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Plant parasitic nematode diversity and prevalence in traditional upland rice in Ivory Coast: preliminary observations on the effects of cropping intensification

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Summary – This study compares nematode prevalence in upland rice fields, which differed in cropping intensity, in three agroecological zones of Ivory Coast. Eighty nematode species from 35 genera were found associated with rice. Population densities of *Helicotylenchus* spp. were significantly lower in long fallows in the forest zone, but the mean population densities of all other nematode genera and species did not differ significantly between fallow regimes in any of the three agroecologies. Mean nematode population densities exhibited a trend, decreasing, under longer fallows in the forest and savannah zones. Nematode diversity was greatest in the forest-savannah, decreased in the savannah and was least in the humid forest. The population density and prevalence of some nematode genera differed between agroecologies. Of the known pests of rice, *Meloidogyne* spp. were most prevalent in the forest, whilst *Pratylenchus* spp. were more prevalent in the forest-savannah and savannah. *Heterodera* spp. occurred in the forest and forest-savannah, but its prevalence was low. © Orstom/Elsevier, Paris

Résumé – ***Diversité et prédominance chez les nématodes parasites des cultures traditionnelles de riz de plateau en Côte d'Ivoire : observations préliminaires sur les conséquences de l'intensification de cette culture*** – La présente étude compare la prédominance des nématodes dans des champs de riz de plateau ayant des fréquences de culture variables, champs situés dans trois zones agroécologiques différentes de la Côte d'Ivoire. Les densités de population des *Helicotylenchus* sont significativement plus faibles lors de jachères longues en zone forestières, mais les densités moyennes des populations de tous les autres genres de nématodes ne montrent de différences significatives dans les rotations avec jachère pour aucun des trois types agroécologiques retenus. Les densités moyennes des populations de nématodes présentent une tendance à décroître sous jachères longues dans les zones forestières et de savane. La diversité des nématodes est la plus élevées en savane arborée ; elle diminue en savane claire et est la plus faible sous forêt humide. La densité de population ainsi que la prédominance de certains genres de nématodes varient suivant les types agroécologiques. Parmi les parasites reconnus du riz, les *Meloidogyne* sont prédominants en forêt tandis que ce sont les *Pratylenchus* en savane, tant arborée que claire. Des *Heterodera* sont rencontrés en forêt et en savane arborée, mais leur prédominance est faible. © Orstom/Elsevier, Paris

Keywords: fallow, intensification, Ivory Coast, *Oryza sativa,* plant parasitic nematodes, rice, WARDA.

Rice production in West Africa is dominated by small holders in traditional upland systems (Anon., 1994). These systems are characterised by low levels of management input and a range of environmental, social and economic constraints, often resulting in poor yields (Anon., 1992). A dramatic escalation in the consumption of rice by urban populations (Adesina & Gaye, 1993) has fuelled demand and led to increasing competition for land. The sustainability of these traditional systems relies upon adequate fallow periods to allow the restoration of soil fertility, maintain soil structure and suppress pests, but intensification, particularly in the traditional rainfed systems, is taking place without a parallel adoption of practices to replace the restorative aspects of traditional fallowing. Becker *et al.* (1994) determined that fallow periods between rice crops in the forest zone of Ivory Coast, have decreased from about 12 years in the mid-1980's to typically 6 years in 1994. In the savannah zone, the number of successive crops grown before leaving the land to fallow has increased from three to five over the same period (Becker & Diallo, 1992).

Fallow periods provide control of certain parasitic nematodes in various crops (Bridge, 1987) including rice (Bridge *et al.*, 1990), whereas intensification can give rise to more severe and new disease problems (Naito, 1994). Many genera of nematodes are associated with rice, though only a few are recognised pests (Bridge *et al.*, 1990). Estimates of their economic importance vary (Prot & Rahman, 1994) and reliable estimates of yield loss in African upland rice environments are still required. The aim of this work was to survey plant parasitic nematodes associated with rice in traditional upland and hydromorphic ecosystems in the different agroecologies of Ivory Coast and examine the influence of intensification on their prevalence and population dynamics. Hydromorphic rice is differentiated from true upland rice in that the rooting zone of plants in this ecosystem lie within reach of the water table, and following heavy rain may be temporally waterlogged (Anon., 1994).

Data were compared with a previous survey made in 1977 (Fortuner, 1981) in order to assess the change in incidence of nematodes associated with rice in Ivory Coast since 1977.

