Global status of nematode problems of groundnut, pigeonpea, chickpea, sorghum and pearl millet, and suggestions for future work

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ABSTRACT. Analysis of responses received from 40 cooperators in 20 countries to a questionnaire on nematode problems of groundnut, pigeonpea, chickpea, sorghum and pearl millet suggested that *Meloidogyne* spp. are internationally important nematode pests of groundnut, chickpea and pigeonpea. *Pratylenchus* spp. are important on all the five crops. In India, *Heterodera cajani* and *Rotylenchulus reniformis* are important pathogens of pigeonpea. Over the last 10–15 years, extensive nematode disease surveys have been undertaken for these crops in Australia, Egypt, India, Jamaica, Senegal, Sudan, Thailand and Zimbabwe; however, $<10\%$ of the total crop areas were covered by these surveys. Except for Brazil, Egypt, USA and Zimbabwe, growers do not use nematicides to control the nematodes. Cultural practices, especially crop rotations, are the most commonly used control measures. Species of *Meloidogyne*, *Pratylenchus* and *Rotylenchulus* on the legumes, and species of *Hoplolaimus*, *Pratylenchus*, *Quinisulcius* and *Xiphinema* on the cereals, are strongly suspected of increasing the severity of fungal diseases. Work aimed at finding host resistance is being done in Brazil, Fiji, India and the USA, and some sources of resistance have been identified against *Meloidogyne arenaria*, *M. incognita*, *M. javanica* and *R. reniformis*. Facilities for resistance screening work now exist in many countries. Information on damage thresholds of important pest species are available only from Brazil, Fiji, India and the USA.

KEYWORDS: Cereals; damage thresholds; interactions; legumes; management techniques; *Meloidogyne* spp.; nematodes; *Pratylenchus* spp.; surveys

Introduction

Chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* (L.) Millsp.) are the most important pulse crops of the semi-arid tropics (SAT) and developing world. Chickpea is important in India, West Asia, North Africa, around the Mediterranean Sea, and in parts of East Africa. Pigeonpea is grown throughout the SAT, particularly in India and East Africa. Groundnut (*Arachis hypogaea* L.) is the most important oilseed crop of the SAT. Areas $>100\,000$ ha are planted to groundnut in 23 countries, 95% of which are classified as less developed countries (ICRISAT, 1987). Sorghum (*Sorghum bicolor* (L.) Moench) and pearl millet (*Pennisetum glaucum* (L.) R.Br.) together provide the highest calorie and protein intake among cereal diets in many parts of the SAT (ICRISAT, 1987). Yields of these crops are low in the developing nations where the demand for food is rapidly increasing.

Pests and diseases are important constraints on crop yields in most countries. When compared with insect pests and fungal diseases, very little research has been done on nematode problems of groundnut, pigeonpea, chickpea, sorghum and pearl millet, and the published literature on nematode pests of these crops is scanty. On the basis of limited surveys, personal communications with nematologists, and from published reports, it is apparent that these crops are susceptible to a wide range of plant-parasitic nematodes (Sharma, 1985; Nene, Sheila and Sharma, 1989). Many more pathogenic species are likely to be found if all areas where these crops are grown are surveyed extensively and nematodes isolated from diseased plants are identified to species. The information that has appeared in the literature, although useful, does not provide a comprehensive global picture of major nematode disease problems. We therefore have only a limited idea of the occurrence, extent, and possible importance of nematode diseases of these five important subsistence crops of the SAT. We prepared a questionnaire covering many aspects of research on nematode problems of these crops and distributed it to over 400 nematologists and crop protection workers concerned with these crops. This paper summarizes the data received, supplemented by available information and results of our nematode surveys.

Materials and methods

In 1987, a six-page questionnaire containing 15 questions was designed to seek information on the various

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aspects (surveys, important nematode species, pathogenic effects and damage thresholds, nematode management techniques, and host resistance) of work being done on nematode problems of groundnut, pigeonpea, chickpea, sorghum and pearl millet in different countries, particularly in the SAT. Copies of this questionnaire were sent to 80 nematologists working on, or known to have worked on, nematodes of cereals and legumes. Copies of the questionnaire were also sent to plant protection scientists through the International Arachis, Pigeonpea and Chickpea Newsletters. Forty scientists provided data sought in the questionnaire. Scientists in some African and South-East Asian countries intimated that no work was currently being done on nematode problems of the five crops in their countries.

