Fundam. appl. Nematol., 1998, **21** (6), 645-654

Plant parasitic nematodes associated with crops grown by smallholders in Mozambique

Rinie VAN DEN OEVER*, Esther VAN DEN BERG** and Jorge A. CHIRRUCO***

**191c Anh Giac Str., My Tho, Tien Giang Prov., Vietnam,*
**National Collection of Nematodes, Biosystematics Division, Plant Protection Research Institute, Private Bag X134, Pretoria 0001, South Africa,*
*and ***Plant Protection Department (DSV), c/o INIA, CP 3658, Maputo, Mozambique*

Accepted for publication 15 December 1997.

Summary - Crop surveys in Mozambique during 1992-1996 revealed the presence and the large distribution of several plant-parasitic nematodes. Root-knot (*Meloidogyne* spp.) and lesion (*Pratylenchus* spp.) nematodes are the predominant and most widespread forms. Several nematode species were found for the first time in Mozambique, whereas others were found on different crops than in previous surveys. *Pratylenchus zeae* was found frequently on maize, and also on common bean (*Phaseolus vulgaris* L.), sugarcane, and sunflower. Root-knot nematodes were serious pests of common bean, when the beans were grown together with maize in Niassa province, and also of cowpea in experimental fields and irrigation areas in the south, sunflower in Niassa province, tobacco in Nampula and Manica provinces, and vegetables from several areas. Root-knot nematode was not found to be a problem on cassava in Mozambique. The peanut pod nematode *Ditylenchus africanus* was found in Maputo and Gaza provinces and may have been introduced with imported groundnut used for seed or human consumption. © Orstom/Elsevier, Paris

Résumé - ***Nématodes phytoparasites associés aux cultures paysannes du Mozambique*** - Des enquêtes effectuées sur les cultures du Mozambique de 1992 à 1996 ont révélé la présence et l'importance de nombreux nématodes phytoparasites, *Meloidogyne* spp. et *Pratylenchus* spp. étant les plus répandus et prédominants. Plusieurs espèces ont été trouvées pour la première fois au Mozambique, tandis que d'autres étaient relevées sur d'autres plantes que celles signalées lors des enquêtes précédentes. *Pratylenchus zeae* est fréquent sur le maïs, mais aussi sur le haricot (*Phaseolus vulgaris* L.), la canne à sucre et le tournesol. *Meloidogyne* spp. sont de sérieux ennemis du haricot commun lorsqu'il est interplanté avec le maïs dans la province de Niassa, et également du niébé dans les champs expérimentaux et les zones irriguées du sud, du tournesol dans la province du Niassa, du tabac dans les provinces de Nampula et Manica, et enfin des plantes maraîchères en de nombreuses localités. Mais au Mozambique ces nématodes ne constituent pas un problème pour le manioc. *Ditylenchus africanus*, qui attaque les gousses d'arachide, a été trouvé dans les provinces de Maputo et Gaza et pourrait y avoir été introduit lors de l'importation d'arachides utilisées comme semences ou pour la consommation humaine. © Orstom/Elsevier, Paris

Keywords: crops, Mozambique, plant parasitic nematodes, survey.

Since 1968, nematological research in Mozambique has focused on commercial crops such as banana (Lima & Reis, 1969), sugarcane (Reis, 1974), and citrus (Reis, 1982). After independence in 1975, attention was given mainly to agricultural production on state farms and co-operatives, where food and cash crops are grown in a monoculture system. In 1983, it was decided that smallholders should get more attention in order to improve the production of food crops in their mixed farming systems. Maize is the predominant staple crop in most provinces, and cassava in some provinces. Cowpea is the most widely grown legume intercrop, followed by groundnut, whereas common beans are favoured in some areas at higher altitude.

During 1984-1990, various crops were sampled for the presence of nematodes, but the areas visited were restricted to parts of the southern provinces of Maputo and Gaza, because of safety problems (Van den Oever & Mangane, 1992).

As little was known about the importance and distribution of nematodes in the rest of the country, especially on food crops, several surveys were carried out in smallholders fields during 1992-1996 to obtain additional information on the incidence of nematodes on the most important crops throughout Mozambique.

Materials and methods

SURVEYS

A summary of the most important surveys carried out during the study period is presented in Table 1.

Food crops in Niassa province, mainly common beans, were sampled to establish whether the root-knot nematode problem, observed in some bean

Table 1. *Areas and crops sampled during the surveys carried out in smallholders fields in 1992-1996.*

Province (districts)	Period	Main crops sampled	No of samples	Type of sample
Niassa (32)[3]	May 92	common bean	7	r[1] + s[2]
		banana	7	r + s
		pumpkin	4	r + s
Niassa (32)	March 93	common bean	6	s ± r
		maize	2	r
Niassa (32)	Febr. 94	common bean	8	r
		maize	17	r
Niassa (32, 33, 34)	May 95	common bean	38	r + s
		sunflower	9	r + s
Maputo (2)	Jan. 93	maize	58	s
		cowpea	40	s
		cassava	15	s
		groundnut	6	s
		pumpkin	11	s
Inhambane (11, 12, 14, 16, 17)	June 93	cassava	30	r + s
Inhambane (11, 12)	Dec. 93	groundnut	12	r + s + sh[4]
Gaza (9, 10)	Dec. 93	groundnut	10	r + s + sh
Gaza (7, 9, 10)	Dec. 94	groundnut	24	r + s + sh
Maputo (3, 5, 6)	March 95	groundnut	21	r + s + sh
Nampula (27, 28, 30)	April 95	groundnut	14	r + s + sh
		cowpea	21	r + s
Nampula (24, 25, 26, 27, 29, 30)	Aug./ Sept. 94	cassava	27 (+8)[5]	r + s
		cowpea	4	r
		pigeon pea	2	r
Nampula (30, 31)	Jan. 96	tobacco	27 (+ 5)[6]	r
		maize	5	r
Manica (19, 20, 21)	March 96	tobacco	19 (+ 33)[7]	r
		maize	3 (+ 7)[7]	r

[1] r = roots; [2] s = soil; [3] (.) district number (Fig. 1); [4] sh = groundnut shell; [5] samples were stolen; [6] samples of tobacco company; [7] samples of tobacco companies

experiments at the Agricultural Experiment Station in Lichinga (EAL), also existed in smallholders fields in the area. Maize is cultivated in a mixed cropping system with common bean, with two bean crops during one maize crop. For the survey, roots and soil of ten to fifteen plants per field were collected.

