffeae	”
P. scribneri	”
P. subranjani	”
P. thornei	”
P. vulnus	Orui, 1996; Orui and Mizukubo, 1999a; Waeyenberge *et al*., 2000
P. zeae	Orui and Mizukubo, 1999b, c; Waeyenberge *et al*., 2000
Punctodera punctata	Fleming *et al*., 2000
Radopholus similis	Sarah, 1997; Elbadri *et al*., 2002
Xiphidorus minor	Lamberti *et al*., 1999a
Xiphinema americanum	Vrain *et al*., 1992[a]; Vrain, 1993; Knoetze *et al*., 2000
X. bricolensis	Vrain *et al*., 1992[a]; Vrain, 1993
X. chambersi	Lamberti *et al*., 2002a
X. citricolum	Lamberti *et al*., 2002b
X. diffusum	Knoetze *et al*., 2000
X. diversicaudatum	Lamberti *et al*., 1999c
X. elongatum	Knoetze *et al*., 2000
X. floridae	Lamberti *et al*., 2002b
X. index	Knoetze *et al*., 2000
X. italiae	Lamberti *et al*., 1999c; Knoetze *et al*., 2000
X. laevistriatum	Lamberti *et al*., 2002b
X. naturale	Lamberti *et al*., 2002a
X. pachtaicum	Lamberti *et al*., 1999c
X. pacificum	Vrain *et al*., 1992[a]; Vrain, 1993
X. rivesi	”
X. simile	Lamberti *et al*., 1999c
X. taylori	”
X. vuittenezi	”
X. vulgare	Lamberti *et al*., 2001a

[a] Cited in Powers and Fleming (1998).

Table 9. Plant-parasitic nematodes species characterized by RAPD-PCR.

Species	Reference
Aphelenchus avenae	Ali *et al*., 1999a
Bursaphelenchus mucronatus	Braasch *et al*., 1995; Irdani *et al*., 1995[a]; Kusano *et al*., 1999; Irdani, 2000; Wang *et al*. 2001
B. fraudulentus	Braasch *et al*., 1995
B. sexdentati	Irdani, 2000
B. tusciae	Braasch *et al*., 1995; Irdani *et al*., 1995[a]; Kusano *et al*., 1999; Wang *et al*., 2001
B. xylophilus	” ” ” ”
Ditylenchus dipsaci	Esquibet *et al*., 1998
Globodera “mexicana”	Thiéry *et al*., 1997[a]
G. pallida	Fleming *et al*., 1993; Roosien *et al*., 1993[a]; Chacon *et al*., 1994[a]; Folkertsma *et al*., 1994[a], 1996a; Pastrik *et al*., 1995[a]; Burrows *et al*., 1996[a]; Blok *et al*., 1997a; Fullaondo *et al*., 1997[a], 1999; Thiéry *et al*., 1997[a]; Bendezu *et al*., 1998; Subbotin *et al*., 1999b; Bendezu and Evans, 2001; Conceição *et al*., 2003
G. rostochiensis	Fleming *et al*., 1993; Roosien *et al*., 1993[a]; Chacon *et al*., 1994[a]; Folkertsma *et al*., 1994[a]; Blok *et al*., 1997a; Fullaondo *et al*., 1997[a], 1999; Thiéry *et al*., 1997[a]; Bendezu *et al*., 1998; Subbotin *et al*., 1999b; Bendezu and Evans, 2001; Conceição *et al*., 2003

(*continued on the next page*)

Table 9. Plant-parasitic nematodes species characterized by RAPD-PCR.

Species	Reference
G. tabacum	Thiéry *et al*., 1997[a]
Heterodera avenae	López-Braña *et al*., 1996[a]; Romero *et al*., 1996
H. cruciferae	Caswell-Chen *et al*., 1992[a]
H. daverti	Ambrogioni and Irdani, 2001
H. glycines	Erickson *et al*., 1993; Li *et al*., 1996[a]; Silva *et al*., 2000; Zheng *et al*., 2000
H. schachtii	Caswell-Chen *et al*., 1992[a]; Kaplan *et al*., 1999
H. trifolii	Ambrogioni and Irdani, 2001
H. trifolii f. sp. *beta*	”
Meloidogyne arenaria	Cenis, 1993[a]; Castagnone-Sereno *et al*., 1994[a]; Guirao *et al*., 1995[a]; Blok *et al*., 1997b; Yu *et al*., 1998; Lecouls *et al*., 1999; Orui, 1999; Randig *et al*., 2001; Xu *et al*., 2001
M. camelliae	Orui, 1999
M. chitwoodi	Williamson *et al*., 1997[a]; Waeyenberge and Moens, 2001
M. fallax	Waeyenberge and Moens, 2001
M. hapla	Cenis, 1993[a]; Castagnone-Sereno *et al*., 1994[a]; Guirao *et al*., 1995[a]; Blok *et al*., 1997b; Williamson *et al*., 1997[a]; Yu *et al*., 1998; Orui, 1999; Waeyenberge and Moens, 2001
M. incognita	Cenis, 1993[a]; Castagnone-Sereno *et al*., 1994[a]; Guirao *et al*., 1995[a]; Blok *et al*., 1997b; Yu *et al*., 1998; Orui, 1999; Swain *et al*., 1999; Randig *et al*., 2001; Xu *et al*., 2001; Meher *et al*., 2003
M. javanica	Powers *et al*., 1991[b]; Cenis, 1993[a]; Castagnone-Sereno *et al*., 1994[a]; Guirao *et al*., 1995[a]; Blok *et al*., 1997b; Carneiro *et al*., 1998; Yu *et al*., 1998; Orui, 1999; Boiteux *et al*., 2000; Randig *et al*., 2001; Xu *et al*., 2001
M. mali	Orui, 1999
M. marylandi	”
M. mayaguensis	Blok *et al*., 1997b
M. suginamensis	Orui, 1999
Nacobbus aberrans	Ibrahim *et al*., 1997[a]
Radopholus similis	Hahn *et al*., 1994[a], 1996; Siddiqi and Hahn, 1995; Kaplan and Opperman, 1997; Sarah, 1997
R. bridgei	Siddiqi and Hahn, 1995; Hahn *et al*., 1996
R. citri	Hahn *et al*., 1996

[a] Cited in Powers and Fleming (1998).
[b] Cited in Curran and Robinson (1993).

Table 10. Plant-parasitic nematodes species characterized by other DNA-based techniques.

Technique	Species	Reference
Microsatellites or Single Sequence Repeats (SSRs)	*Globodera “mexicana”*	Thiéry and Mugniéry, 2000
	G. pallida	Blok and Phillips, 1995[a]; Fullaondo *et al*., 1997[a]; Thiéry and Mugniéry, 2000
	G. rostochiensis	Blok and Phillips, 1995[a]; Fullaondo *et al*., 1997[a]
Satellite DNA (SatDNA)	*Bursaphelenchus xylophilus*	Tarès *et al*., 1994[a]; Abad, 2000
	Meloidogyne arenaria	Castagnone-Sereno *et al*., 2000
	M. chitwoodi	Castagnone-Sereno *et al*., 1998, 1999; Castagnone-Sereno, 2000
	M. exigua	Randig *et al*., 2002b
	M. fallax	Castagnone-Sereno *et al*., 1999; Castagnone-Sereno, 2000
	M. hapla	Castagnone-Sereno *et al*., 1995a, 1998; Piotte *et al*., 1995[a]
Sequence Characterized	*Meloidogyne arenaria*	Zijlstra *et al*., 2000; Fourie *et al*., 2001

(*continued on the next page*)

Table 10. (*continued*)

Technique	Species	Reference
Amplified Regions (SCARs	*M. chitwoodi*	Zijlstra, 2000; Fourie *et al.*, 2001
	M. exigua	Randig *et al.*, 2002a
	M. fallax	Zijlstra, 2000; Fourie *et al.*, 2001
	M. hapla	
	M. incognita	Zijlstra *et al.*, 2000; Fourie *et al.*, 2001; Randig *et al.*, 2002a
	M. javanica	Zijlstra *et al.*, 2000; Fourie *et al.*, 2001
	M. paranaensis	Randig *et al.*, 2002a
PCR-Single-Strand Conformational Polymorphism (PCR-SSCP)	*Bursaphelenchus mucronatus*	Zhang *et al.*, 2001
	B. xylophilus	
	Ditylenchus dipsaci	Zouhar *et al.*, 2002
	Globodera pallida	Clapp *et al.*, 2000
	G. rostochiensis	
	Heterodera arenaria/avenae	Clapp *et al.*, 2000
	H. ciceri	
	H. daverti	
	H. hordecalis	
	H. mani	
	H. schachtii	
	H. trifolii	
	Meloidogyne ardenensis	
	M. duytsi	
	M. maritima	
DNA-microarrays	*Heterodera glycines*	De Boer *et al.*, 2002

[a]Cited in Powers and Fleming (1998).

Literature cited

Abad P., 2000. Satellite DNA used as a species-specific probe for identification of *Bursaphelenchus xylophilus*. *Bulletin OEPP* 30, 571–574.