The respondents were requested to rank the three most important nematodes or nematode-caused diseases. Based on the number of first, second and third places, a weighted index was calculated by assigning

TABLE 1. Important nematode problems of groundnut, pigeonpea, chickpea, sorghum and pearl millet

		Nematode problems		
Crop	Country	Most important	Very important	Important
Groundnut	Australia	*Pratylenchus brachyurus*	*Meloidogyne hapla*	
	Brazil	*P. brachyurus*	*Criconemella ornata*	*Meloidogyne arenaria*
	Egypt	*Meloidogyne javanica*	*Meloidogyne incognita*	*M. arenaria*
	India	*M. arenaria*	*Pratylenchus* spp.	*Tylenchorhynchus* spp.
	Jamaica	*Meloidogyne* sp.	*Xiphinema* sp.	*Pratylenchus* sp.
	Malawi	*M. arenaria*		
	Mexico		*M. arenaria*	
	Nepal	*Meloidogyne* sp.		
	Thailand	*P. brachyurus*	*C. ornata*	*Helicotylenchus* sp.
	USA	*M. arenaria*	*P. brachyurus*	
	Zambia	*Meloidogyne* sp.		
	Zimbabwe	*P. brachyurus*	*Meloidogyne* sp.	
Pigeonpea	Brazil	*M. javanica*	*P. brachyurus*	*Helicotylenchus dihystera*
	Egypt	*Heterodera cajani*	*M. incognita*	
	Ethiopia	*Meloidogyne* sp. (*M. incognita*)		
	Fiji	*Rotylenchulus reniformis*	*Meloidogyne* sp.	*Radopholus similis*
	India	*H. cajani*	*Meloidogyne* spp. (*M. incognita* and *M. javanica*)	*R. reniformis*
	Jamaica	*R. reniformis*	*Pratylenchus* sp.	*Helicotylenchus* sp.
	Malawi	*M. javanica*		
	Nepal	*Meloidogyne* sp.		
	Sudan	*P. sudanensis*	*Tylenchorhynchus* sp.	*Ditylenchus sp.*
	Trinidad	*R. reniformis*	*Pratylenchus zeae*	*H. dihystera*
	USA	*Meloidogyne* sp.	*Pratylenchus* sp.	
	Zambia	*Meloidogyne* sp.		
	Zimbabwe	*M. javanica*	*Pratylenchus* sp.	*Helicotylenchus* sp.
Chickpea	Brazil	*Meloidogyne* spp. (*M. incognita* and *M. javanica*)	*P. brachyurus*	*R. reniformis*
	Ethiopia	*Meloidogyne* sp. (*M. incognita*)		
	India	*Meloidogyne* spp. (*M. incognita* and *M. javanica*)	*R. reniformis*	
	Malawi	*Meloidogyne* sp. (*M. javanica*)		
	Nepal	*Meloidogyne* spp. (*M. incognita* and *M. javanica*)		
	Pakistan	*Meloidogyne* spp. (*M. incognita* and *M. javanica*)		
	USA	*Meloidogyne* sp.	*Pratylenchus* sp.	
	Zambia	*Meloidogyne* sp.		
	Zimbabwe	*M. javanica*	*Pratylenchus* sp.	
Sorghum	Australia	*Pratylenchus* sp.		
	Brazil	*P. brachyurus*	*Meloidogyne* sp.	*H. dihystera*
	Egypt	*P. zeae*	*P. thornei*	
	India	*Tylenchorhynchus* sp. (*T. vulgaris*)	*Pratylenchus* sp. (*P. zeae*)	
	Pakistan	*P. thornei*	*Tylenchorhynchus mashoodi*	
	Sudan	*Pratylenchus* spp. (*P. sudanensis*, *P. neglectus*)		
	Thailand	*P. zeae*	*Helicotylenchus* sp.	
	USA	*Pratylenchus* sp. (*P. zeae*)	*Paratrichodorus* sp.	
	Zimbabwe	*P. zeae*	*Hoplolaimus* sp.	*Rotylenchulus parvus*
Pearl millet	Brazil	*M. javanica*	*Paratrichodorus minor*	*C. ornata*
	India	*Helicotylenchus* sp. (*H. indicus*)	*Tylenchorhynchus* sp.	
	Pakistan	*Tylenchorhynchus* sp.	*Hoplolaimus* sp.	
	USA	*Pratylenchus* sp. (*P. zeae*)		
	Zimbabwe	*P. zeae*	*Rotylenchulus* sp.	*Trichodorus* sp.