Maize, cowpea, cassava, groundnut, and pumpkin grown by smallholders in the Gueguegue, Umpala, Massaca I, and Radio Marconi areas in Boane district were sampled during a survey on pests and diseases carried out by the Plant Production and Protection Department of the Faculty of Agronomy of the Eduardo Mondlane University in early 1993. Soil around the roots of ten to fifteen plants per field was collected.

As groundnut is an important legume crop in Mozambique, it was decided to sample some production areas in the south and the north to establish whether nematodes were as much a problem there as they are in the neighbouring country of South Africa. Smallholders fields were visited at harvest time. Twenty plants per field were uprooted, roots and pods collected for nematode extraction, and the seed source was established.

In 1992, cassava tubers from an introduced cultivar in an experiment at the Agricultural Experiment Sta-

tion of Umbelúzi (AEU) in Maputo province were brought in by the staff of the National Agricultural Research Institute (INIA). They were heavily distorted and infested by root-knot nematodes. Therefore, some cassava varietal field experiments were sampled at harvest time at AEU (1992, 1993) and Nhacoongo Agricultural Experiment Station (NAES) in Inhambane province (1995). A survey was also done in smallholders fields in Inhambane and Nampula provinces where cassava is a major crop. Tubers and roots of five to ten plants per field were examined and roots and soil collected for extraction.

Heavy root-knot nematode infestation was frequently observed in cowpea in the south and in some places in Nampula province during the cassava survey of 1994. Consequently, cowpea was surveyed during the groundnut survey in Nampula province in April 1995. In each field, roots and soil were collected from ten plants of the second cycle crop.

During the groundnut-cowpea survey in Nampula province in 1995, some tobacco plants heavily infested with root-knot nematode were found in two fields where cowpea did not show any sign of infestation. As tobacco cultivation had recently increased again in Nampula and Manica provinces, where it had been intensively cultivated in the past, a survey was carried out. In the Ribaue and Malema districts, both in Nampula province, mainly smallholders fields were visited. These farmers are supported by a private enterprise which sells the seed to them and buys their harvest. In Manica province, fields of four tobacco-producing companies and smallholders were sampled. In Nampula, ten plants per field and ten to twenty plants per nursery were sampled. In Manica, the number of plants sampled varied from fifteen to twenty per field.

Maize was also sampled in several fields in both these provinces, where it was grown as a rotation crop with tobacco, to see whether maize was infested with the same root-knot nematode species as the one attacking tobacco.

Apart from the above surveys organized on certain target crops, root and soil samples were also collected during other field trips to see whether nematodes constitute a problem in certain areas. In other cases, samples were brought in by colleagues of DSV, the staff of INIA, or other persons.

Handling and determination of nematodes

Nematodes were extracted from 10 g of roots using the blender and cottonwool filter method (Stemerding, 1963) with collection of the suspension 24 and 48 h after processing. The same method was used for groundnut shell tissue. For comparative purposes, the nematodes from the Nampula cassava samples were extracted by both the maceration-sodium hypochlorite method of Hussey and Barker (1973) and the method of Stemerding (1963). The former method was used for all tobacco roots collected during 1996.

Nematodes were extracted from 100 ml of soil by Cobb's modified decanting and sieving method (s'Jacob & Van Bezooyen, 1984).

Nematodes were killed with hot formalin-propionic acid (FP4:1), processed using Seinhorst's (1959) rapid glycerol-ethanol method, and mounted in pure anhydrous glycerol.

Perineal patterns of *Meloidogyne* spp. were cleaned in lactic acid 45% and mounted in pure anhydrous glycerol (Taylor & Netscher, 1974).

Most nematodes were identified by the taxonomists of the Biosystematics Division of the Plant Protection Research Institute in Pretoria, South Africa, and some at the International Institute of Parasitology in St. Albans, UK.

Results

Fig. 1 shows the sampling localities. Table 2 lists the nematodes found associated with various crops. The districts of origin of the species identified are indicated by numbers between brackets. These numbers correspond to the numbers in Fig. 1. Twenty-six nematode species and one genus are new records for Mozambique.

Maize

One hundred and eleven samples were collected in eleven districts. Lesion nematodes were found in 95% of the samples. *Pratylenchus zeae* was identified in samples from four districts. A *Pratylenchus* species, probably *P. sefaensis*, was found on maize at the EAL. *Rotylenchulus parvus* was frequently found in samples from sandy or loamy soils in the south. Root-knot nematodes were mostly absent or present in low numbers, with the exception of one sample with 110 juveniles (J2)/g of root in Niassa province and one sample in Manica province where maize was cultivated in rotation with tobacco, in which 1064 eggs and J2/g of root were found.