Materials and methods

Studies were made in three locations where WARDA (West Africa Rice Development Association) has multidisciplinary, village-level studies in the humid-forest, forest-savannah transition and savannah agroecologies of Ivory Coast (Table 1). A total of 105 upland rice fields with different cropping intensities were sampled (Table 2). In Gagnoa, upland fields were topographically and hydrologically heterogeneous comprising areas which, because of the proximity of the water table, were prone to water logging after heavy rain. It was not possible to reliably differentiate areas of transient and indistinct variations in soil hydrology during sampling. A further 22 fields in Danané and Man, and seven at Bouaké (forest-savannah) were also sampled. All sites were sampled between crop flowering and maturity, from June to September 1995. Roots and rhizospheric soil were collected from ten plants per field. Five plants were removed from each of two parallel lines along the length, but avoiding the edges, of each field. Samples from each field were bulked and processed for extraction within 48 h. Nematodes were extracted from a 100 ml sub-sample of soil and from 5 g fresh weight of roots, using a modified Baermann filter technique (Hooper, 1986). For wet soils, nematodes were extracted using a modified flotation and sieving method (Hooper, 1990). Soil samples were dispersed in approximately 12 l of water in a bucket. After a settling period of 1 min the water was decanted through nested 90 and 53 µm mesh sieves. This process was repeated and nematodes washed from the sieves were extracted using a modified Baermann funnel technique. Dryer soils were mixed thoroughly by 'coning and quartering' (Anscombe, 1950) before sub-sampling. Wet soils were sub-sampled by removing a series of small amounts of soil from around the roots of the ten plants by hand. The volume of soil sampled in this way was measured by displacement. Roots were washed free of soil, dabbed dry, finely chopped and mixed thoroughly before sub-sampling. Extracted nematodes were recovered after an incubation period of 48 h and counts of nematode genera made using a Leica Wild M3C stereomicroscope. The volume of nematode extract was reduced by settling or by sieving through a 20 µm mesh sieve and counts made of 2 × 10% aliquots from the suspension. Nematodes were heat relaxed, preserved in 4% formalin and identified.

Data of nematode population densities from long and short fallow fields in the savannah and forest-savannah, were compared using Student's *t*-test. Relationships between $log(n+1)$ of nematode population densities and fallow length in the forest were examined by regression analysis.

***Table 1.** Agroecological data for the study areas in the Ivory Coast (from Girard et al., 1971)*

Area	Agroecological zone	Latitude	Rainfall (mm)	Rainfall distribution
Gagnoa	Humid-forest	6° 10' N	1 489	bimodal
Touba	Forest-savannah	6° 20' N	1 406	mono-modal
Boundiali	Savannah	6° 30' N	1 433	mono-modal

***Table 2.** Number of sites examined in study areas and classification of fallow periods.*

Area	No. of sites	Fallow classification	Fallow definition
Gagnoa	21	short	1-6 years prior fallow
	20	long	≥ 7 years prior fallow
Touba	20	short	no fallow previous year
	16	long	≥ 3 years prior fallow
Boundiali	13	short	< 5 years bush fallow or > 3 years crop
	15	long	> 6 years bush fallow or < 2 years crop

Table 3. *List of nematodes associated with rice in different agroecological zones in Ivory Coast.*

	Agroecological zone		
	Forest	Forest-savannah	Savannah
Number of fields surveyed	42	65	34
Aphelenchoides sp.	•	•	
Aphelenchoides bicaudatus (Imamura, 1931) Filipjev & Schuurmans Stekhoven, 1941		•	
Aphelenchus sp.	•	•	
Aphelenchus avenae Bastian, 1865	•	•	
Aulosphora oostenbrinki (Luc, 1958) Siddiqi, 1980	•	•	
Basiria sp.	•		
Boleodorus sp.	•		
Coslenchus sp. *		•	
Criconema sp.		•	
Mesocriconema curvatum (Raski, 1952) Loof & De Grisse, 1989**		•	
Mesocriconema onoense (Luc, 1959) Loof & De Grisse, 1989		•	
Mesocriconema ornata (Raski,1958) Loof & De Grisse, 1989		•	•
Mesocriconema palustris (Luc, 1970) Loof & De Grisse, 1989*		•	
Mesocriconema tescorum (de Guiran, 1963) Loof & De Grisse, 1989*		•	
Mesocriconema sp.		•	
Discocriconemella limitanea (Luc,1959) De Grisse &Loof, 1965**		•	
Ditylenchus sp.		•	•
Filenchus sp	•	•	
Helicotylenchus cf. *abunaamai* Siddiqi, 1972		•	
Helicotylenchus cf. *digonicus* Perry *in* Perry, Darling & Thorne, 1959			•
Helicotylenchus dihystera (Cobb, 1893) Sher, 1961	•		
Helicotylenchus cf. *egyptiensis* Tarjan, 1964	•	•	
Helicotylenchus erythrinae (Zimmermann, 1904) Golden,1956	•	•	
Helicotylenchus cf. *indicus* Siddiqi, 1963		•	
Helicotylenchus microcephalus Sher, 1966		•	
Helicotylenchus mucronatus Siddiqi 1964	•	•	
Helicotylenchus cf. *nigeriensis* Sher, 1966	•		•
Helicotylenchus pseudorobustus (Steiner, 1914) Golden, 1956		•	•
Helicotylenchus n. sp.	•	•	•
Helicotylenchus sp.	•	•	•
Hemicriconemoides cocophillus (Loos, 1949) Chitwood & Birchfield, 1957		•	
Hemicriconemoides mangiferae Siddiqi 1961		•	
Hemicriconemoides snoeki Doorsselaere & Samsoen, 1982	•		
Hemicycliophora cf. *nortoni*, Brzeski, 1974	•		
°*Heterodera sacchari* Luc & Merny, 1963	•		
°*Heterodera* sp.	•	•	
Heteroderidae	•	•	
°*Hirschmanniella oryzae* (van Breda de Haan, 1902) Luc & Goodey, 1964	•		
°*Hirschmanniella spinicaudata* (Schuurmans Stekhoven, 1944) Luc & Goodey, 1964	•		•
°*Hirschmanniella* sp.	•		
Hoplolaimus pararobustus (Schuurmans Stekhoven &, Teunissen 1938) Sher *in* Coomans, 1963			•
Lobocriconema crassianulatum (de Guiran, 1963) De Grisse & Loof 1965		•	•
Malenchus sp.		•	
°*Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949	•		
°*Meloidogyne javanica* (Treub, 1885) Chitwood, 1949	•		