Abelleira A., M. Escuer, M. Arias and J.P. Mansilla, 2003. The genus *Bursaphelenchus* Fuchs (Nematoda: Aphelenchida) in north-west Spain. *Nematology* 5, 677–685.

Abrantes I.M. de O., M. Arias, A. Bello, S.N. do Espírito Santo, P. Joaquim, F. Lamberti, L.G. Reis, C.J. Rodrigues Jr., M.S.N. de A. Santos and N. Vovlas, 1995. Nemátodes do cafeeiro na República Democrática de São Tomé e Príncipe e selecção de cultivares resistentes. *Comunicações do Instituto de Investigação Científica Tropical, Série Ciências Agrárias* 19, 131–141.

Ali M.R., Y. Yamagughi and N. Ishibashi, 1999a. RAPD and PCR-RFLP analysis on genetic diversity of *Aphelenchus avenae* isolates from Kyushu and some other districts of Japan. *Japanese Journal of Nematology* 29, 24–34.

Ali M.R., Y. Yamagughi and N. Ishibashi, 1999b. Esterase isozyme phenotypes of 15 isolates of fungivorous nematode, *Aphelenchus avenae* Bastian 1865, from Kyushu and other districts of Japan. *Japanese Journal of Nematology* 29, 35–40.

Ambrogioni L. and T. Irdani, 2001. Identification of *Heterodera schachtii* group species in Italy by morphometrics and RAPD-PCR. *Nematologia Mediterranea* 29, 159–168.

Andrés M.F., J. Pinochet, A. Hernández-Dorrego and A. Delibes, 2000. Detection and analysis of inter- and intraspecific diversity of *Pratylenchus* spp. using isozyme markers. *Plant Pathology* 49, 640–649.

Andrés M.F., M.D. Romero, M.J. Montes and A. Delibes, 2001. Genetic relationships and isozyme variability in the *Heterodera avenae* complex determined by isoelectric focusing. *Plant Pathology* 50, 270–279.

Arnheim N. and H. Erlich, 1992. Polymerase chain reaction strategy. *Annual Review of Biochemistry* 61, 131–156.

Atkinson H.J., P.D. Harris, E.J. Halk, C. Novitski, J. Leighton-Sands, P. Nolan and P.C. Fox, 1988. Monoclonal antibodies to the soya bean cyst nematode, *Heterodera glycines*. *Annals of Applied Biology* 112, 459–469.

Backett K.D., H.J. Atkinson and J.M.S. Forrest, 1993.

Stage-specific monoclonal antibodies to the potato cyst nematode *Globodera pallida* (Stone) Behrens. *Journal of Nematology* 25, 395–400.

Bakker J., A. Schots, L. Bouwman-Smits and F.J. Gommers, 1988. Species-specific and thermostable proteins from second stage larvae of *Globodera rostochiensis* and *G. pallida*. *Phytopathology* 78, 300–305.

Baldwin J.G. and G.B. Cap, 1992. Systematics of *Nacobbus*, the false root-knot nematode. In: *Nematology from Molecule to Ecosystem* (F.J. Gommers, P.W.Th. Maas, ed.), European Society of Nematologists, Inc., Dundee, Scotland, UK, 101–112.

Bekal S., J.P. Gauthier and R. Rivoal, 1997. Genetic diversity among a complex of cereal cyst nematodes inferred from RFLP analysis of the ribosomal internal transcribed spacer region. *Genome* 40, 479–486.

Bendezu I.F. and K. Evans, 2001. Pathotype characterization of populations of potato cyst nematodes *Globodera pallida* and *G. rostochiensis* by RAPD-PCR. *International Journal of Nematology* 11, 200–208.

Bendezu I.F., K. Evans, P.R. Burrows, D. de Pomerai and M. Canto-Saenz, 1998. Inter and intra-specific genomic variability of the potato cyst nematodes *Globodera pallida* and *G. rostochiensis* from Europe and South Africa using RAPD-PCR. *Nematologica* 44, 49–61.

Benton A.W. and R.F. Myers, 1966. Esterases, phosphatases, and protein patterns of *Ditylenchus triformis* and *Panagrellus redivivus*. *Nematologica* 12, 495–500.

Bergé J.B. and A. Dalmasso, 1976. Variations génétiques associés à un double mode de reproduction parthénogénétique et amphimictique chez le nématode *Meloidogyne hapla*. *Compte Rendu de l'Académie des Sciences, Paris, Série D* 282, 2087–2090.

Blok V.C., M.S. Phillips and B.E. Harrower, 1997a. Comparison of British populations of potato cyst nematodes with populations from continental Europe and South America using RAPDs. *Genome* 40, 286–293.

Blok V.C., M.S. Phillips, J.W. McNicol and M. Fargette, 1997b. Genetic variation in tropical *Meloidogyne* spp. as shown by RAPDs. *Fundamental and Applied Nematology* 20, 127–133.

Boiteux L.S., J.G. Belter, P.A. Roberts and P.W. Simon, 2000. RAPD linkage map of the genomic region encompassing the root-knot nematode (*Meloidogyne javanica*) resistance locus in carrot. *Theoretical and Applied Genetics* 100, 439–446.

Bossis M., 1991. Discrimination entre *Heterodera carotae* et *H. cruciferae* par l'électrophorèse (SDS-PAGE) de protéines solubles extraites à partir de kystes individualisés. *Revue de Nématologie* 14, 325–327.

Bossis M., F.A. Andaloussi, G. Caubel, M. Esquibet and L. Renault, 1998. Caractérisation par électrophorèse bidimensionelle de populations (marocaines et françaises) de *Ditylenchus dipsaci* collectés sur féverole. *Colloques de l'INRA* 88, 187–197.

Bossis M., G. Caubel and C. Porte, 1997. Variabilité protéique observée par electrophoresis bidimensionelle sur neuf isolats d'*Heterodera schachtii* provenant de six pays européens et sur deux isolats de *H. trifolii* f. sp. *beta*. *Fundamental and Applied Nematology* 20, 149–155.

Bossis M. and R. Rivoal, 1989. Polymorphisme esterasique chez *Heterodera avenae* Woll.: variations intra et inter parcellaires. *Nematologica* 35, 331–390.

Bossis M. and R. Rivoal, 1996. Protein variability in cereal cyst nematodes from different geographic regions assessed by two-dimensional gel electrophoresis. *Fundamental and Applied Nematology* 19, 25–34.

Braasch H. and W. Burgermeister, 2002. *Bursaphelenchus rainulfi* sp. n. (Nematoda: Parasitaphelenchidae), first record of the genus *Bursaphelenchus* Fuchs, 1937 from Malasyia. *Nematology* 4, 971–978.

Braasch H., W. Burgermeister and K.-H. Pastrik, 1995. Differentiation of three *Bursaphelenchus* species by means of RAPD-PCR. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 47, 310–314.

Braasch H., K. Metge and W. Burgermeister, 1999. *Bursaphelenchus*-Arten (Nematoda, Parasitaphelenchidae) in Nadelgeholzen in Deutschland und ihre ITS-RFLP-Muster. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 51, 312–320.

Carneiro R.M.D.G., M.R.A. Almeida and R.G. Carneiro, 1996. Enzyme phenotypes of Brazilian populations of *Meloidogyne* spp. *Fundamental and Applied Nematology* 19, 555–560.

Carneiro R.M.D.G., M.R.A. Almeida and P. Quénéhervé, 2000. Enzyme phenotypes of *Meloidogyne* spp. populations. *Nematology* 2, 645–654.

Carneiro R.M.D.G., P. Castagnone-Sereno and D.W. Dickson, 1998. Variability among four populations of *Meloidogyne javanica* from Brazil. *Fundamental and Applied Nematology* 21, 319–326.

Carneiro R.M.D.G., W. Moreira, M.R.A. Almeida and A.C.M.M. Gomes, 2001. Primeiro registo de *Meloidogyne mayaguensis* em goiabeira no Brasil. *Nematologia Brasileira* 25, 223–228.

Castagnone-Sereno P., 2000. Use of satellite DNA for specific diagnosis of the quarantine root-knot nematodes *Meloidogyne chitwoodi* and *M. fallax*. *Bulletin OEPP* 30, 581–584.

Castagnone-Sereno P., G. Espárrago, P. Abad, F. Leroy and M. Bongiovanni, 1995a. Satellite DNA as a target for PCR-specific detection of a plant-parasitic nematode *Meloidogyne hapla*. *Current Genetics* 28, 566–570.

Castagnone-Sereno P., F. Leroy and P. Abad, 2000. Cloning and characterization of an extremely conserved satellite DNA family from the root-knot nematode *Meloidogyne arenaria*. *Genome* 43, 346–353.

Castagnone-Sereno P., F. Leroy, M. Bongiovanni, C. Zijlstra and P. Abad, 1999. Specific diagnosis of two root-knot nematodes, *Meloidogyne chitwoodi* and *M. fallax*, with satellite DNA probes. *Phytopathology* 89, 380–384.

Castagnone-Sereno P., M.N. Rosso, M. Bongiovanni and A. Dalmasso, 1995b. Electrophoretic analysis of near-isogenic avirulent and virulent lineages of the

parthenogenetic root-knot nematode *Meloidogyne incognita*. *Physiological and Molecular Plant Pathology* 47, 293–302.