Cowpea

Eighty-two samples were collected, of which 43 were soil samples from Boane 2 and Panda and the rest root and soil samples from Maputo, Marracuene, Inhambane, Ribaue, Monapo, and Namapa. Although *Meloidogyne incognita* and *M. javanica* often caused severe damage in experimental fields of the Faculty of Agronomy in Maputo, in INIA fields at Ricatla, and in fields of an NGO at Muele, Inhambane, less severe or low infestations were found in most smallholders fields. In August 1994, a few seriously infested cowpea plants were found in cassava fields in three districts of Nampula province. In April

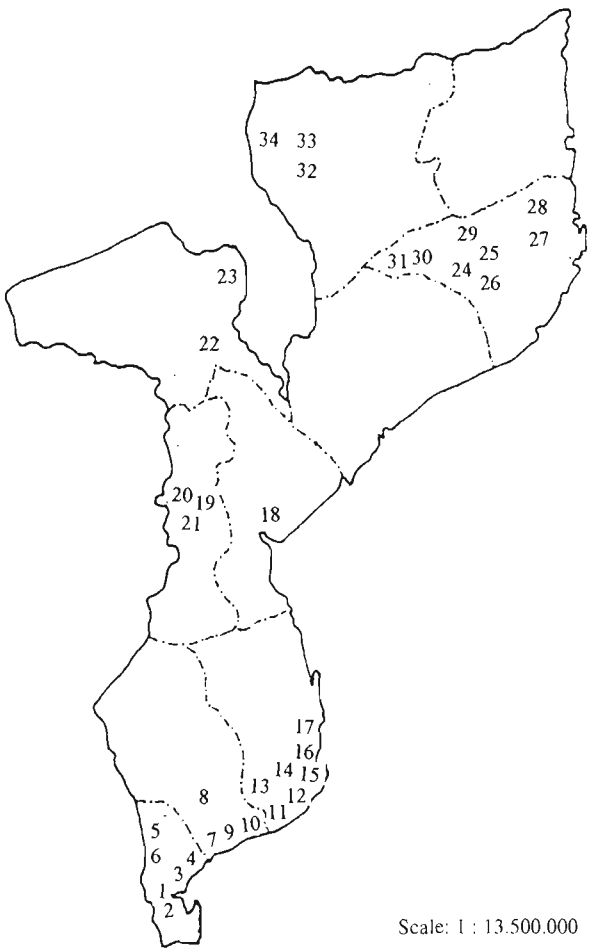

Fig. 1. *Map of Mozambique showing the districts where the samples were collected.*
Maputo province: 1. Maputo and Green Zones, 2. Boane, 3. Marracuene, 4. Manhiça, 5. Magude, 6. Moamba.
Gaza province: 7. Bilene, 8. Chokwe, 9. Xai Xai, 10. Manjacaze.
Inhambane province: 11. Zavala, 12. Inharrime, 13. Panda, 14. Homoine, 15. Inhambane, 16. Morrumbene, 17. Massinga.
Sofala province: 18. Dondo.
Manica province: 19. Gondola, 20. Manica, 21. Sussundenga.
Tete province: 22. Moatize, 23. Angonia + Tsangano.
Nampula province: 24. Nampula + Murrupula, 25. Meconta, 26. Mogovolas, 27. Monapo, 28. Nacaroa + Namapa, 29. Mecuburi, 30. Ribaue, 31. Malema.
Niassa province: 32. Lichinga, 33. Sanga, 34. Lago.

1995, no heavy infestation was observed in the 21 cowpea samples collected in four districts, but plants were much younger than in 1994.

Lesion nematodes were found in 85% of the cowpea samples, with large numbers of *Pratylenchus brachyurus* present in samples from the INIA Experimental Station at Ricatla (up to 2390 nematodes/g of root) and from one smallholder field in Monapo district (583 nematodes/g of root).

Other nematode species identified from cowpea were generally found in low to medium numbers.

Common bean

Common beans are grown in areas of higher altitude in Niassa and the north of Tete during the warm rainy season, and in the rest of the country during the cold, dry season in fields under irrigation. Most of the 82 samples were collected in Niassa and Tete provinces during the rainy season.

Root-knot nematodes were present in 95% of the samples, often in high numbers, and caused yield reduction. Root galls were visible in only 18% of the 22 bean root samples collected in smallholders fields in Niassa in 1995, but all 22 samples contained large numbers of root-knot nematodes. This makes identification of the problem in the field very difficult.

In Niassa province, 53% of the 43 samples collected in smallholders fields during the second bean crop had more than 100 *Meloidogyne* J2/g of root, but only 21% of the fourteen samples taken during the first crop reached the same level of infestation.

At EAL, much higher numbers of root-knot nematodes were found in bean roots from the second crop than from the first one in variety trials set up to evaluate host suitability (Van den Oever *et al.*, 1996).

Both *M. incognita* and *M. javanica* were found in samples from three different districts. In September 1995, a very heavy *M. ethiopica* infestation was observed in the Domué region of Angonia district in Tete province, where extensive cultivation takes place in this densely populated area.

Apart from root-knot nematodes, lesion nematodes were also present in large numbers in 14% of the samples from smallholders in Niassa province. Heavy root-knot nematode infestation was sometimes accompanied by the presence of lesion nematodes. *Pratylenchus zeae* was found in smallholders fields, whereas *P. brachyurus* was predominant in a sample from the EAL.

Several other genera and species were found in bean roots and soil (Table 2), but they seem to be of minor importance.

Groundnut

Ninety-five samples were collected in four provinces, three in the south and one in the north. Lesion nematodes were present in 76% of the samples, but the populations exceeded 100 nematodes/g of pod shell in only 5% of the samples. The numbers were much higher in shell tissue than in roots at harvest time. Generally, only 5% of pods in a sample showed

Table 2. *Plant-parasitic nematodes found on different crops in Mozambique during 1992-1996.*

Maize (*Zea mays* L.)
- *Helicotylenchus dihystera* (2, 32)[1]
- *Hoplolaimus pararobustus* (2)
- *Longidorus pisi* (2)
- *Meloidogyne incognita* (32)
- *Mesocriconema obtusicaudatum* (12)
- *Mesocriconema sphaerocephalum* (32)
- *Paratrichodorus minor* (32)
- **Pratylenchus* cf. *sefaensis* (32)
- *Pratylenchus zeae* (1, 2, 32)
- **Rotylenchulus clavicaudatus* (2)
- *Rotylenchulus parvus* (2)
- *Rotylenchus incultus* (23)
- **Scutellonema labiatum* (32)
- *Scutellonema unum* (12)
- *Tylenchorhynchus goffarti* (2)
- **Tylenchorhynchus ventrosignatus* (2)
- *Xiphinema malutiense* (12)
- **Xiphinema paritaliae* (12)
- *Xiphinema parvistilus* (2)
- *Xiphinema variabile* (2)