(continued next page)

Table 3. *(cont.)*

	Agroecological zone		
	Forest	Forest-savannah	Savannah
°*Meloidogyne arenaria* (Neil 1889) Chitwood, 1949	•		
°*Meloidogyne* sp.	•	•	•
Paralongidorus sp.		•	
Paratrichodorus minor (Colbran, 1956) Siddiqi, 1973		•	
Paratylenchus sp.		•	
°*Pratylenchus brachyurus* (Godfrey, 1929) Filipjev & Schuurmans Stekhoven, 1941	•	•	•
°*Pratylenchus zeae* Graham, 1951	•	•	•
°*Pratylenchus* n. sp.		•	
Rotylenchulus reniformis Linford & Oliveira, 1940	•		
Rotylenchulus variabilis Dasgupta, Raski & Sher, 1968		•	
Rotylenchulus sp.			•
Rotylenchus n. sp. *		•	
°*Sarisodera africana* Luc, Germani & Netscher, 1973***		•	
Scutellonema cavenessi Sher 1964		•	
Scutellonema clathricaudatum Whitehead, 1959		•	•
Trophotylenchulus sp. **		•	
Tylenchorhynchus n. sp. *		•	
Tylenchorhynchus annulatus (Cassidy, 1930) Golden, 1971			•
Tylenchorhynchus (Divittus) labiatus (Jairajpuri, 1984) Siddiqi, 1986		•	
Tylenchus sp.	•	•	
Trichodorus eburneus De Waele & Carbonell, 1983	•		
Triversus annulatus (Merny, 1964) Sher, 1974			•
Trophurus sp.			•
Xiphinema bergeri Luc, 1973			•
Xiphinema ebriense Luc,1958	•		
Xiphinema hygrophilum Southey & Luc, 1974	•		
Xiphinema italiae Meyl, 1953*		•	
Xiphinema longicaudatum Luc, 1961	•		
Xiphinema nigeriense Luc, 1961	•		
Xiphinema rotundatum Schuurmans Steckhoven & Teunissen, 1938		•	
Xiphinema savanicola Luc & Southey, 1980		•	
Xiphinema tarjani Luc, 1975	•		
Xiphinema n. sp. 1**		•	
Xiphinema n. sp. 2***		•	
Xiphinema sp.	•	•	•

* nematodes identified from M'bé; ** Danane and *** Man; ° nematodes recovered from roots.

The relative abundance of genera, for each agroecological zone, was examined using the relationship between the mean intensity and prevalence, as defined by Boag (1993), of each nematode genus:

$$\text{Mean intensity} = \frac{\text{Total number of nematodes of a genus/(dm}^3\text{ soil + 5 g roots)}}{\text{Number of fields positive for that genus}}$$

$$\text{Prevalence} = \frac{\text{Total number of nematodes of field positive for a genus} \times 100}{\text{Total number of fields sampled}}$$