Castagnone-Sereno P., J.P. Semblat, F. Leroy and P. Abad, 1998. A new *Alu*I satellite DNA in the root-knot nematode *Meloidogyne fallax*: relationships with satellites from the sympatric species *M. hapla* and *M. chitwoodi*. *Molecular Biology and Evolution* 15, 1115–1122.

Castillo P., N. Vovlas, S. Subbotin and A. Troccoli, 2003. A new root-knot nematode, *Meloidogyne baetica* n. sp. (Nematoda: Heteroderidae), parasitizing wild olive in Southern Spain. *Phytopathology* 93, 1093–1102.

Castro J.M. da C., R.D. de Lima and R.M.D.G. Carneiro, 2003. Variabilidade isoenzimática de populações de *Meloidogyne* spp. provenientes de regiões brasileiras produtoras de soja. *Nematologia Brasileira* 27, 1–12.

Cenis J.L., C.H. Opperman and A.C. Triantaphyllou, 1992. Cytogenetic, enzymatic and restriction fragment length polymorphism variation of *Meloidogyne* spp. from Spain. *Phytopathology* 82, 527–531.

Cetintas R., R.D. Lima, M.L. Mendes, J.A. Brito and D.W. Dickson, 2003. *Meloidogyne javanica* on peanut in Florida. *Journal of Nematology* 35, 433–436.

Chen Y., J. Wu, X. Hu and S. Yu, 1998. Using phastsystem for rapid identification of root-knot nematodes. *Acta Phytopathologica Sinica* 28, 73–77.

Cherry T., A.L. Szalanski, T.C. Todd and T.O. Powers, 1997. The internal transcribed spacer region of *Belonolaimus* (Nemata: Belonolaimidae). *Journal of Nematology* 29, 23–29.

Clapp J.P., C.D. van der Stoel and W.H. van der Putten, 2000. Rapid identification of cyst (*Heterodera* spp., *Globodera* spp.) and root-knot (*Meloidogyne* spp.) nematodes on the basis of ITS2 sequence variation detected by PCR-single-strand conformational polymorphism (PCR-SSCP) in cultures and field samples. *Molecular Ecology* 9, 1223–1232.

Conceição I.L.P.M. da, M.C. Vieira dos Santos, I.M. de O. Abrantes and M.S.N. de A. Santos, 2003. Using RAPD markers to analyse genetic diversity in Portuguese potato cyst nematode populations. *Nematology* 5, 137–143.

Cotroneo A. and P. Gotta, 1997. Verifica del metodo ELISA per l'identificazione dei nematodi cisticoli della patata e sue modifiche per l'identificazione di *Globodera pallida* in popolizione miste. *Informatore Fitopatologico* 47, 47–52.

Cunha M.J.M., M. Bossis, I.M. de O. Abrantes, M.S.N. de A. Santos and D. Mugniéry, 2000. Protein variability among Portuguese and other populations of *Globodera rostochiensis* revealed by two-dimensional gel electrophoresis with computed image analysis. *Nematology* 2, 461–471.

Cunha M.J. da, I.L.P. da Conceição, L.M. Pires, I.M. de O. Abrantes and M.S.N. de A. Santos, 2002. Protein variation in potato cyst nematodes revealed by capillary electrophoresis. *Nematology* 4, 168 (abstract).

Curran J., 1991. Application of DNA analysis to nematode taxonomy. In: *Manual of Agricultural Nematology (*W.R. Nickle ed.), Marcel Dekker, Inc., New York, 125–143.

Curran J., D.L. Baillie and J.M. Webster, 1985. Use of genomic DNA restriction fragment length differences to identify nematode species. *Parasitology* 90, 137–144.

Curran J. and M.P. Robinson, 1993. Molecular aids to nematode diagnosis. In: *Plant Parasitic Nematodes in Temperate Agriculture* (K. Evans, D.L. Trudgill, J.M. Webster, ed.), CAB International, Wallingford, UK, 545–564.

Curtis R.H.C., M.S. Al-Hinai, A.E.R. Diggines and K. Evans, 1997. Serological identification and quantification of *Heterodera avenae* from processed soil samples. *Nematologica* 43, 199–213.

Curtis R.H.C., J. Dunn, M. Yeung, M.P. Robinson, F. Martins and K. Evans, 1998. Serological identification and quantification of potato cyst nematodes from clean cysts and processed soil samples. *Annals of Applied Biology* 133, 65–79.

Dalmasso A., P. Castagnone-Sereno, M. Bongiovanni and A. de Jong, 1991. Acquired virulence in the plant parasitic nematode *Meloidogyne incognita*. 2. Two-dimensional analysis of isogenic isolates. *Revue de Nématologie* 14, 277–283.

Dautova M., H. Overmars, J. Bakker, G. Smant and F.J. Gommers, 2002. Nuclear and mitochondrial DNA polymorphisms in three mitotic parthenogenetic *Meloidogyne* spp. *European Journal of Plant Pathology* 108, 209–220.

Davies K.G., 1997. Identification and quantification of plant parasitic nematodes using immunological techniques. In: *Diagnosis of Key Nematode Pests of Chickpea and Pigeonpea and their Managment* (S.B. Sharma ed.), Proceedings 25–30 November, 1996, Patancheru, India, 3–11.

Davies K.G. and B. Carter, 1995. A comparision of immunoassays for the quantification of root-knot nematodes extracted from soil. *Bulletin OEPP* 25, 367–375.

Davies K.G., R.H. Curtis and K. Evans, 1996. Serologically based diagnostic and quantification tests for nematodes. *Pesticide Science* 47, 81–87.

Davies K.J. and E.B. Lander, 1992. Immunological differentiation of root-knot nematodes (*Meloidogyne* spp.) using monoclonal and polyclonal antibodies. *Nematologica* 38, 353–366.

De Boer J.M., J.P. McDermontt, X.H. Wang, T. Maier, F. Qui, R.S. Hussey, E.L. Davies and T.J. Baum, 2002. The use of DNA microarrays for the development expression analysis of cDNAs from the oesophageal gland cell region of *Heterodera glycines*. *Molecular Plant Pathology* 3, 261–270.

De Boer J.M., H.A. Overmars, J. Bakker and F.J. Gommers, 1992a. Analysis of two-dimensional protein patterns from developmental stages of the potato cyst-nematode, *Globodera rostochiensis*. *Parasitology* 105, 461–474.

De Boer J.M., H.A. Overmars, L. Bouwman-Smits, M.

De Boevere and F.J. Gommers, 1992b. Protein polymorphisms within *Globodera pallida* assessed with mini two dimensional gel electrophoresis of single females. *Fundamental and Applied Nematology* 15, 495–501.

De Boer J.M., H.A. Overmars, H. Pomp, E.L. Davis, J.F. Zilverentant, A. Goverse, G. Smant, J.P.W.G. Stokkermans, R.S. Hussey, F.J. Gommers, J. Bakker and A. Schots, 1996. Production and characterization of monoclonal antibodies to antigens from second stage juveniles of the potato cyst nematodes, *Globodera rostochiensis*. *Fundamental and Applied Nematology* 19, 545–554.

De Giorgi C., M.F. Sialer, M. di Vito and F. Lamberti, 1994. Identification of plant-parasitic nematodes by PCR amplification of DNA fragments. *Bulletin OEPP* 24, 447–451.

De Guiran G., M.J. Lee, A. Dalmasso and M. Bongiovanni, 1985. Preliminary attempt to differentiate pinewood nematodes (*Bursaphelenchus* spp.) by enzyme electrophoresis. *Revue de Nématologie* 8, 85–92.

Den Nijs L.J.M.F. and C.A.M. Lock, 1990. Quantification of *Globodera rostochiensis* and *G. pallida* in mixed populations using species-specific thermostable proteins. *Netherlands Journal of Plant Pathology* 96, 179–186.

Dickson D.W., J.N. Sasser and D. Huisingh, 1970. Comparative disc electrophoretic protein analysis of selected *Meloidogyne*, *Ditylenchus*, *Heterodera*, and *Aphelenchus* spp. *Journal of Nematology* 2, 286–293.

Doneghan J. and M. McKenzie, 1987. Distinguishing *Globodera achilleae* from the potato cyst nematodes *G. rostochiensis* and *G. pallida*, using isoelectric focusing. In: *Abstracts, Meeting of the Nematology Group, Association of Applied Biologists*, Imperial College, London. Association of Applied Biologists, Wellesbourne, UK, 18 (abstract).

Doucet M.E. and C.N. Gardenal, 1992. The genus *Nacobbus* in Argentina. 4. Preliminary comparision of populations of *N. aberrans* (Thorne, 1935) Thorne & Allen, 1944 by means of isoenzyme phenotypes. *Nematropica* 22, 243–246.

Doucet M.E., E.E. Montamat and A.L. Giayetto, 2002. Variability of enzyme phenotypes in a population of *Nacobbus aberrans* (Nematoda: Tylenchida) from Cordoba, Argentina. *Nematologia Mediterranea* 30, 27–30.