Sorghum (*Sorghum bicolor* (L.) Moench)
- *Pratylenchus brachyurus* (32)
- *Pratylenchus zeae* (32)
- *Pratylenchus* sp. (32)

Bean (*Phaseolus vulgaris* L.)
- *Helicotylenchus dihystera* (32, 33, 34)
- *Helicotylenchus microcephalus* (23)
- *Hemicriconemoides cocophillus* (23)
- *Hoplolaimus pararobustus* (23)
- **Meloidogyne ethiopica* (23)
- *Meloidogyne incognita* (32)
- *Meloidogyne javanica* (32)
- *Mesocriconema obtusicaudatum* (32)
- *Paratrichodorus minor* (32)
- *Pratylenchus brachyurus* (32)
- *Pratylenchus zeae* (2,32, 33, 34)
- *Rotylenchulus parvus* (32)
- **Scutellonema clathricaudatum* (33, 34)
- *Scutellonema labiatum* (32)
- *Scutellonema magniphasmum* (23, 32, 34)
- *Scutellonema unum* (32)
- *Tylenchorhynchus goffarti* (2, 32)
- **Tylenchorhynchus mashhoodi* (32)
- **Xiphinema barbercheckae* (32, 34)
- **Xiphinema paritaliae* (32, 34)

Anthurium (*Anthurium* spp.)
- *Meloidogyne javanica* (1)
- **Paratylenchus minutus* (1)
- *Pratylenchus coffeae* (1)

Sweet pepper (*Capsicum annuum* L.)
- *Rotylenchus incultus* (1)

Cowpea (*Vigna unguiculata* (L.) Walp.)
- *Hoplolaimus pararobustus* (1, 3)
- *Meloidogyne incognita* (1, 3)
- *Meloidogyne javanica* (1, 3)
- **Paratrichodorus lobatus* (1, 3)
- *Pratylenchus brachyurus* (1, 3, 15, 27)
- *Rotylenchulus parvus* (28)
- *Rotylenchus incultus* (1)
- *Scutellonema brachyurus* (2)
- **Scutellonema magniphasmum* (27)
- *Scutellonema truncatum* (2)
- *Scutellonema unum* (30)
- *Tylenchorhynchus goffarti* (1)
- **Xiphinema* cf. *ifacolum* (1)
- **Xiphinema limpopoense* (1)

Groundnut (*Arachis hypogaea* L.)
- *Ditylenchus africanus* (3, 10)
- **Hemicycliophora typica* (3)
- *Pratylenchus brachyurus* (12, 27, 28, 30)
- *Rotylenchus brevicaudatus* (3, 12)
- *Scutellonema unum* (30)

Pigeonpea (*Cajanus cajan* (L.) Mill.)
- *Meloidogyne javanica* (3)
- **Mesocriconema obtusicaudatum* (12)
- *Scutellonema unum* (24)

Soybean (*Glycine max* (L.) Merr.)
- *Meloidogyne* sp.
- *Pratylenchus brachyurus* (32)
- *Pratylenchus zeae* (32)

Hyacinth bean (*Lablab niger* Medik.)
- *Meloidogyne* sp. (32)

Cassava (*Manihot esculenta* Crantz)
- **Hemicycliophora typica* (14)
- *Pratylenchus brachyurus* (2, 12)
- *Meloidogyne incognita* (2)
- **Rotylenchulus parvus* (14, 16, 17)
- *Rotylenchulus reniformis* (2)
- *Scutellonema unum* (12)

Potato (*Solanum tuberosum* L.)
- *Meloidogyne javanica* (32)
- *Pratylenchus* sp. (23)
- *Tylenchorhynchus goffarti* (23)
- **Tylenchorhynchus mashhoodi* (23)

Pumpkin (*Cucurbita pepo* L.)
- *Helicotylenchus dihystera* (32)
- *Meloidogyne incognita* (13, 32)
- *Meloidogyne javanica* (32)
- *Paratrichodorus lobatus* (1)
- *Paratrichodorus minor* (1)
- *Rotylenchus incultus* (1, 2)
- *Scutellonema truncatum* (2)

Chillies (*Capsicum annuum* L.)
- *Rotylenchulus parvus* (2)

Banana (*Musa* spp.)
- *Helicotylenchus dihystera* (4)
- *Helicotylenchus multicinctus* (32)
- *Hoplolaimus pararobustus* (32)
- *Meloidogyne* sp. (32)
- **Paratrichodorus lobatus* (4)
- **Paratylenchus minutus* (1)
- *Pratylenchus zeae* (32)
- *Radopholus similis* (4)
- *Rotylenchus unisexus* (32)
- **Scutellonema magniphasmum* (32)
- **Tylenchorhynchus annulatus* (4)

Citrus (*Citrus* spp.)
- *Tylenchulus semipenetrans* (2)
- *Xiphinema diffusum* (2)

Sugarcane (*Saccharum officinarum* L.)
- *Criconemella* sp. (18)
- **Helicotylenchus crenacauda* (18)
- *Helicotylenchus dihystera* (32)
- *Pratylenchus zeae* (18)
- *Scutellonema unum* (18)

Tobacco (*Nicotiana tabacum* L.)
- *Meloidogyne incognita* (19, 21, 30, 31)
- *Meloidogyne javanica* (20, 21, 30)
- *Pratylenchus* sp. (19, 20, 21, 30, 31)

Cotton (*Gossypium* spp.)
- *Scutellonema brachyurus* (8)

Sunflower (*Helianthus annuus* L.)
- *Helicotylenchus dihystera* (32, 33)
- *Meloidogyne javanica* (32)
- *Pratylenchus zeae* (34)
- **Scutellonema clathricaudatum* (33, 34)
- **Scutellonema magniphasmum* (33, 34)
- **Tylenchorhynchus mashhoodi* (33)
- **Xiphinema barbercheckae* (33)
- **Xiphinema paritaliae* (33)

Tomato (*Lycopersicon esculentum* Mill.)
- *Helicotylenchus dihystera* (23, 27)
- *Helicotylenchus microcephalus* (27)
- *Hemicriconemoides cocophillus* (23)
- *Hoplolaimus pararobustus* (23)
- *Meloidogyne incognita* (1, 8, 15, 23)
- *Meloidogyne javanica* (1, 15, 20, 22)
- *Paratrichodorus minor* (23)
- **Pratylenchus* cf. *sefaensis* (23)
- *Rotylenchulus parvus* (1, 8)
- *Scutellonema magniphasmum* (23)
- *Xiphinema elongatum* (1)
- **Xiphinema paritaliae* (23)

Okra *Abelmoschus esculentus* (L.) Moench
- *Pratylenchus zeae* (2)

1 Numbers relate to the district numbers in Fig. 1.
* New host plants for the region.

symptoms. *Pratylenchus brachyurus* was identified in samples from four districts.