Results

Amongst the three specific areas of study and additional sites in Ivory Coast, a total of 35 genera and 80 species of plant parasitic nematodes were identified, of which ten species were endoparasitic in rice roots (Table 3). Nematode diversity expressed in terms of the number of genera and species differed between agroecologies. The greatest diversity was found in the forest-savannah (52 species in 25 genera) and the least in the savannah (20 species in 14 genera). The nematode diversity of the humid forest was intermediate (37 species in 18 genera). Six new species were found, from the following genera *Helicotylenchus* (1), *Pratylenchus* (1), *Tylenchorhynchus* (1), *Rotylenchus* (1) and *Xiphinema* (2). The relative abundance of genera differed between agroecologies (Fig. 3). *Helicotylenchus* spp. were abundant at all three sites, although the relative abundance of individual species showed specific distributions relative to agroecology. *Helicotylenchus* n. sp., for example, was particularly widespread in the savannah where it occurred in 75% of fields and at high population densities up to 2500 × 100 ml^{-1} soil. The same species was less prevalent in the forest-savannah and humid forest where it occurred in 41% and 5% of fields respectively. *Helicotylenchus* was the most prevalent genus in the forest-savannah (100% of fields) and with *Pratylenchus* the most prevalent in the savannah (96%). In the forest, *Meloidogyne* spp. were the most prevalent (68%).

Helicotylenchus spp. populations declined with increasing fallow length in the humid forest ($r = -0.373$; $P \leq 0.05$) (Fig. 1). No significant differences in nematode populations between long and short fallow fields were detected for nematode genera in the savannah or forest-savannah (Fig. 2). In the forest and forest-savannah, however, a trend of reducing populations of parasitic nematodes in less intensive fields was observed, which was less evident in the savannah.

Discussion

This study has given a good indication of the diversity of plant parasitic nematodes on rice in upland/hydromorphic environments in the Ivory Coast. The greatest diversity of genera and species occurred in the transitional zone between forest and savannah, suggesting that this, ecologically more diverse zone, provides a broader range of available nematode niches. The more stable forest environment had fewer genera still and the intensively cropped savannah, the least.

The diversity of genera in the forest and savannah has changed very little since earlier surveys done by Fortuner (1981). This observation and that of the similarity of generic diversity in long and short fallows, in either agroecological zone, suggests a tolerance, in the community structure of nematodes, to the prevailing environmental perturbations. This supports Norton's (1989) assertion that nematode species found in a crop are generally the same from one decade to the next, assuming no major alterations in

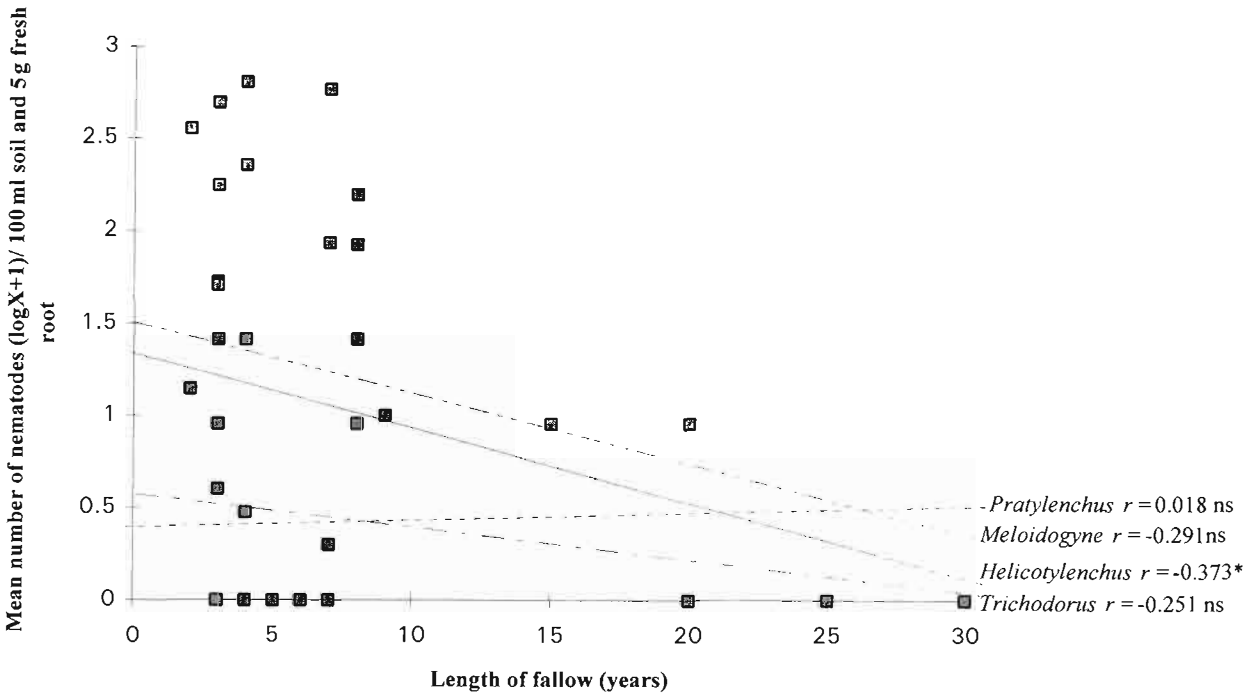

Fig. 1. Trends in the population densities of four prevalent genera of plant parasitic nematodes associated with rice in the forest zone of Ivory Coast after different periods of fallow (Only data points for Helicotylenchus *are shown; ns = not significant; * = significant at $P \leq 0.05$).*