the first place a score of 3, second place a score of 2 and third place a score of 1. This method helped to identify major nematode problems across the countries. Information on important nematode problems, surveys, pathogenic effects and damage thresholds, interactions, control measures and host resistance from respondents in 20 countries was compiled and tabulated.

Results

Important nematode problems

Root-knot nematodes (*Meloidogyne* spp.) cause important problems with groundnut, pigeonpea and chickpea, and lesion nematodes (*Pratylenchus* spp.) are important on all the five crops in many countries (*Table 1*). Brazil and Thailand have similar nematode problems on groundnut. *Meloidogyne arenaria*, which is the most important nematode problem of groundnut in Malawi, the United States and India, is less important than *M. javanica* in Egypt. Ibrahim and El-Saedy (1976) found *M. javanica* to be more widespread than *M. arenaria* in Egypt. This species is found attacking groundnut in Andhra Pradesh, Punjab, Gujarat and Karnataka states of India. *Meloidogyne incognita* is not considered important on groundnut in any country so far (Minton, 1984). Taha and Yousif (1976) observed infection of groundnut roots, pegs, pods and nodules in Egypt. In West Africa the root-knot nematodes are not important on groundnut. Surveys have indicated that *Scutellonema* spp. are the most important nematodes on groundnut in Niger and in Senegal (Germani, Baujard and Luc, 1985; Sharma, 1988). *M. javanica* and *M. incognita* are important on pigeonpea and chickpea. Pigeonpea is highly susceptible to *M. arenaria* (Sasser and Hartman, 1985). In India, where 90% of all pigeonpeas are produced, *Heterodera cajani* is the most important nematode. This nematode was earlier reported from India and has now been recorded in Egypt. The reniform nematode, *Rotylenchulus reniformis*, is important on pigeonpea in Fiji, India, Jamaica and Trinidad. *Heterodera ciceri* in Syria and *M. artiellia* in the mediterranean region cause important problems with chickpea (Greco, 1987) (*Table 1*).

Surveys

In many countries including Brazil, Ethiopia, Kenya, Malawi, Mexico, Nepal, and Pakistan, systematic extensive surveys have not been undertaken. In Australia, Egypt, India, Jamaica, Senegal, Thailand, and Zimbabwe, surveys were conducted within the last 10–15 years but, in general, not more than 10% of the total crop area was covered by these surveys. In the USA and in Sudan 25% of groundnut area has been covered by nematode surveys. Some of the places where surveys are required are listed in *Table 2*.

TABLE 2. Regions where surveys need to be conducted

Country	Crop[a]	Region
Brazil	1,2,3,4,5	Savana
Egypt	1	Eastern and Western Nile
	3,4,5	Upper Egypt
Ethiopia	1	Harargie
	2	Harargie, Wello, Keffe
	3	Slewa, Gojam, Gonder
	4	Harargie, Wello
Fiji	2	Dry zone of Fiji
Jamaica	1,2	Country wide
Kenya	2,3,4,5	East and West Kenya
Malawi	1	Central Malawi
	2	Central and South Malawi
	3,4,5	South Malawi
Mexico	1	Morelos, Nayarit states
	4	Guanajuato, Morelos, Sinaloa, Tamaulipas
Nepal	1,2,3,4,5	Entire crop-growing region
Pakistan	1,2,3	Punjab
	4,5	Punjab and Sind
Sudan	1	West and North Sudan
	2	North and South Sudan
	3	North Sudan
	4	East and West Sudan
Thailand	1	Kalasin, Loei, Nakorn Ratchasima, Sri Saket
	4	Loei, Nakorn Ratchasima
USA	1	Florida state, South and Far West Texas
	4	Mississippi, Texas
Zambia	1	Eastern province