The peanut pod nematode *Ditylenchus africanus* was found in the south of Mozambique in December 1994, which is the first record of this nematode outside South Africa. The nematode was found in 17% of the twelve samples from Inhambane, 15% of the 34 Gaza samples and 81% of the 21 Maputo samples. This nematode was found in large numbers only in two fields in Manjacaze (Gaza) and Moamba (Maputo).

Forty-nine percent of the farmers used bought seed, whereas the others used seed from the previous harvest. Seed bought for consumption was frequently used for planting. The peanut pod nematode was not found in Nampula province.

Other leguminous crops

Root-knot nematode was observed in two of the four pigeon pea samples, in the four hyacinth bean and two soybean samples.

Cassava

During the present survey, no root-knot nematode infestation as damaging as the one observed on introduced cultivar TMS 30395 mentioned earlier was found. However, in four cassava variety trials at NAES in Inhambane province, large numbers of root-knot nematodes were found on several cultivars during 1995, but no distorted tubers were observed.

Root-knot nematode densities in excess of 100 J2/g of root were observed in only 7% of the thirty cassava root samples from smallholders fields from Inhambane province. Those were from fields where cotton had formerly been grown under irrigation. In one field where only a few *Meloidogyne* juveniles were found in the cassava roots, the weed *Tephrosia purpurea* (L.) Pers. was heavily infested. Nine different cassava cultivars were used by the farmers in Inhambane province. Fifty percent of the farmers had cultivated cassava for more than 2 years in a row in the same field, and 28% for 5 years or longer.

In Nampula province, where cassava had been grown only for 1 or 2 years after the war, no serious root-knot nematode infestation was detected in the 27 samples from smallholders fields. However, heavy root-knot nematode infestations were observed in cowpea, pigeon pea, and tomato planted as mixed crops with cassava. Eighteen cultivars were used in the area including bitter and sweet cultivars.

Where partly galled cassava roots as well as infected cowpea and pigeon pea roots were extracted with both the sodium hypochlorite and the cottonwool filter methods, the former method always yielded considerably more nematodes.

Low numbers of lesion nematodes were found in 44% of the samples and *Pratylenchus brachyurus* was identified in samples from two districts.

Potato

During the rainy season potato is grown in combination with maize and beans in the higher altitude areas and the potatoes harvested are frequently used as seed for the next potato crop. In a few samples from Niassa province, infested tubers yielded *Meloidogyne javanica* females. Smaller infestations were found in six root samples from Angonia district in Tete province.

Banana

Although banana used to be an export crop, it is now grown only for the local market. Banana-trees are often grown as borders around field crops, but can also be found scattered throughout the field. Eleven samples were collected from smallholders, three at a co-operative farm and eight from the Maragra sugar estate in Manhiça district. Spiral nematodes (*Helicotylenchus multicinctus* and/or *H. dihystera)* were found in 91% of the samples and root-knot nematodes in 82% of the samples. The burrowing nematode *Radopholus similis* was present only in three of the Maragra samples.

Citrus

Four samples were collected during two visits at one estate in Boane district. *Tylenchulus semipenetrans* was present in all four samples.

Sugarcane

Nine soil samples were collected by researchers from Faculty of Agronomy at the Mafambisse sugarcane estate in Dondo district, one root and soil sample in a smallholders field, and three samples at the Maragra sugarcane estate in Manhiça district. Lesion nematodes were recovered from 91% of the samples (*Pratylenchus zeae* was identified from the Mafambisse samples) and root-knot nematodes from 23% of the samples.

Tobacco

Of the 32 samples collected in Nampula province, 62% were from smallholders fields, 16% from private farms, and 7% from the only tobacco company in the area. This company used EDB fumigation or the burning of firewood and plant residues for seedbed treatment. Methylbromide was not used as it had been delivered too late. The farmers burned firewood and/or plant residues to treat their seedbeds. None of the fields sampled in this study were treated and serious root-knot nematode infestation was observed early in the season.

In Manica province, 42% of the 55 root and soil samples collected were from smallholders fields and the rest from four tobacco-growing companies. Three of the companies used methylbromide to disinfect their seedbeds. The fourth company and the smallholders obtained their tobacco plants from these companies. All four companies used EDB fumigation to treat their fields and three of them used fenamiphos after transplanting. *M. incognita* and *M. javanica* were found in both provinces.

Tobacco was grown in rotation with maize, sorghum, beans, and cassava in Nampula province and with maize, beans, cowpea, sorghum, groundnut, and Rhodes grass in Manica province. Maize was used mostly as rotation crop, because it is the staple crop in these areas. In a tobacco nursery in Ribaue, where sunflower had been grown the previous year, a heavy root-knot nematode infestation was observed in all the tobacco seedlings.

SUNFLOWER

In Niassa province, sunflowers are usually grown by smallholders as a border crop in maize and common bean fields. Root-knot nematodes were found in all fourteen samples collected and numbers were in excess of 100 J2/g of root in 54% of the samples. *M. javanica* was identified in one sample from Malica, Lichinga district. *Pratylenchus zeae, Helicotylenchus dihystera,* and *Scutellonema* spp. were of minor importance.