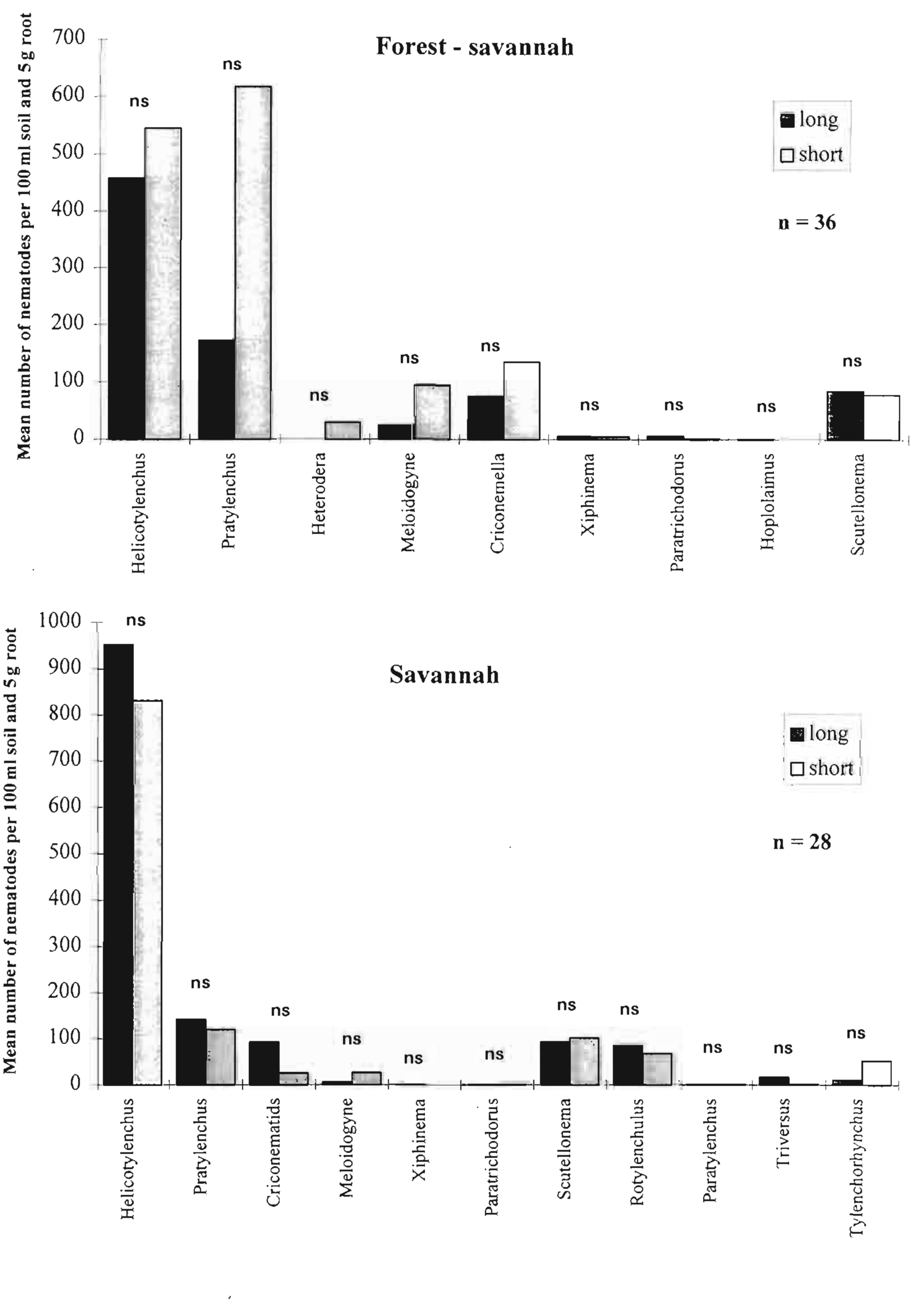

Fig. 2. *Effect of fallow length on mean plant parasitic nematode populations recovered from upland rice in two agroecological zones in Ivory Coast. (ns = not significant).*