Eisenback J.D., E.C. Bernard, J.L. Starr, T.A. Lee Jr. and E.K. Tomaszewski, 2003. *Meloidogyne haplanaria* n. sp. (Nematoda: Meloidogynidae), a root-knot nematode parasitizing peanut in Texas. *Journal of Nematology* 35, 395–403.

Elbadri G.A.A., P. de Ley, L. Waeyenberge, A. Vierstraete, M. Moens and J. Vanfleteren, 2002. Intraspecific variation in *Radopholus similis* isolates assessed with restriction fragment length polymorphism and DNA sequencing of the internal transcribed spacer region of the ribosomal RNA cistron. *International Journal for Parasitology* 32, 199–205.

Erba P.S. and D.W. Dickson, 1979. Disc electrophoretic analysis of two Florida populations of *Meloidogyne javanica*. *Journal of Nematology* 11, 297 (abstract).

Erickson S., R. Denny and N. Young, 1993. Differentiating populations of *Heterodera glycines* with "RAPD" primers. *SON-Molecular Biology Committee Newsletter* 5.

Eriksson K.B. and J. Granberg, 1969. Studies of *Ditylenchus dipsaci* races using electrophoresis in acrylamide gel. *Nematologica* 15, 530–534.

Eroshenko A.S., S.A. Subbotin and I.P. Kazachenko, 2001. *Heterodera vallicola* sp. n. (Tylenchida: Heteroderidae) from elm trees, *Ulmus japonica* (Rehd.) Sarg. in the Primorsky territory, the Russian Far East, with rDNA identification of closely related species. *Russian Journal of Nematology* 9, 9–17

Esbenshade P.R. and A.C. Triantaphyllou, 1985. Use of enzyme phenotypes for identification of *Meloidogyne* species. *Journal of Nematology* 17, 6–20.

Esbenshade, P.R. and A.C. Triantaphyllou, 1986. Partial characterization of esterases in *Meloidogyne* (Nematoda). *Comparative Biochemistry and Physiology, B (Comparative Biochemistry)* 83, 31–36.

Esbenshade P.R. and A.C. Triantaphyllou, 1988. Genetic analysis of esterase polymorphism in the soybean cyst nematode, *Heterodera glycines*. *Journal of Nematology* 20, 486–492.

Esquibet M., S. Bekal, P. Castagnone-Sereno, J.P. Gauthier and G. Caubel, 1998. Differentiation of normal and giant *Vicia faba* populations of the stem nematode *Ditylenchus dipsaci*: agreement between RAPD and phenotypic characteristics. *Heredity* 81, 291–298.

Evans A.A.F., 1971. Taxonomic value of gel electrophoresis of proteins from mycophagous and plant-parasitic nematodes. *International Journal of Biochemistry* 2, 72–79.

Evans K., R.H. Curtis, M.P. Robinson and M. Yeung, 1995. The use of monoclonal antibodies for the identification of potato cyst nematodes. *Bulletin OEPP* 25, 357–365.

Fallas G.A., M.L. Hahn, M. Fargette, P.R. Burrows and J.L. Sarah, 1996. Molecular and biochemical diversity among isolates of *Radopholus* spp. from different areas of the world. *Journal of Nematology* 28, 422–430.

Fargette M., 1988. Présence de race B du nématode phytoparasite *Meloidogyne incognita* en Côte d'Ivoire et leur caractérisation par l'électrophorèse des estérases. *Compte Rendu de l'Academie des Sciences, Paris, Série III* 306, 437–440.

Ferris V.R., J.M. Ferris, L.L. Murdock and J. Faghihi, 1986. *Heterodera glycines* in Indiana: III. 2-D protein patterns of geographical isolates. *Journal of Nematology* 18, 177–182.

Fleming C.C. and R.J. Marks, 1982. A method for the quantitative estimation of *Globodera rostochiensis* and *Globodera pallida* in mixed species samples. *Record of Agricultural Research* 30, 67–70.

Fleming C.C. and R.J. Marks, 1983. The identification

of the potato cyst nematodes *Globodera rostochiensis* and *G. pallida* by isoelectric focusing of proteins on polyacrylamide gels. *Annals of Applied Biology* 103, 277–281.

Fleming C.C., J. Rao, B. Moreland, D. Craig and S.J. Turner, 2000. Diagnostics of cyst nematodes and tephritid fruit flies using mitochondrial and ribosomal DNA. *Bulletin OEPP* 30, 385–590.

Fleming C., R. Shields and R. Stratford, 1993. Identification of potato cyst nematodes using the polymerase chain reaction. *Proceedings of Crop Protection in Northern Britain*, 183–188.

Folkerstma R.T., K.E. de Groot, P.H.G. van Koert, M.P.E. van Gentpelzer, J.N.A.M.R. van der Voort, A. Schots, J. Bakker, F.J. Gommers and J. Helder, 1996a. Cluster-analysis of 36 *Globodera pallida* field populations using 2 sets of molecular markers. *European Journal of Plant Pathology* 102, 577–584.

Folkerstma R.T., J.N.A.M.R. van der Voort, K.E. de Groot, P.M. van Zandvoort, A. Schots, F.J. Gommers, J. Helder and J. Bakker, 1996b. Gene pool similarities of potato cyst nematode populations assessed by AFLP analysis. *Molecular Plant-Microbe Interactions* 9, 47–54.

Fourie H., C. Zijlstra and A. H. McDonald, 2001. Identification of root-knot nematode species occurring in South Africa using The SCAR-PCR technique. *Nematology* 3, 675–680.

Fox P.C. and H.J. Atkinson, 1986. Recent developments in the biochemical taxonomy of plant-parasitic nematodes. *Agricultural Zoology Reviews* 1, 301–330.

Fujiwara R., S. Kurogi, Y. Nagatomo and H. Takaki, 1997. Identification of *Meloidogyne* spp. by enzyme linked immunosorbent assay using monoclonal antibody. *Proceedings of the Association for Plant Protection of Hyushu* 43, 94–96.

Fullaondo A., E. Barrena, M. Viribay, I. Barrena, A. Salazar and E. Ritter, 1999. Identification of potato cyst nematode species *Globodera rostochiensis* and *G. pallida* by PCR using specific primer combinations. *Nematology* 1, 157–163.

Fullaondo A, A. Vicario, A. Aguirre, I. Barrena and A. Salazar, 2001. Quantitative analysis of two-dimensional gel electrophoresis protein patterns: a method for studying genetic relationships among *Globodera pallida* populations. *Heredity* 87, 266–272.

Ganguly A.K. and D.R. Dasgupta, 1989. Note on some enzyme profile from three species of root-knot nematode *Meloidogyne* spp. *Indian Journal of Nematology* 19, 291–293.

Ganguly A.K., D.R. Dasgupta and S.P. Rajasekhar, 1990. b-Esterase variation in three common species of *Heterodera*. *Indian Journal of Nematology* 20, 113–114.

Ganguly A.K. and H.K. Sharma, 1992. Esterase phenotypes from different populations of *Meloidogyne incognita* from India. *Indian Journal of Nematology* 22, 65–67.

Gonzalez J.A., M.S. Phillips and D.L. Trudgill, 1997. RFLP analysis in Canary Islands and North European populations of potato cyst nematodes (*Globodera* spp.): hybridization with cloned fragments. *Nematologica* 43, 157–172.

Grenier E., M. Bossis, D. Fouville, L. Renault and D. Mugniéry, 2001. Molecular approaches to the taxonomic position of Peruvian potato cyst nematodes and gene pool similarities in indigenous and imported populations of *Globodera*. *Heredity* 86, 277–290.

Hafez S.L., S. Al-Rehiayani, M. Thornton and P. Sundararaj, 1999. Differentiation of two geographically isolated populations of *Pratylenchus neglectus* based on their parasitism of potato and interactions with *Verticillium dahliae*. *Nematropica* 29, 25–36.

Hahn M.L., P.R. Burrows and D.J. Wright, 1996. Genomic diversity between *Radopholus similis* populations from around the world detected by RAPD-PCR analysis. *Nematologica* 42, 537–545.

Hinch J.M., F. Alberdi, S.C. Smith, J.R. Woodward and K. Evans, 1998. Discrimination of European and Australian *Globodera rostochiensis* and *G. pallida* pathotypes by high performance capillary electrophoresis. *Fundamental and Applied Nematology* 21, 123–128.

Hoyer U., W. Burgermeister and H. Braasch, 1998. Identification of *Bursaphelenchus* species (Nematoda, Aphelenchoididae) on the basis of amplified ribosomal DNA (ITS-RFLP). *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 50, 273–277.

Huettel R.N., 1986. Analysis of phosphoglucose isomerase from single female soybean cyst nematodes, races 1, 3, 4 and 5 by isoelectric focusing. *Journal of Nematology* 18, 613 (abstract).

Huettel R.N., D.W. Dickson and D.T. Kaplan, 1983a. Biochemical identification of the two races of *Radopholus similis* by starch gel electrophoresis. *Journal of Nematology* 15, 338–344.

Huettel R.N., Dickson D.W. and D.T. Kaplan, 1983b. Biochemical identification of the two races of *Radopholus similis* by polyacrylamide gel electrophoresis. *Journal of Nematology* 15, 345–348.