[a]1, Groundnut; 2, Pigeonpea; 3, Chickpea; 4, Sorghum; 5, Pearl millet

Pathogenic effects and damage thresholds

Pathogenic effects of important nematode species have been examined on groundnut in Australia (*M. hapla*, *P. brachyurus*), Brazil (*P. brachyurus*), India (*M. arenaria* and *M. javanica*), and the USA (*M. arenaria*, *M. hapla* and *P. brachyurus*); on pigeonpea in Fiji (*R. reniformis*, *Meloidogyne* sp. and *Radopholus similis*), India (*H. cajani*, *Meloidogyne* spp., and *R. reniformis*), and Sudan (*P. sudanensis*); on chickpea in Brazil (*M. javanica*) and India (*Meloidogyne* spp., *R. reniformis*), and Syria (*H. ciceri* and *M. artiellia*), on sorghum in Brazil (*M. javanica*), India (*Pratylenchus* sp.), Sudan (*P. sudanensis*) and the USA (*P. zeae*, *Quinisulcius acutus*); and on pearl millet in India (*Pratylenchus* sp. and *Tylenchorhynchus* sp.). Respondents from Egypt, Ethiopia, Malawi, Nepal, Pakistan, Trinidad, Zambia and Zimbabwe indicated that pathogenic effects of potentially important nematode species have not been examined. Information on damage thresholds of important species is available from Brazil, Fiji, India, Syria and the USA (*Table 3*). In most of the countries work has not yet started on this aspect.

Interactions with micro-organisms

Species of *Meloidogyne*, *Pratylenchus*, and *Rotylenchulus* on the legumes, and species of *Hoplolaimus*, *Pratylenchus*, *Quinisulcius* and *Xiphinema* on cereals are strongly suspected of increasing the severity of diseases caused by fungal pathogens (*Table 4*). *Sclerotium rolfsii* on groundnut, *Fusarium udum* on pigeonpea, and *F. oxysporum* on chickpea cause very important and widespread disease problems, and the presence of *Meloidogyne* spp. aggravates the disease situations.

Control measures

Countries where growers use nematicides are Brazil, Egypt, USA and Zimbabwe. In Australia, Brazil, Egypt, Fiji, India, Malawi, Trinidad, the USA and Zimbabwe, cultural practices and crop rotations are the commonly used control measures. Root-knot nematodes on the three legumes have been effectively controlled by inclusion of cereals or grasses in the cropping system, and rotation with soybean is effective for reducing the *Pratylenchus* sp. problem on sorghum and pearl millet (*Table 5*).

TABLE 3. Damage threshold levels for important nematode species

Crop	Country	Nematode	Threshold level (nematode g^{-1} or cm^{-3} soil)
Groundnut	India	*Meloidogyne arenaria*	1.0
	USA	*M. arenaria*	>0.01
		Pratylenchus brachyurus	>0.2
Pigeonpea	Fiji	*Rotylenchulus reniformis*	4.0
		Meloidogyne sp.	4.0
		Radopholus similis	4.0
	India	*Heterodera cajani*	0.1–1.0
		M. incognita	1.0–2.0
		R. reniformis	1.0–2.0
Chickpea	Brazil	*M. javanica*	0.5–1.0
	India	*M. incognita*	1.0–2.0
		M. javanica	1.0
		R. reniformis	2.0
	Syria	*H. ciceri*	1.0
		M. artiellia	0.01–0.10
Sorghum	India	*Pratylenchus* sp.	2.0–5.0
	USA	*P. zeae*	0.2
Pearl millet	India	*Tylenchorhynchus vulgaris*	1.0

Screening for disease resistance

Most respondents indicated that work on screening of genotypes for identification of resistance against important nematodes was not being done in their countries. Germplasm materials are being screened in Brazil (chickpea, sorghum and pearl millet for resistance to *M. javanica*), Fiji (pigeonpea for resistance to *R. reniformis*), India (groundnut for resistance to *M. arenaria*; pigeonpea for resistance to *H. cajani*, *R. reniformis*, *M. incognita* and *M. javanica*; chickpea for resistance to *Meloidogyne* spp.), and the USA (groundnut and pigeonpea for resistance to *M. arenaria*). Good host-screening facilities for *Meloidogyne* spp. exist in Brazil (groundnut and pigeonpea), Ethiopia (pigeonpea), Fiji (groundnut), Jamaica (groundnut), Zambia (groundnut, pigeonpea, chickpea), Malawi (groundnut, chickpea), Mexico (groundnut), Nepal (groundnut, pigeonpea and chickpea), Pakistan (groundnut, pigeonpea and chickpea), and Zimbabwe (groundnut); and for *Pratylenchus* spp. in Jamaica (groundnut, pigeonpea), Pakistan (pigeonpea, chickpea, sorghum and pearl millet), the Sudan (pigeonpea), Thailand (groundnut), and Zimbabwe (groundnut, sorghum and pearl millet). Some sources of resistance have been identified against important nematode problems (*Table 6*).