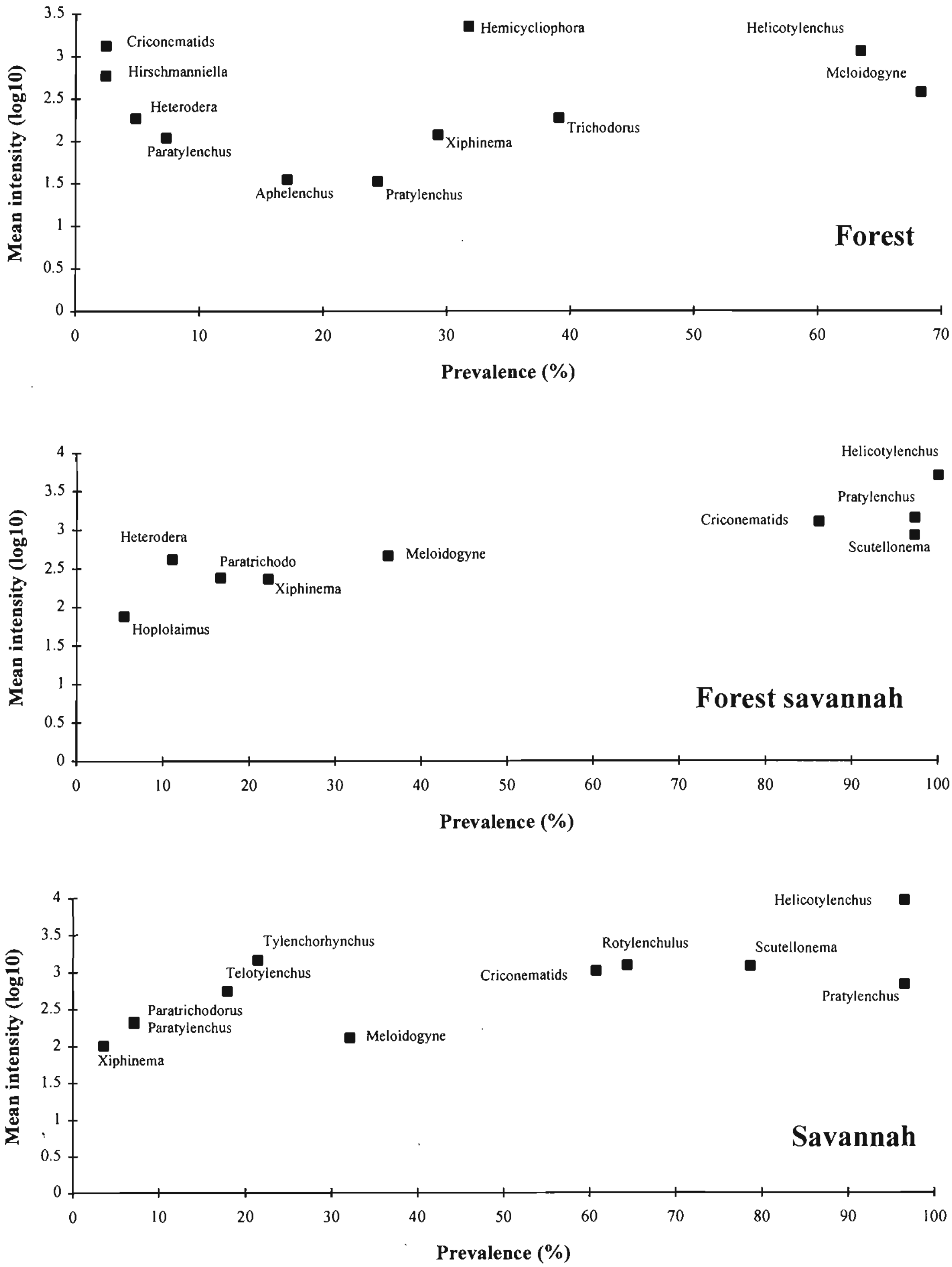

Fig. 3. *Prevalence and mean intensity of plant parasitic nematodes associated with upland/hydromorphic rice in three agroecological zones in Ivory Coast (The* Hemicycliophora *group comprises nematodes from the genera* Aulosphora *and* Hemicycliophora *whilst the Criconematid group comprises nematodes from* Mesocriconema, Hemicriconemoides, Lobocriconema *and* Criconema*).*

habitat. It seems likely that the intensification of rice production documented by Becker *et al.* (1994) has not caused perturbations beyond the tolerance of the plant parasitic nematode communities on rice.

The prevalence and intensity of nematodes, however, has been affected by intensification since Fortuner's (1981) study. This is most notable in the savannah where the prevalence of the genus *Pratylenchus* has increased markedly. Criconematids are also now more prevalent in the savannah as are *Rotylenchulus* spp. which were recorded in 64% of fields compared with 5% in 1977. The incidence of *Xiphinema* spp., on the other hand, has reduced, perhaps reflecting their preference for less disturbed habitats.