Hussey R.S., 1979. Biochemical systematics of nematodes.-.a review. *Helminthological Abstracts series B, Plant Nematology* 48, 141–148.

Hyman B.C., 1996. Molecular systematics and population biology of phytonematode: some unifying principles. *Fundamental and Applied Nematology* 19, 309–313.

Hyman B.C. and T.O. Powers, 1991. Integration of molecular data with systematics of plant parasitic nematodes. *Annual Review of Phytopathology* 29, 89–107.

Hyman B.C. and L.E. Whipple, 1996. Application of mitochondrial DNA polymorphism to *Meloidogyne* molecular population biology. *Journal of Nematology* 28, 268–276.

Ibrahim S.K., 1991. Peroxidase isoenzymes from *Meloidogyne* spp. cultured on different hosts. *Revue de Nématologie* 14, 335–344.

Ibrahim S.K., K.G. Davies and R.N. Perry, 1996. Identification of the root-knot nematode, *Meloidogyne incognita*, using monoclonal antibodies raised to non-

specific esterases. *Physiological and Molecular Plant Pathology* 49, 79–88.

Ibrahim S.K., S.T. Minnis, A.D.P. Barker, M.D. Russel, P.P.J. Haydock, K. Evans, I.G. Grove, S.R. Woods and A. Wilcox, 2001. Evaluation of PCR, IEF and ELISA techniques for the detection and identification of potato cyst nematodes from field soil samples in England and Wales. *Pest Management Science* 57, 1068–1074.

Ibrahim S.K. and R.N. Perry, 1993. Use of esterase patterns of females and galled roots for the identification of species of *Meloidogyne*. *Fundamental and Applied Nematology* 16, 187–190.

Ibrahim S.K., R.N. Perry, P.R. Burrows and D.J. Hooper, 1994a. Differentiation of species and populations of *Aphelenchoides* and of *Ditylenchus angustus* using a fragment of ribosomal DNA. *Journal of Nematology* 26, 412–421.

Ibrahim S.K., R.N. Perry and D.J. Hooper, 1994b. Use of esterase and protein patterns to differentiate two new species of *Aphelenchoides* on rice from other species of *Aphelenchoides* and from *Ditylenchus angustus* and *D. myceliophagus*. *Nematologica* 40, 267–275.

Ibrahim S.K., R.N. Perry and R.M. Webb, 1995. Use of isoenzyme and protein phenotypes to discriminate between six *Pratylenchus* species from Great Britain. *Annals of Applied Biology* 126, 317–377.

Irdani T., 2000. Genetic analysis of three *Bursaphelenchus* species by Random Amplified Polymorphic DNA. *Nematologia Mediterranea* 28, 111–120.

Iwahori H., N. Kanzaki and K. Futai, 1999. Phylogenetic relationship among several isolates of *Bursaphelenchus xylophilus* and *B. mucronatus* based on their ribosomal DNA sequences. In: *Proceedings of the International Symposium on Sustainability of Pine Forests in Relation to Pine Wilt and Decline*, 27–28 October, 1998, Tokyo, Japan, 35–38.

Iwahori H., K. Tsuda, N. Kanzaki, K. Izui and K. Futai, 1998. PCR-RFLP and sequencing analysis of ribosomal DNA of *Bursaphelenchus* nematodes related to pine wilt disease. *Fundamental and Applied Nematology* 21, 655–666.

Jatala P. and L. Gavilano, 1991. Electrophoretic studies of protein patterns of the *Globodera pallida* and *G. rostochiensis* eggs. *Nematropica* 21, 127 (abstract).

Jatala P., L. Gavilano, I. Bendezú and T. Boluarte, 1993. Electrophoretic differences in esterase patterns of 25 *Nacobbus aberrans* populations from North and South America. *Nematropica* 23, 121 (abstract).

Jaumot M., J. Pochet and C. Fernández, 1997. Protein analysis of root-lesion nematodes using SDS-PAGE. *Nematropica* 27, 33–39.

Jones J.T., D.J. Ambler and M.P. Robinson, 1988. The application of monoclonal antibodies to the diagnosis of plant pathogens and pests. In: *Brighton Crop Protection Conference, Pest and Diseases* 2, 767–776.

Jones J.T. and B.E. Harrrower, 1998. A comparision of the efficiency of differential display and cDNA-AFLPs as tools for the isolation of differentially expressed parasite genes. *Fundamental and Applied Nematology* 21, 81–88.

Jones J.T., M.S. Phillips and M.R. Armstrong, 1997. Molecular approaches in plant nematology. *Fundamental and Applied Nematology* 20, 1–14.

Kaplan D.T. and C.H. Opperman, 1997. Genome similarity implies that citrus-parasitic burrowing nematodes do not represent a unique species. *Journal of Nematology* 29, 430–440.

Kaplan M., E.P. Caswell-Chen and V.M. Williamson, 1999. Assessment of host-induced selection on three geographic isolates of *Heterodera schachtii* using RAPD and AFLP markers. *Phytopathology* 89, 68–73.

Karssen G., 1995. Morphological and biochemical differentiation in *Meloidogyne chitwoodi* populations in The Netherlands. *Nematologica* 41, 314–315 (abstract).

Karssen G. and J. Grunder, 2002. First report of the root-knot nematode *Meloidogyne kralli* in Switzerland. *Plant Disease* 86, 919.

Karssen G. and T. van Hoenselaar, 1998. Revision of the genus *Meloidogyne* Goeldi, 1892 (Nematoda: Heteroderidae) in Europe. *Nematologica* 44, 713–788.

Kennedy M.J., J.E. Schoelz, P.A. Donald and T.L. Niblack, 1997. Unique immunogenic proteins in *Heterodera glycines* eggshells. *Journal of Nematology* 29, 276–281.

Knoetze R., J.T. Burger and A.J. Meyer, 2000. Discrimination of some *Xiphinema* species from South Africa by rDNA-RFLP analysis. *African Plant Protection* 6, 25–30.

Kusano T., K. Nakamura, T. Fujii, Y. Sugawarw, Y. Ichikawa, E. Masuyama, H. Shinkawa, M. Okamatsu, Y. Kitaura, K. Tsubaki, T. Uchida, K. Togashi, S. Enoki, S. Jikumaru and S. Ikeda, 1999. RAPD-PCR fingerprinting patterns of six *Bursaphelenchus xylophilus* isolates and a *B. mucronatus* isolate. In: *Proceedings of the International Symposium on Sustainability of Pine Forests in Relation to Pine Wilt and Decline*, 27–28 October, 1998, Tokyo, Japan, 52–56.

Lamberti F., R. Crozzoli, S. Molinari, F. de Luca, A. Agostinelli and N. Greco, 1999a. Two species of *Xiphidorus* Monteiro (Nematoda: Dorylaimida): new records for Venezuela. *Nematologia Mediterranea* 27, 83–93.

Lamberti F., L. Duncan, F. de Luca, S. Molinari, A. Agostinelli, D. Dunn, M.I. Coiro and V. Radicci, 2001a. Biometric and molecular characterization and juvenile development stages of *Xiphinema vulgare* Tarjan, 1964 (Nematoda, Dorylaimida). *Nematologia Mediterranea* 29, 137–144.

Lamberti F., P. Kunz, J. Grunder, S. Molinari, F. de Luca, A. Agostinelli and V. Radicci, 2001b. Molecular characterization of six *Longidorus* species from Switzerland with the description of *Longidorus helveticus* sp. n. (Nematoda, Dorylaimida). *Nematologia Mediterranea* 29, 181–205

Lamberti F., F. de Luca, S. Molinari, L. Duncan, A. Agostinelli, M.I. Coiro, D. Dunn and V. Radicci, 2002a. *Xiphinema chambersi* and *Xiphinema naturale* sp. n.,

two monodelphic longidorids (Nematoda, Dorylaimida) from Florida. *Nematologia Mediterranea* 30, 3–10.

Lamberti F., F. de Luca, S. Molinari, L. Duncan, A. Agostinelli, M.I. Coiro, D. Dunn and V. Radicci, 2002b. Studies on some species of the *Xiphinema americanum* group (Nematoda, Dorylaimida) occurring in Florida. *Nematologia Mediterranea* 30, 31–44.

Lamberti F., S. Molinari, F. de Luca, A. Agostinelli and M. di Vito, 1999b. Longidorids (Nematoda, Dorylaimida) from Syria with description of *Longidorus pauli* sp. n. and *Paralongidorus halepensis* sp. n. with SOD enzymes and PCR-RFLP profiles. *Nematologia Mediterranea* 27, 63–78.

Lamberti F., M. Sabová, F. de Luca, S. Molinari, A. Agostinelli, M.I. Coiro and B. Valocká, 1999c. Phenotypic variations and genetic characterization of *Xiphinema* populations from Slovakia (Nematoda: Dorylaimida). *Nematologia Mediterranea* 27, 261–275.

Lawler C. and M.A. Harmey, 1993. Immunological detection of nematode antigens on the surface of a wood section. *Fundamental and Applied Nematology* 16, 521–523.