TABLE 4. Interactions of nematodes with other pathogens on groundnut, pigeonpea, chickpea, sorghum and pearl millet in different countries

Crop	Country	Nematode	Other pathogens
Groundnut	USA	*Meloidogyne arenaria*	*Pythium* sp.
	Brazil, USA	*M. arenaria*	*Sclerotium rolfsii*
	India	*M. arenaria*	*F. solani*, *Aspergillus niger*, *A. flavus*, *S. rolfsii*
	Australia, USA	*M. hapla*	*Cylindrocladium crotalariae*
	Egypt	*Meloidogyne*	*Fusarium* sp., *Rhizoctonia* sp.
	USA	*Pratylenchus brachyurus*	*Pythium* sp., *S. rolfsii*
	Thailand	*P. brachyurus*	*Fusarium* sp.
Pigeonpea	India	*Meloidogyne* spp. (*M. incognita* and *M. javanica*)	*Fusarium udum*
	Malawi	*Meloidogyne* sp.	*F. udum*
	India	*Rotylenchulus reniformis*	*F. udum*
	Fiji	*R. reniformis*	*Fusarium* sp.
	Sudan	*P. sudanensis*	*Fusarium* sp.
Chickpea	Brazil, India	*M. incognita*, *M. javanica*	*F. oxysporum*
Sorghum	USA	*P. zeae*, *Quinisulcius acutus*	*F. moniliforme*
Pearl millet	Zimbabwe	*Xiphinema* sp.	*Fusarium* sp.

TABLE 5. Management techniques effective against nematode problems with groundnut, pigeonpea, chickpea, sorghum and pearl millet

Crop	Country	Nematode	Nematicide (kg a.i. ha⁻¹) cropping sequences, rotations
Groundnut	Australia	*Meloidogyne hapla*	Groundnut/maize or sorghum
	USA	*M. arenaria*	Groundnut–cotton Groundnut–Bahia grass for 3–6 years Groundnut–Paspalum Phenamiphos (2.2–4.4) Aldicarb (2.2–3.5) Carbofuran (3.5)
		Pratylenchus brachyurus	Aldicarb (3.5), Carbofuran (3.5), Ethoprop (3.5) 1,3 D (12–30)
	Brazil	*P. brachyurus*	Groundnut–pearl millet–soybean
	Egypt	*Meloidogyne* sp.	Carbofuran (2.5)
	Malawi	*Meloidogyne* sp.	Maize–groundnut–tobacco
	Zimbabwe	*Pratylenchus* sp.	Groundnut–sorghum/millet
Pigeonpea	Fiji	*Rotylenchulus reniformis*	Rice or maize/fallow/pigeonpea
	Brazil	*M. javanica*	Pigeonpea–wheat
	Zimbabwe	*Meloidogyne* sp.	Carbofuran (2.0) Phenamiphos (2.0)
Chickpea	Brazil	*Meloidogyne* spp. (*M. javanica*, *M. incognita*)	Maize–chickpea–maize–groundnut Groundnut–chickpea–maize
	Zimbabwe	*Meloidogyne* sp.	Phenamiphos (2.0)
Sorghum	USA	*Pratylenchus* sp.	Sorghum/soybean
Pearl millet	USA	*Trichodorus* sp., *Pratylenchus* sp.	Rotation with soybean