VEGETABLES

Twenty-seven tomato, 30 pumpkin, eight other cucurbits, nine okra, eight cruciferae, six lettuce, three green pepper, and one chilli pepper samples were collected. Tomato, pumpkin, and okra had the most severe root-knot nematode infestation. Pumpkin and okra are generally cultivated in combination with maize and cowpea.

M. incognita and/or *M. javanica* were found on tomatoes from eight locations.

The lesion nematode found in a tomato sample from Angonia district in Tete province could be *P. sefaensis. Rotylenchulus parvus* and *R. reniformis* were also collected from tomato.

Pumpkin soil from Boane district yielded males and females of *Scutellonema truncatum.* Males of this species were found for the first time (Van den Berg & Van den Oever, 1993).

ANTHURIUM

On two farms with ornamental plants, root and soil samples were collected from *Anthurium* to find out whether nematodes were the cause of the stunted growth of the plants. Populations of a *Pratylenchus* sp. in excess of 100/g of root were observed in 43% of the seven root and soil samples from *Anthurium. M. javanica* and a pin nematode, *Paratylenchus minutus*, were also present, but in low numbers.

Discussion

In the neighbouring countries of South Africa, Malawi, Zimbabwe, and Tanzania (Saka & Siddiqi, 1979; Keetch & Buckley, 1984; Page *et al.*, 1985; Hillocks *et al.*, 1995; Kleynhans *et al.*, 1996) the following nematodes from Table 2 have either not been found yet or have been reported from different crops than in Mozambique: *Pratylenchus sefaensis, Meloidogyne ethiopica, Helicotylenchus crenacauda, Hemicycliophora typica, Mesocriconema obtusicaudatum, Paratrichodorus lobatus, Paratylenchus minutus, Rotylenchulus clavicaudatus, Rotylenchulus parvus, Scutellonema clathricaudatum, S. labiatum, S. magniphasmum, Tylenchorhynchus annulatus, T. mashhoodi, T. ventrosignatus, Xiphinema barbercheckae, X.* cf. *ifacolum, X. limpopoensis,* and *X. paritaliae.* In other parts of the world, *P. sefaensis* has been reported from maize in Senegal (type and host locality) and Gambia (Merny *et al.*, 1974), *H. crenacauda* from sugarcane in Indonesia (Maqbool, 1991), *S. clathricaudatum* from sunflower in Sudan (Nour Eldin & Siddiqi, 1995), *T. mashhoodi* from bean in India and potato in Pakistan (Maqbool, 1991) and *P. minutus* from *Anthurium* in Trinidad (Bala & Hosein, 1996).

In Mozambique, *Pratylenchus zeae* was the most common lesion nematode on maize. This is also the case in Zimbabwe (Page *et al.*, 1985), South Africa (De Waele & Jordaan, 1988), and Malawi (Hillocks *et al.*, 1995). In Mozambique, *P. zeae* was also found on sorghum, common bean, sugarcane, sunflower, banana, okra, and soybean. It was not found on cowpea, groundnut, and cassava, crops on which *P. brachyurus* was the predominant lesion nematode. Jones and Hillocks (1995) also reported that cowpea and groundnut were not infested by *P. zeae* in Malawi.

The second most important nematode on maize was *Rotylenchulus parvus,* found more often in the south than in the north of Mozambique. *R. parvus* was usually present in maize soil together with *P. zeae*, which was also the case in Zimbabwe (Page *et al.*, 1985) and Malawi (Hillocks *et al.*, 1995).

Root-knot nematodes were generally not found or were present only in low numbers in maize roots except in two instances. On the contrary, Riekert (1993) reported that root-knot nematodes are as important as lesion nematodes on maize in South Africa.

According to Swarup and Sosa Moss (1990), root galls on maize may be small or large, but may also be totally absent. As a result, maize has often been mistakenly considered a poor host or even immune. As Riekert (1995) did not see any galls or egg-masses on maize roots, he developed a modified sodium

hypochlorite (SH) extraction technique to obtain eggs and juveniles from maize roots. In this technique, 50 g of roots are shaken with SH for 4 min and the suspension is quickly passed through a range of sieves (apertures 710, 250, 75, 63, 45, 25, and 10 µm), using the suction of a vacuum pump to prevent clogging of the finer sieves.

When the sodium hypochlorite technique of Hussey and Barker (1973) was used to extract root-knot nematodes from the maize roots sampled in fields where maize was grown in rotation with tobacco, root-knot nematode juveniles and eggs in excess of 100/g root were found in 20% of the fifteen samples. Thus, maize is a host of *Meloidogyne*, although not as good a host as cowpea, beans, and sunflower. In Zimbabwe, where *M. javanica* is the most important root-knot nematode on tobacco, less root damage was caused by *M. javanica* to tobacco after 5 years of groundnut, cotton or sunn hemp (*Crotalaria spectabilis*) than after maize, sunn hemp (*C. juncea*) or soybeans (Shepherd & Barker, 1990). A 3- to 5-year rotation with grass such as Rhodes grass, *Chloris gayana* cv. Katambora, is even more effective (Shepherd, 1982), and this control method was used by some of the tobacco companies in Manica province.

Although maize is presently the main rotation crop with tobacco in Mozambique, this programme will not be sufficient to reduce root-knot nematodes to an acceptable level for tobacco cultivation.

Although severe root-knot nematode infestation on cowpea was regularly found at several experimental stations and in irrigated fields where the introduced erect cultivars were grown, heavy infestation was seldom observed in rainfed smallholders fields. Mainly local cultivars are grown in combination with maize or cassava with low plant density throughout Mozambique. Twelve local cultivars tested during a trial turned out to be good hosts of *M. incognita* and *M. javanica*, although some seemed to be tolerant (Van den Oever & Chirruco, 1996). Probably the low plant density combined with a long dry season and the use of tolerant cultivars prevents root-knot nematodes from becoming a severe problem for cowpea in smallholders fields.

In the north (Nampula province), sampling was principally during April on the second cycle cowpea crop, when the first crop had already been harvested. Different cowpea types and cultivars are grown during the two seasons. These differences have not been taken into account yet. Therefore sampling should be done in both seasons before conclusions can be made concerning the northern part of Mozambique.