Lawson E.C., G.E. Carter and S.A. Lewis Jr., 1984. Application of isoelectric focusing to the taxonomic identification of *Meloidogyne* spp. *Journal of Nematology* 16, 91–96.

Lecouls A.C., M.J. Rubio-Cabetas, J.C. Minot, R. Voisin, A. Bonnet, G. Salesses, E. Dirlewanger and D. Esmenjaud, 1999. RAPD and SCAR markers linked to the *Ma1* root-knot nematode resistance gene in Myrobalan plum (*Prunus cerasifera* Ehr.). *Theoretical and Applied Genetics* 99, 328–335.

Lee Y.B., W.M Park and S.B. Paik,1988. A comparative study on the protein and some isoenzyme patterns between races of the soybean cyst nematode (*Heterodera glycines* Ichinoe). *Korean Journal of Plant Pathology* 4, 49–53.

Liao J.L. and Z.X. Feng, 1995. A root-knot nematode *Meloidogyne hainanensis* sp. nov. (Nematoda: Meloidogynidae) parasitizing rice in Hainan, China. *Journal of South China Agricultural University* 16, 34–39.

Liao J.L., L.H. Zhang and Z.X. Feng, 2000. Identification of *Bursaphelenchus xylophilus* by PCR amplification of ribosomal DNA. In: *Proceedings of the First Asian Conference on Plant Pathology*, 26–28 August, Beijing, China, 202 (abstract).

Liao J.L., L.H. Zhang and Z.X. Feng, 2001. Reliable identification of *Bursaphelenchus xylophilus* by rDNA amplification. *Nematologia Mediterranea* 29, 131–135.

Lopez R., 1985. Electrophoretic patterns of some *Meloidogyne* spp. from Costa Rica. *Turrialba* 35, 71–76.

Maafi Z.T., S.A. Subbotin and M. Moens, 2003. Molecular identification of cyst-forming nematodes (Heteroderidae) from Iran and a phylogeny based on ITS-rDNA sequences. *Nematology* 5, 99–111.

Masler E.P., 2002. A polyclonal antiserum that recognizes the major female-specific proteins from the soybean cyst nematode *Heterodera glycines*. *International Journal of Nematology* 12, 119–124.

Meher H.C., K.K. Kaushal, E. Khan and S.H. Naved, 1998. Use of esterase phenotypes of females for precise diagnosis of four *Heterodera* species. *Indian Journal of Nematology* 28, 81–84.

Meher H.C., S.B. Sharma and G. Singh, 2003. Genetic polymorphism in four geographically diverse *Meloidogyne incognita* populations in India. *Annals of Plant Protection Sciences* 11, 96–100.

Mizukubo T., Y. Orui and N. Minagawa, 1997. Morphology and molecular characteristics of *Pratylenchus japonicus* (Ryss, 1988) n. stat. (Nematoda, Pratylenchidae). *Esakia* 37, 203–214.

Mokabli A., S. Valette and R. Rivoal, 2001. Différenciation de quelques espèces de nématodes à kystes des céréales et des graminées par électrophorèse sur gel d'acétate de cellulose. *Nematologia Mediterranea* 29, 103–108.

Molinari S., 2001. Polymorphism of esterase isozyme zymograms of *Meloidogyne* populations detected by phastsystem. *Nematologia Mediterranea* 29, 63–66.

Molinari S., K. Evans, J. Rowe and M. Russell, 1996. Identification of *Heterodera* cysts by SOD isozyme electrophoresis profiles. *Annals of Applied Biology* 129, 361–368.

Molinari S., F. de Luca, F. Lamberti and C. de Giorgi, 1997. Molecular methods for the identification of longidorid nematodes. *Nematologia Mediterranea* 25, 55–61.

Mota M.M., H. Braasch, M.A. Bravo, A.C. Penas, W. Burgermeister, K. Metge and E. Sousa, 1999. First report of *Bursaphelenchus xylophilus* in Portugal and in Europe. *Nematology* 1, 727–734.

Navas A., P. Castagnone-Sereno, J. Blasquez and G. Esparrago, 2001. Genetic structure and diversity within local populations of *Meloidogyne* (Nematoda: Meloidogynidae). *Nematology* 3, 243–253.

Nobbs J.M., 1992. Morphological and biochemical differences between single cyst cultures of *Heterodera oryzae* Luc & Berdon-Brizuela, 1961 (Nematoda: Heteroderidae). *Afro-Asian Journal of Nematology* 2, 118–123.

Nobbs J.M., S.K. Ibrahim and J. Rowe, 1992. A morphological and biochemical comparison of the four cyst nematodes species, *Heterodera elachista*, *H. oryzicola*, *H. oryzae* and *H. sacchari* (Nematoda: Heteroderidae) known to attack rice (*Oryza sativa*). *Fundamental and Applied Nematology* 15, 551–562.

Noel G.R. and Z.L. Liu, 1998. Esterase allozymes of soybean cyst nematode, *Heterodera glycines*, from China, Japan, and the United States. *Journal of Nematology* 30, 468–476.

Noel G. R. and B.A. Stanger, 1991. Esterase phenotypes of *Heterodera glycines* from Asia and the United States. *Nematropica* 21, 129 (abstract).

Ohms J.P. and D.H.K. Heinicke, 1985. Pathotypen des kartoffelnematoden. II. Bestimmung der rassen von *Globodera rostochiensis* durch die mikro 2D electrophorese von einzelzystem. *Journal of Plant Diseases and Protection* 92, 225–232.

Orui Y., 1996. Discrimination of the main *Pratylenchus* species (Nematoda: Pratylenchidae) in Japan by PCR-RFLP analysis. *Applied Entomology and Zoology* 31, 505–514.

Orui Y., 1997. Discrimination of *Globodera rostochiensis* and four *Heterodera* species (Nematoda: Heteroderidae) by PCR-RFLP analysis. *Japanese Journal of Nematology* 27, 67–75 (in Japanese).

Orui Y., 1998. Identification of Japanese species of the genus *Meloidogyne* (Nematoda: Meloidogynidae) by PCR-RFLP analysis. *Applied Entomology and Zoology* 33, 43–51.

Orui Y., 1999. Species identification of *Meloidogyne* spp. (Nematoda: Meloidogynidae) in Japan by random amplified polymorphic DNA (RAPD-PCR). *Japanese Journal of Nematology* 29, 7–15.

Orui Y. and T. Mizukubo, 1999a. Species composition of *Pratylenchus* (Nematoda: Tylenchida) in crop fields of Central Japan, along with an observation of the geographic border lying between *Pratylenchus coffeae* and its closely allied species. *Japanese Journal of Nematology* 29, 1–6 (in Japanese).

Orui Y. and T. Mizukubo, 1999b. Geographical distribution of *Pratylenchus* species in tobacco fields in Eastern Japan. *Japanese Journal of Applied Entomology and Zoology* 43, 75–79 (in Japanese).

Orui Y. and T. Mizukubo, 1999c. Discrimination of seven *Pratylenchus* species (Nematoda: Pratylenchidae) in Japan by PCR-RFLP analysis. *Applied Entomology and Zoology* 34, 205–211.

Payan L.A. and D.W. Dickson, 1990. Comparison of populations of *Pratylenchus brachyurus* based on isozyme phenotypes. *Journal of Nematology* 22, 538–545.

Peng D., S.A. Subbotin, M. Moens, W. Tang and A. Said, 2000. Intraspecific rDNA restriction fragment length polymorphism of *Heterodera avenae*. In: *Proceedings of the First Asian Conference on Plant Pathology*, 26–28 August, Beijing, China, 195 (abstract).

Platzer E.G., 1981. Potential use of protein patterns and DNA nucleotide sequences in nematode taxonomy. In: *Plant Parasitic Nematodes*. Vol. III (B.M. Zuckerman, R.A. Rohde, ed.), Academic Press, Inc., New York, NY, USA, 3–21.

Pourjame E., L. Wberge, M. Moens and E. Gerart, 1999. Morphological, morphometrical and molecular study of *Pratylenchus coffeae* and *P. loosi* (Nematoda: Pratylenchidae). In: *Proceedings, 51st International Symposium on Crop Protection*, 4 May 1999, Gent, Belgium, Part I. Mededelingen-Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, Universiteit Gent, Belgium, 64, 391–401.

Powers T.O. and C.C. Fleming, 1998. Biochemical and molecular characterization. In: *The Physiology and Biochemistry of Free-Living and Plant-Parasitic Nematodes* (R.N. Perry, D.J. Wright, ed.) CAB International, Wallingford, UK, 335–379.

Powers T.O. and T.S. Harris, 1993. A polymerase chain reaction method for identification of five major *Meloidogyne* species. *Journal of Nematology* 25, 1–6.

Powers T.O., A.L. Szalanski, P.G. Mullin, T.S. Harris, T. Bertozzi and J.A. Griesbach, 2001. Identification of seed gall nematodes of agronomic and regulatory concern with PCR-RFLP of ITS1. *Journal of Nematology* 33, 191–194.

Pozdol R.F., G.R. Noel and D.I. Edwards, 1981. Comparative analysis of *Heterodera glycines* races by a refined polyacrylamide gel slab electrophoresis technique. *Journal of Nematology* 13, 456–457 (abstract).