As Merny (1970) and Fortuner (1981) noted, the prevalence and mean intensity of genera varied between agroecological zones. Prevalence and mean intensity data will be determined by many biotic and abiotic factors, including host presence and status, nematode feeding specialisation, temperature and hydrology. Furthermore, data will be influenced by a number of practical aspects such as sampling time and the relative extraction efficiencies for different genera. Although our results could be influenced by population dynamics we would expect most species to be present at the flowering stage of the crop, which is when sampling took place. In this preliminary study, we have examined variation in nematode communities at the field level, selected as representative of large agroecological zones and at this level a number of observations can be made. The genus *Helicotylenchus*, for example, was prevalent throughout the country and probably reflects the diversity of species of *Helicotylenchus,* their non-specialised feeding habit, broad host range and perhaps tolerance of abiotic soil factors. Twelve species of *Helicotylenchus*, including one new species, were found between agroecological zones, and the numeric distribution of species of *Helicotylenchus* mirrored the overall generic diversity of plant parasitic nematodes. This wide species diversity on rice, within the genus *Helicotylenchus* agrees with earlier reports (Fortuner & Merny, 1979; Bridge *et al.,* 1990; Coyne *et al.,* 1996).

Pratylenchus spp. were amongst the most prevalent species in the savannah and forest-savannah and appear to be well suited to the rapid exploitation of the more intensive cropping of rice. *Pratylenchus* spp. and predominantly *P. zeae* is widespread throughout sub-Saharan Africa. It is recorded from Zimbabwe (Martin, 1972) and Senegal (Fortuner, 1975), Nigeria (Babatola, 1984), South Africa (De Waele & Van den Berg, 1988), Kenya (Kariaga & Agama, 1994), Guinea, Togo and Benin (Coyne *et al.,* 1996). The genus *Meloidogyne,* was less common in the savannah and forest-savannah zones, perhaps due to a more specialised parasitism of a host in the forest zone, where it was more prevalent.

Heterodera sacchari is regionally widespread (Bridge *et al.,* 1990) but would appear to have a more restricted local distribution. The occurrence of *Heterodera* spp. in the forest and forest-savannah may indicate a preference, on rice, for less arid conditions. Recent work has shown that in rice *H. sacchari* is common in, and at the upper periphery of the hydromorphic ecosystems (unpubl.).

Rice is a good host of *Scutellonema clathricaudatum* (Caveness, 1967) and has been found in upland conditions in a number of West African countries (Luc *et al.,* 1964; Caveness, 1967). It was considered to be indigenous to the forest vegetation (Plowright & Hunt, 1994) but was found only in the forest-savannah and savannah in this study.

Criconematids are reported frequently from upland rice (Bridge *et al.,* 1990), *Aulosphora oostenbrinki* has been recorded on rice from the Ivory Coast (Fortuner, 1981; Fortuner & Couturier, 1983) and in Togo and Benin (Coyne *et al.,* 1996). Rice is clearly a good host for this nematode which may become the dominant parasitic nematode on rice following forest clearance (Fortuner & Couturier, 1983).

Two new species were recorded in the genus *Xiphinema,* giving a total of ten species, occurring largely in the forest and forest-savannah. A high diversity of *Xiphinema* spp. has previously been associated with rice. Fortuner (1981), observed nine species, five of which were recorded in the current study. Other authors (Fortuner & Merny, 1979; Babatola, 1984; Plowright & Hunt, 1994; Coyne *et al.*, 1996) have jointly recorded an additional eleven species in the region. Rice is a new host record for *X. italiae* and *X. tarjani.*

Hoplolaimus pararobustus has previously been recorded in Nigeria (Babatola, 1984). *H. clarissimus*, however, is more widespread with records from Togo (Coyne *et al.*, 1996), Senegal (Fortuner & Merny, 1973) and Ivory Coast (Coyne *et al.*, unpubl.). *Trichodorus eburneus,* which belongs to a predominantly temperate genus, multiplies well on rice in the forest zone. This is a new host record, although the genus is widespread in W. Africa (Fortuner & Merny, 1973; Fortuner, 1981; Coyne *et al.*, 1996).

Our data suggests that, at present, rice cropping intensity, particularly in the forest, has not adversely affected the incidence and intensity of plant parasitic nematodes. However, a trend of greater parasitic nematode abundance in more intensively cropped fields was observed. The genus *Heterodera,* for example, were present in short fallows in the forest-savannah but was not detected in long fallows. In Indonesia, nematode populations in new fields (second rice crop) compared with fields continuously cropped for 13 years, revealed a substantial increase in rice parasitic nematodes with both *Meloidogyne* and *Pratylenchus* receiving pest status in older fields (Prot *et al.*, 1992). Comparable rice cropping intensities occur in the savannah in the Ivory Coast and the incidence of *Pratylenchus* has clearly increased in these systems. Accurate nematode yield loss data for different agroecological zones are not yet available, but losses due to *Pratylenchus* and *Heterodera* in upland rice are likely to occur (Babatola, 1984; Plowright *et al.*, 1989). Rice production will continue to intensify, assisted by advances in rice breeding for weed competitive varieties and the development of improved fallows (Johnson, 1995). Ultimately, this intensification will require the integration of nematode management practices to maintain the sustainability of this rapidly evolving and environmentally delicate system.