TABLE 6. Genotypes found to be resistant to important nematode species

Country	Crop	Nematode	Genotypes[a]
Brazil	Groundnut	*Meloidogyne javanica*	Tatui
	Sorghum	*M. javanica*	BR 501, BR 502, BR 503
	Pearl millet	*M. javanica*	FAO 1, FAO 2
Fiji	Pigeonpea	*Rotylenchulus reniformis*	QPL 67, QPL 116, QPL 511
India	Chickpea	*Meloidogyne* sp.	ICC 11311, 11315, 11321, 12236, RSG 130, 143, 238, 239
	Pigeonpea	*M. incognita*	ICPL 8, 81, 93, 94, 111, 143, 146, 227, 316, 8324, 8343, ICP 6997, 7025, 7182, 7197, 7234, 7898, 8308, 8662, 10976, 10978, 10979, 10984, 10986, 10991, 10993, 10996, 11049, 11204, 11206, 11207, 11231
		R. reniformis	ICP 12744, PDM 1, Basant, Prabhat, UPAS 120, Pant A 10
	Groundnut	*M. arenaria*	Mbwa Runner, Robut-33-1
Malawi	Pigeonpea	*M. javanica*	ICP 3465, 8864, 9145, 9174, 11299, 12729, 12748, 12753
Zambia	Chickpea	*Meloidogyne* sp.	BG1, CPS 1, JG 74, ICCC 38, JG 62

[a]BG, Bengal gram; BR, ?; CPS, chickpea selection; ICC, ICRISAT chickpea accession; ICCC, ICRISAT chickpea cultivar; ICP; ICRISAT pigeonpea accession; ICPL, ICRISAT pigeonpea breeding line; JG, Jabalpur gram; Pant, Pantnagar (Uttar Pradesh, India); PDM, Peddapuram (Andhra Pradesh, India); QPL, University of Queensland (Australia) pigeonpea lines

Discussion

On a global basis, plant-parasitic nematodes are estimated to cause losses in yield of 13.7% in chickpea, 12% in groundnut, 11.8% in pearl millet, 13.2% in pigeonpea and 6.9% in sorghum (Sasser and Freckman, 1987). At present, < 10% of the crop areas have been covered by surveys and it seems reasonable that, as more and more areas under these crops are surveyed, additional nematode problems will be identified. Availability of trained manpower in the developing countries will be crucial for this work to be done. On the basis of information made available from different countries, the root-knot nematodes, *Meloidogyne* spp., and the lesion nematodes, *Pratylenchus* spp., are internationally important nematode problems on groundnut, pigeonpea and chickpea. *Pratylenchus* spp. are also most important on sorghum and millet. Species of this genus attack many other crops including cereals, legumes, vegetables and fruit trees in the SAT. We suggest that an International *Pratylenchus* Project be formulated on the pattern of the International *Meloidogyne* Project (Sasser and Carter, 1985) with active involvement of nematologists in the tropics and with research emphasis on management of nematode problems based on host resistance, and physical and cultural methods of nematode control. Nematode problems of pigeonpea in India are somewhat different from those in most other countries. *H. cajani* and *R. reniformis* are widespread in the country and deserve more attention than *Meloidogyne* spp.

It is apparent that farmers do not have many practical solutions to nematode problems in the tropics. Exploitation of solar heat to reduce the nematode populations during the summer fallow period, and knowledge of hosts and non-hosts of problem nematodes could be useful in suggesting proper crop rotations to reduce the damage caused by nematodes. Rotation of legumes with cereals and grasses in the cropping sequence reduces the population of *Meloidogyne* sp. However, the presence in the field of weed hosts of *Meloidogyne* spp. allows the nematodes to reproduce and cause serious losses to subsequent susceptible legume crops. Some sources of resistance have been identified in the legumes, particularly to the *Meloidogyne* spp., and there is a need to test these, at different locations in the 'hot spots' to confirm the resistances, and to make use of these resistant sources in breeding programmes. There is no groundnut cultivar available with a high level of resistance to *M. arenaria* and *M. hapla*. In most countries, work on screening for identification of sources for resistance to important nematodes, has not started, although facilities for screening work exist. The majority of respondents indicated that they would like to collaborate with ICRISAT scientists in screening the germplasm material. We suggest that international agriculture research centres (such as IITA, Nigeria; ICRISAT, India; AVRDC, Taiwan; IRRI, Philippines) that are located in the tropics should take the lead and collaborate more actively with nematologists in the National Agricultural Research Systems, particularly in the multilocation screening of genotypes for resistance to important nematodes, and in evaluation of traditional and improved cropping systems for their impact on populations of the most important nematode pests of crops in the different regions of the tropics.

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