Radivojevic M., D. Krnjaic, S. Krnjaic, J. Bacic, S.A. Subbotin, M. Madani and M. Moens, 2001. Molecular methods confirming the presence of *Globodera rostochiensis* (Wollenweber, 1923) in Yugoslavia. *Russian Journal of Nematology* 9, 139–141.

Rajasekhar S.P., A.K. Ganguly and D.R. Dasgupta, 1990. Effect of some biotic and abiotic factors on the stability of esterase of *Meloidogyne incognita* and *Meloidogyne javanica*. *Indian Journal of Nematology* 20, 37–43.

Randig O., M. Bongiovanni, R.M.G. Carneiro and P. Castagnone-Sereno, 2002a. Genetic diversity of root-knot nematodes from Brazil and development of SCAR markers specific for the coffee-damaging species. *Genome* 45, 862–870.

Randig O., M. Bongiovanni, R.M.G. Carneiro, J.-L. Sarah and P. Castagnone-Sereno, 2002b. A species-specific satellite DNA family in the genome of the coffee root-knot nematode *Meloidogyne exigua*: application to molecular diagnostics of the parasite. *Molecular Plant Pathology* 3, 431–437.

Randig O., F. Leroy, M. Bongiovanni and P. Castagnone-Sereno, 2001. RAPD characterization of single females of the root-knot nematodes, *Meloidogyne* spp. *European Journal of Plant Pathology* 107, 639–643.

Rao G.M.V.P., A.K. Ganguly and S. Ganguly, 1998. Variations in b-esterase profiles of two geographical populations of *Rotylenchulus reniformis*. *Indian Journal of Nematology* 28, 235–237.

Reid A., R.H. Manzanilla-López and D.J. Hunt, 2003. *Nacobbus aberrans* (Thorne, 1935) Thorne & Allen, 1944 (Nematoda: Pratylenchidae); a nascent species complex revealed by RFLP analysis and sequencing of the ITS-rDNA region. *Nematology* 5, 441–451.

Robinson M.P., 1989. Quantification of soil and plant populations of *Meloidogyne* using immunoassay techniques. *Journal of Nematology* 21, 583–585.

Robinson M.P., G. Butcher, R.H. Curtis, K.G. Davies and K. Evans, 1993. Characterization of a 34 kD protein from potato cyst nematodes, using monoclonal antibodies with potential for species diagnosis. *Annals of Applied Biology* 123, 337–347.

Rodrigues A.C.F. de O. and I.M. de O. Abrantes, 1992. Differentiation of *Meloidogyne* species by means of isoelectric focusing. *Nematologica* 38, 432 (abstract).

Romero M.D., M.F. Andres, I. López-Braña and A. Delibes, 1996. A pathogenic and biochemical comparison of two spanish populations of the cereal cyst nematode. *Nematologia Mediterranea* 24, 235–244.

Rumpenhorst H.J., 1985. Vergleichende elektrophoretische Untersuchungen von proteinen einiger Zystennematoden von Getreide und Gräsern. *Mitteilungen aus der Biologischen Bundesaustalt fur Land-und Fartmirtschaft Berlin-Dahlem* 226, 64–74.

Saïd A., S.A. Subbotin and M. Moens, 2002. Identification of the beet cyst nematode *Heterodera schachtii* by PCR. *European Journal of Plant Pathology* 108, 497–506.

Santos M.S.N. de A., K. Evans, C.A. Abreu, F.F. Martins and I.M. de O. Abrantes, 1989. Os nemátodes de quisto da batateira em Portugal. *Ciência Biológica Ecology and Systematics* 9, 1–26.

Santos M.S.N. de A., K. Evans, C.A. Abreu, F.F. Martins and I.M. de O. Abrantes, 1995. A review of potato cyst nematodes in Portugal. *Nematologia Mediterranea* 23, 35–42.

Sarah, 1997. Knowledge of the intraspecific diversity of the nematode *Radopholus similis*. *Fruits (Paris)* 52, 261–266.

Schmitz B., W. Burgermeister and H. Braasch, 1998. Molecular genetic classification of Central European *Meloidogyne chitwoodi* and *M. fallax*. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 50, 310–317.

Schots A., F.J. Gommers and E. Egberts, 1992. Quantitative ELISA for the detection of potato cyst nematodes in soil samples. *Fundamental and Applied Nematology* 15, 55–61.

Schots A., T. Hermson, S. Schouten, F.J. Gommers and E. Egberts, 1989. Serological differentiation of the potato cyst nematodes *Globodera pallida* and *G. rostochiensis*. II. Preparation and characterisation of species specific monoclonal antibodies. *Hybridoma* 8, 401–413.

Scott H.A. and R.D. Riggs, 1971. Immunoelectrophoretic comparisons of three plant parasitic nematodes. *Phytopathology* 61, 751–752.

Semblat J.P., M. Bongiovanni, E. Wajnberg, A. Dalmasso, P. Abad and P. Castagnone-Sereno, 2000. Virulence and molecular diversity of parthenogenetic root-knot nematodes, *Meloidogyne* spp. *Heredity* 84, 81–89.

Semblat J.P., E. Wajnberg, A. Dalmasso, P. Abad and P. Castagnone-Sereno, 1998. High-resolution DNA fingerprinting of parthenogenetic root-knot nematodes using AFLP analysis. *Molecular Ecology* 7, 119–125.

Shashi S., K. Satish and H.K. Bajaj, 1998a. Esterase and malate dehydrogenase phenotypes in *Heterodera cajani* Koshy *et al*. In: *Nematology: Challenges and Opportunities in 21st century. Proceedings of the Third International Symposium of Afro-Asian Society of Nematologists*, Sugarcane Breeding Institute, April 16-19, 1998, Coimbatore, India, 156–160.

Shashi S., K. Satish and H.K. Bajaj, 1998b. Catalase and glutamate oxalacetate transaminase isozyme patterns of races of *Heterodera cajani* and *H. zeae*. *Haryana Agricultural University Journal of Research* 28, 175–177.

Shashi S., K. Satish and H.K. Bajaj, 1999. Electrophoretic patterns of proteins and some enzymes of some *Heterodera* species. In: *Proceedings of National Symposium on Rational Approaches in Nematode Management for Sustainable Agriculture*, 23–25 November, 1998, Anand, India, Nematological Society of India, 65–70.

Shashi S., K. Satish, H.K. Bajaj and A.K. Ganguly, 1998c. Esterase and malate dehydrogenase patterns of races of *Heterodera cajani* and *H. zeae*. *Indian Journal of Nematology* 28, 105–109.

Siddiqi M.R. and M.L. Hahn, 1995. *Radopholus bridgei* sp. n. (Tylenchida: Pratylenchidae) from Indonesia and its differentiation by morphological and molecular characters. *Afro-Asian Journal of Nematology* 5, 38–43.

Silva A.T. da, J.C.V. Penna, L.R. Goulart, M.A. dos Santos and N.E. Arantes, 2000. Genetic variability among and within races of *Heterodera glycines* Ichinoche assessed by RAPD markers. *Genetics and Molecular Biology* 23, 323–329.

Subbotin S.A., P.D. Halford and R.N. Perry, 1999a. Identification of populations of potato cyst nematodes from Russia using protein electrophoresis, rDNA-RFLPs and RAPDs. *Russian Journal of Nematology* 7, 57–63.

Subbotin S.A., P.D. Halford, A. Warry and R.N. Perry, 2000a. Variations in ribosomal DNA sequences and phylogeny of *Globodera* parasitising solanaceous plants. *Nematology* 2, 591–604.

Subbotin S.A., H.J. Rumpenhorst and D. Sturhan, 1996. Morphological and electrophoretic studies on populations of the *Heterodera avenae* complex from the former USSR. *Russian Journal of Nematology* 4, 29–38.

Subbotin S.A., D. Sturhan, H.J. Rumpenhorst and M. Moens, 2002. Description of the Australian cereal cyst nematode *Heterodera australis* sp. n. (Tylenchida: Heteroderidae). *Russian Journal of Nematology* 10, 139–148.

Subbotin S.A., D. Sturhan, L. Waeyenberge and M. Moens, 1997. *Heterodera riparia* sp. n. (Tylenchida: Heteroderidae) from common nettle, *Urtica dioica* L., and rDNA-RFLP separation of species from the *H. humuli* group. *Russian Journal of Nematology* 5, 143–157.

Subbotin S.A., L. Waeyenberge and M. Moens, 2000b. Identification of cyst forming nematodes of the genus *Heterodera* (Nematoda: Heteroderidae) based on the ribosomal DNA-RFLP. *Nematology* 2, 153–164.

Subbotin S.A., L. Waeyenberge, I.A. Molokanova and M. Moens, 1999b. Identification of *Heterodera avenae* group species by morphometrics and rDNA-RFLPs. *Nematology* 1, 195–207.

Suchitra A. and A.K. Ganguly, 1999. Enzymatic analysis of four races of *Meloidogyne incognita*. In: *Proceedings of National Symposium on Rational Approaches in Nematode Management for Sustainable Agriculture*, 23–25 November, 1998, Anand, India, Nematological Society of India, 139–142.