Common bean was heavily infected with root-knot nematodes in smallholders fields in Niassa province, especially during the second bean crop. New ridges are prepared for the second bean crop between the existing maize and bean ridges of the first crop, which means that infected soil is put on top of non-cultivated soil. Rotation within the field with only part of the field sown with beans between the maize during the second bean crop could reduce the severity of the nematode problem, as the actually grown and newly introduced and accepted varieties were all good hosts for root-knot nematodes (Van den Oever *et al.*, 1996). It would be better to sow sunn hemp (*C. spectabilis*) between the maize in the areas where no beans are grown to reduce the infestation more rapidly and to improve soil fertility. However, this would necessitate extra farm labour without a direct commercial return, something farmers may not be willing to accept.

In most bean root samples, no galls were visible on the roots, but distinct galls were present in other samples. This is in agreement with Blazey *et al.* (1964), who mention that the gall size on the roots of *Phaseolus* spp. is variable and may be nearly undetectable. In previous years, the INIA staff evaluated roots of different bean cultivars in variety trials for root-knot nematode infestation using the root-knot index of the international bean germplasm testing programme. This may have resulted in an underestimation of the root-knot nematode problem, as infestation may have been present without visible root galls.

In smallholders fields, high *Pratylenchus zeae* numbers were found in bean roots grown together with maize. Both crops are good hosts for this nematode and they increase the nematode numbers in the soil. Although *P. scribneri* and *P. penetrans* were reported as causing yield reduction in common bean (Sikora & Greco, 1990), and *P. zeae* was reported from beans in Malawi (Saka & Siddiqi, 1979) and legumes in South Africa (Kleynhans *et al.*, 1996), their economic importance in the production of common bean is unknown. In some cases, both lesion nematode and root-knot nematode numbers were very high in bean roots, but their interaction is unknown.

Very few *Pratylenchus brachyurus* specimens were recovered from groundnut roots compared to those from pod shell tissues. This is in agreement with Good *et al.* (1958), who stated that shells contain six to eight times more root lesion nematodes than roots. Although many farmers in the south of Mozambique have grown groundnuts for many years in the same fields, lesion nematodes do not seem to be a problem. At harvest, plants are packed in heaps under trees where the pods are harvested. Thus the pod shells, the main source of inoculum, are kept away from the fields. In some areas farmers harvest two crops of groundnut per year, but different fields are used for the two crops.

The peanut pod nematode *Ditylenchus africanus* (formerly determined as *D. destructor*) was found outside South Africa for the first time. The nematode

enters through the pod shell to infect the seed and reduces seed quality (Venter *et al.*, 1991). The nematode is seedborne and therefore disseminated by the seed. In southern Mozambique, all groundnuts available for consumption originate from South Africa. Several farmers use these groundnuts as seed and it is likely that this practice is at the origin of the local infestation.

Cassava was found not to be seriously infested with root-knot nematode in Mozambique, which contradicts the results of Coyne and Namaganda (1994). They found 94% of the 88 cassava samples from smallholders in Uganda infested and of these 16% displayed moderate to severe galling. Although more than half of the farmers in Inhambane province planted cassava in the same field for 2 years or more, no severe root-knot nematode infestation was found. In Nampula province where fields were used for 1 or 2 years, even smaller infestations were observed. According to McSorley *et al.* (1983), the various cassava cultivars display much variation in tolerance and susceptibility towards *Meloidogyne* attack. Presumably, the cultivars grown by the local farmers in the two provinces are to a certain extent resistant to root-knot nematodes. The heavy infestations of other crops and weeds growing near the cassava in the same fields support this assumption.

Acknowledgements

We thank M. Pancas, Head of the Plant Protection Department of the Ministry of Agriculture in Maputo for support, S. Mangane for assistance in the Nampula cassava survey, C. Saúde for the collection of the Mafambisse and Boane samples, U. Althof for assistance during 1993, Drs K. Kleynhans, A. Swart, and M. Marais of the Plant Protection Research Institute, Pretoria, South Africa and Dr. M.R. Siddiqi of the International Institute of Parasitology, UK, for identifications. We are grateful to the various farmers for their assistance and the use of their fields during the various surveys and to staff members of INIA for providing samples and assistance. This work was funded by DANIDA, who provided technical and financial support to the Plant Protection Department in Maputo, Mozambique.

References

BALA, G. & HOSEIN, F. (1996). Plant-parasitic nematodes associated with anthuriums and other tropical ornamentals. *Nematropica*, 26: 9-25.

BLAZEY, D.A., SMITH, P.G., GENTILE, A.G. & MIYAGAWA, S.T. (1964). Nematode resistance in the common bean. *J. Heredity*, 55: 20-22.

COYNE, D.L. & NAMANGANDA, J.M. (1994). Root-knot nematodes *Meloidogyne* spp. incidence on cassava in two areas of Uganda. *Roots*, 1: 12-13.

DE WAELE, D. & JORDAAN, E.M. (1988). Plant parasitic nematodes on field crops in South Africa. 1. Maize. *Revue Nématol.*, 11: 65-74.

GOOD, J.M., BOYLE, L.W. & HAMMONS, R.O. (1958). Studies of *Pratylenchus brachyurus* on peanuts. *Phytopathology*, 48: 530-535.

HILLOCKS, R.J., SIDDIQI, M.R. & KHONGA, E.B. (1995). Nematodes associated with subsistence crops in Southern Malawi. *Afro-Asian J. Nematol.*, 5: 14-19.

HUSSEY, R.S. & BARKER, K.R. (1973). A comparison of methods collecting inocula of *Meloidogyne* spp. including a new technique. *Pl. Dis. Rptr*, 57: 1025-1028.

JONES, M.L. & HILLOCKS, R.J. (1995). Host status for *Pratylenchus zeae* of food crops and associated weed species in Malawi. *Afro-Asian J. Nematol.*, 5: 120-126.