Sumiya T., K. Hirata and T. Yaegashi, 2002. Identifica-

tion of three *Globodera* species in Japan by using isoelectric focusing method. *Research Bulletin of the Plant Protection Service, Japan* 38, 49–51.

Swain S.C., A.K. Ganguly, P. Sahoo and T. Mohapatra, 1999. RAPD analysis distinguishes four races of root-knot nematode, *Meloidogyne incognita*. *Indian Journal of Nematology* 29, 1–7.

Szalanski A.L., D.D. Sui, T.S. Harris and T.O. Powers, 1997. Identification of cyst nematodes of agronomic and regulatory concern with PCR-RFLP of ITS1. *Journal of Nematology* 29, 255–267.

Tastet C., M. Bossis, J.-P. Gauthier, L. Renault and D. Mugniéry, 1999. *Meloidogyne chitwoodi* and *M. fallax* protein variation assessed by two-dimensional electrophoregram computed analysis. *Nematology* 1, 301–314.

Tastet C., M. Bossis, L. Renault and D. Mugniéry, 2000. Protein variation in tropical *Meloidogyne* spp. as shown by two-dimensional electrophoregram computed analysis. *Nematology* 2, 343–353.

Tenente R.C.V. and A.A.F. Evans, 1997. Electrophoresis of proteins from several races of *Ditylenchus dipsaci*, recovered from dried infested courgette tissue. *Nematologia Brasileira* 21, 84–91.

Thiéry M. and D. Mugniéry, 2000. Microsatellite loci in the phytoparasitic nematode *Globodera*. *Genome* 43, 160–165.

Tomaszewski E.K., M.A.M. Khalil, A.A. El-Deeb, T.O. Powers and J.L. Starr, 1994. *Meloidogyne javanica* parasitic on peanut. *Journal of Nematology* 26, 436–441.

Torrance L., 1995. Use of monoclonal antibodies in plant pathology. *European Journal of Plant Pathology* 101, 351–363.

Trindade Z.M.C. de A., I.L.P.M. da Conceição, M.S.N. de A. Santos and I.M. de O. Abrantes, 1992. Isoelectric focusing of soluble proteins of *Heterodera* populations. *Nematologica* 38, 439 (abstract).

Trudgill D.L., 1972. Electrophoresis of protein from different populations of the potato cyst nematode. *Annals of Applied Biology* 71, 278–280.

Van der Beek J.G., R. Folkerstma, C. Zijlstra, P.H.G. van Koert, L.M. Poleij and J. Bakker, 1998. Genetic variation among parthenogenetic *Meloidogyne* species revealed by AFLPs and 2D-protein electrophoresis contrasted to morphology. *Fundamental and Applied Nematology* 21, 401–411.

Vos P., H. Rene, M. Bleeker, M. Reijans, T. van de Lee, M. Hornes, A. Frijters, J. Pot, J. Peleman, M. Kuiper and M. Zabeau, 1995. AFLP, a new technique for DNA fingerprinting. *Nucleic Acids Research* 23, 4407–4414.

Vrain T.C., 1993. Restriction Fragment Length Polymorphism separates species of the *Xiphinema americanum* group. *Journal of Nematology* 25, 361–364.

Vrain T.C. and D.G. McNamara, 1994. Potential for the identification of quarantine nematodes by PCR. *Bulletin OEPP* 24, 453–458.

Waeyenberge L. and M. Moens, 2001. *Meloidogyne chitwoodi* and *M. fallax* in Belgium. *Nematologia Mediterranea* 29, 91–97.

Waeyenberge L., A. Ryss, M. Moens, J. Pinochet and T.C. Vrain, 2000. Molecular characterisation of 18 *Pratylenchus* species using rDNA Restriction Fragment Length Polymorphism. *Nematology* 2, 135–142.

Wang S., R.D. Riggs and Y. Yang, 2001. Grouping of populations of *Heterodera trifolii* by host preference and AFLP pattern. *Nematology* 3, 667–674.

Wang L., Y. Wang, B. Yang, X. Hu and S. Yu, 2001. Studies on relationships of *Bursaphelenchus xylophilus* and *B. mucronatus* by RAPD. *Acta Phytopathologica Sinica* 31, 225–229.

Webster J.M. and D.J. Hooper, 1968. Serological and morphological studies on the inter- and intraspecific differences of the plant-parasitic nematodes *Heterodera* and *Ditylenchus*. *Parasitology* 58, 879–891.

Wendt K.R., A. Swart, T.C. Vrain and J.W. Webster, 1995. *Ditylenchus africanus* sp. n. from South Africa; a morphological and molecular characterization. *Fundamental and Applied Nematology* 18, 241–250.

Wharton R.J., R.M.J. Storey and P.C. Fox, 1983. The potential of some immunochemical and biochemical approaches to the taxonomy of potato cyst nematodes. In: *Concepts in Nematode Systematics* (A.R. Stone, H.M. Platt, L.F. Khalil, ed.), Academic Press, London, UK, 235–248.

Williams J.G.K., A.R. Kubelik, K.J. Livak, J.A. Rafalski and S.V. Tingey, 1990. DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic Acids Research* 18, 6531–6535.

Williamson V.M., 1991. Molecular techniques for nematode species identification. In: *Manual of Agricultural Nematology* (W.R. Nickle, ed.), Marcel Dekker, Inc., New York, NY, USA, 107–123.

Wouts W.M., H.J. Rumpenhorst and D. Sturhan, 2001. *Heterodera betae* sp. n., the yellow beet cyst nematode (Nematoda: Heteroderidae). *Russian Journal of Nematology* 9, 33–42.

Xu J., T. Narabu, T. Mizukubo and T. Hibi, 2001. A molecular marker correlated with selected virulence against the tomato resistance gene *Mi* in *Meloidogyne incognita*, *M. javanica*, and *M. arenaria*. *Phytopathology* 91, 377–382.

Xue B.G., D.L. Baillie and J.M. Webster, 1993. Amplified fragment length polymorphisms of *Meloidogyne* spp. using oligonucleotide primers. *Fundamental and Applied Nematology* 16, 481–487.

Yaegashi T. and Y. Toida, 1997. *Meloidogyne javanica* with three bands of esterase phenotype from Honshu, the Main Island of Japan. *Japanese Journal of Nematology* 26, 32–35.

Yu S., Y. Wang, X. Hu and W. Bai, 1998. RAPD analysis of four most common *Meloidogyne* spp. *Acta Phytopathologica Sinica* 28, 359–365.

Zaheer K., C. Fleming and S.J. Turner, 1996a. Genetic variation in potato cyst nematodes in Northern Ireland. *Biochemical Systematics and Ecology* 24, 509–519.

Zaheer K., C. Fleming, S.J. Turner, J.A. Kerr and J. Mcadam, 1992. Genetic variation and pathotype re-

sponse in *Globodera pallida* (Nematoda: Heteroderidae) from the Falkland islands. *Nematologica* 38, 175–189.

Zaheer K., C. Fleming, S.J. Turner and J. Phillips, 1996b. Genetic variation and pathotype response in potato cyst-nematodes from Cyprus. *Nematologia Mediterranea* 24, 161–167.

Zhang L., J. Liao and Z. Feng, 2001. Sequencing and PCR-SSCP analysis of ribosomal DNA of *Bursaphelenchus* nematodes. *Acta Phytopathologica Sinica* 31, 84–89.

Zheng J., S.A. Subbotin, S. He, J. Gu and M. Moens, 2003. Molecular characterisation of some Asian isolates of *Bursaphelenchus xylophilus* and *B. mucronatus* using PCR-RFLPs and sequence ribosomal DNA. *Russian Journal of Nematology* 11, 17–22.

Zheng J., S.A. Subbotin, L. Waeyenberge and M. Moens, 2000. Molecular characterisation of Chinese *Heterodera glycines* and *H. avenae* populations based on RFLPs and sequences of rDNA-ITS regions. *Russian Journal of Nematology* 8, 109–113.

Zijlstra C., 2000. Reliable identification of the quarantine root-knot nematodes *Meloidogyne chitwoodi* and *M. fallax* by PCR-based techniques. *Bulletin OEPP* 30, 575–579.

Zijlstra C., D.T.H.M. Donkers-Venne and M. Fargette, 2000. Identification of *Meloidogyne incognita*, *M. javanica* and *M. arenaria* using sequence characterised amplified region (SCAR) based PCR assays. *Nematology* 2, 847–853.

Zijlstra C., A.E.M. Lever, B.J. Uenk and C. H. van Silfhout, 1995. Differences between ITS regions of isolates of root-knot nematodes *Meloidogyne hapla* and *M. chitwoodi*. *Phytopathology* 85, 1231–1237.

Zijlstra C., B.J. Uenk and C.H. van Silfhout, 1997. A reliable, precise method to differentiate species of root-knot nematodes in mixtures on the basis of ITS-RFLPs. *Fundamental and Applied Nematology* 20, 59–63.

Zouhar M., M. Marek, J. Licinio and P. Ryšánek, 2002. Using point mutations in rDNA for differentiation of bioraces of *Ditylenchus dipsaci* from the Czech Republic. *Plant Protection Science* 38, 358–360.

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