KEETCH, D.P. & BUCKLEY, N.H. (1984). *A check-list of the plant-parasitic nematodes of southern Africa*. Pretoria, South Africa, Department of Agriculture, Techn. Comm., No 195, 213 p.

KLEYNHANS, K.P.N., VAN DEN BERG, E., SWART, A., MARAIS, M. & BUCKLEY, N.H. (1996). *Plant nematodes in South Africa*. Pretoria, South Africa, ARC-Plant Protection Research Institute, Handbook, No 8, 165 p.

LIMA, M.R. & REIS, L.G.L. (1969). *Radopholus similis* (Cobb) Thorne em Moçambique. Relatório de uma visita de estudo. *Comun. Inst. Invest. agron. Moçambique*, 68: 1-26

MAQBOOL, M.A. (1991). *Nematode pests of economic significance affecting major crops of the countries in Asia and the pacific region*. Bangkok, Thailand, FAO, Asia and the Pacific Plant Protection Commission, Technical Document, No 140, 65 p.

MCSORLEY, R.S., O'HAIR, K.O. & PARRADO, J.L. (1983). Nematodes of cassava, *Manihot esculenta* Crantz. *Nematropica*, 13: 261-287.

MERNY, G., FORTUNER, R. & LUC, M. (1974). Les nématodes phytoparasites de Gambie. *Agron. trop., Nogent*, 29: 702-707.

NOUR ELDIN, E.M. & SIDDIQI, M.A. (1995). Plant parasitic nematodes associated with sunflower at Abu-Naama, Sudan and observations on host suitability of sunflower cultivars to *Xiphinema basiri*. *Afro-Asian J. Nematol.*, 5: 148-150.

PAGE, S.L.J., MGUNI, C.M. & SITOLE, S.Z. (1985). *Pests and diseases of crops in communal areas of Zimbabwe*. London, UK, Technical Report Overseas Development Administration, 203 p.

REIS, L.G.L. (1974). Noticia brevia sobre os nemátodos parasitas de cana-de-açucar em Moçambique. *III Jornadas açucareiras de Moçambique*, No 11, 7 p.

REIS, L.G.L. (1982). Plant parasitic nematodes associated with citrus in Moçambique. *Agron. lusitana*, 41: 213-225.

RIEKERT, H.F. (1993). Population dynamics of some economically important nematodes in maize fields in the Western Transvaal. *11th Symp. Nematol. Soc. Southern Africa, March 28-31, Rustenburg, South Africa*: 12. [Abstr.]

RIEKERT, H.F. (1995). A modified sodium hypochlorite technique for the extraction of root-knot nematode eggs and larvae from maize root samples. *Afr. Pl. Prot.*, 1: 41-43.

SAKA, V.W. & SIDDIQI, M.A. (1979). Plant-parasitic nematodes associated with plants in Malawi. *Pl. Dis. Rptr,* 63: 945-948.

SEINHORST, J.W. (1959). A rapid method for the transfer of nematodes from fixative to anhydrous glycerin. *Nematologica,* 4: 67-69.

SHEPHERD, J.A. (1982). Nematode pests of tobacco. *In*: Keetch, D.P. (Ed.). *Nematology in Southern Africa.* Pretoria, South Africa, Dep. of Agric. & Fisheries, Sci. Bull. No 400: 58-67.

SHEPHERD, J.A. & BARKER, K.R. (1990). Nematode parasites of tobacco. *In*: Luc, M., Sikora, R.A. & Bridge, J. (Eds). *Plant parasitic nematodes in subtropical and tropical agriculture.* Wallingford, UK, CAB International: 493-512.

SIKORA, R.A. & GRECO, N. (1990). Nematode parasites of food legumes. *In*: Luc, M., Sikora, R.A. & Bridge, J. (Eds.). *Plant parasitic nematodes in subtropical and tropical agriculture.* Wallingford, UK, CAB International: 181-236.

S'JACOB, J.J. & VAN BEZOOYEN, J. (1984). *A manual for practical work in nematology.* International Course on Plant Protection. Wageningen, The Netherlands, IAC, 76 p.

STEMERDING, S. (1963). Een mixer-wattenfilter methode om vrijbeweeglijke endoparasitaire nematoden uit wortels te verzamelen. *Versl. Meded. plziektenk. Dienst Wageningen,* 141: 170-175.

SWARUP, G. & SOSA-MOSS, C. (1990). Nematode parasites of cereals. *In*: Luc, M., Sikora, R.A. & Bridge, J. (Eds.). *Plant parasitic nematodes in subtropical and tropical agriculture.* Wallingford, UK, CAB International: 109-136.

TAYLOR, D.P. & NETSCHER, C. (1974). An improved technique for preparing perineal patterns of *Meloidogyne* spp. *Nematologica,* 20: 268-269.

VAN DEN BERG, E. & VAN DEN OEVER, H.A.M. (1993). Description of the male of *Scutellonema truncatum* Sher, 1963 from Mozambique (Nemata: Hoplolaimidae). *Phytophylactica,* 25: 157-158.

VAN DEN OEVER, H.A.M. & CHIRRUCO, J.A. (1996). Infestação de nemátodos no feijão nhemba. Avaliação de infestação de variedades de feijão nhemba pelo nemátodo da galha (*Meloidogyne* spp.) e o nemátodo da lesão (*Pratylenchus brachyurus*). 1992/95. *INIA Série Investigação,* No 23, 24 p.

VAN DEN OEVER, H.A.M., DAVIES, G., CHIRRUCO, J.A. & TOCORO, C. (1996). Ensaios e prospecção de nemátodos em Niassa. *INIA Série Investigação,* No 22, 35 p.

VAN DEN OEVER, H.A.M. & MANGANE, S.E. (1992). A survey of nematodes on various crops in Mozambique. *Afro-Asian J. Nematol.,* 2: 74-79.

VENTER, C., DE WAELE, D. & MEYER, A.J. (1991). Reproductive and damage potential of *Ditylenchus destructor* on peanut. *J. Nematol.,* 23: 12-19.