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References

ADESINA, A.A. & GAYE, M. (1993). *Rice trends in Sub-Saharan Africa: a synthesis of statistics on rice production, trade and consumption.* Bouaké, Ivory Coast, West Africa Rice Development Association, 10 p.

ANON. (1992). *West Africa Rice Development Association, Bouaké, Ivory Coast*, Annual Report 1992, 64 p.

ANON. (1994). *West Africa Rice Development Association, Bouaké, Ivory Coast*, Annual Report 1994, 126 p.

ANSCOMBE, F.J. (1950). Soil sampling for potato root eelworm cysts. *Ann. appl. Biol.*, 37: 286-295.

BABATOLA, J.O. (1983). Pathogenicity of *Heterodera sacchari* on rice. *Nematol. medit.*, 11: 21-25.

BABATOLA, J.O. (1984). Rice nematode problems in Nigeria: their occurrence, distribution and pathogenesis. *Trop. Pest Manag.*, 30: 256-265.

BABATOLA, J.O. (1986). The role of *Pratylenchus brachyurus* in upland rice culture. *Niger. J. Pl. Protect.*, 10: 7-10.

BECKER, L. & DIALLO, R. (1992). *Characterization and classification of rice agroecosystems in Côte d'Ivoire.* Bouaké, Côte d'Ivoire, West Africa Rice Development Association, 246 p.

BECKER, M., HEINRICHS, E.A. & JOHNSON, D.E. (1994). Effect of cropping intensification on constraints in upland rice. *West Afr. Rice Devel. Ass., Ann. Rep. 1994*: 27-28.

BOAG, B. (1993). Standardisation of ecological terms in nematology. *Fundam. appl. Nematol.*, 16: 190-191.

BRIDGE, J. (1987). Control strategies in subsistence agriculture. *In*: Brown, R.H. & Kerry, B.R. (Eds). *Principles and practice of nematode control in crops.* Marrickville (Australia) Orlando & London, Australia Academic Press: 389-420.

BRIDGE, J., LUC, M. & PLOWRIGHT, R.A. (1990). Nematode parasites of rice. *In*: Luc, M., Sikora, R.A. & Bridge, J. (Eds). *Plant parasitic nematodes in subtropical and tropical agriculture.* Wallingford, UK, CAB International: 69-108.

CAVENESS, F.E. (1967). Shadehouse host range of some Nigerian nematodes. *Pl. Dis. Rptr*, 51: 115-119.

COYNE, D.L., PLOWRIGHT, R.A. & FOFANA, I. (1996). Preliminary investigations of nematodes associated with rice in Guinea, Benin and Togo. *Afro-Asian J. Nematol.*, 6: 70-73.

DE WAELE, D. & VAN DEN BERG. (1988). Nematodes associated with upland rice in South Africa, with a description of *Hemicycliophora oryzae* sp. n. (Nemata: Criconematoidea). *Revue Nématol.*, 11: 45-51.

FORTUNER, R. (1975). Les nématodes parasites des racines associés au riz au Sénégal. (Haute-Casamance et régions Centre et Nord) et en Mauritanie. *Cah. ORSTOM, sér. Biol.*, 10: 147-159.

FORTUNER, R. (1981). Les nématodes associés au riz pluvial en Côte d'Ivoire. *Agron. trop., Nogent*, 36: 70-77.

FORTUNER, R. & COUTURIER, G. (1983). Les nématodes parasites de plantes de la forêt de Taï (Côte d'Ivoire). *Revue Nématol.*, 6: 3-10.

FORTUNER, R. & MERNY, G. (1973). Les nématodes parasites des racines associés au riz en Basse Casamance (Sénégal) et en Gambie. *Cah. ORSTOM, sér. Biol.*, 21: 4-43.

FORTUNER, R. & MERNY, G. (1979). Root parasitic nematodes of rice. *Revue Nématol.*, 2: 79-102.

GIRARD, G., SIRCOULON, J. & TOUCHBEUF, P. (1971). Aperçu sur les régimes hydrauliques. *In*: Anon. *Le milieu de la Côte d'Ivoire.* Paris, France, Mémoire ORSTOM, No. 50: 113-151.

HOOPER, D.J. (1986). Extraction of free living stages from soil. *In*: Southey, J.F. (Ed.). *Laboratory methods for work with plant and soil nematodes.* London, UK, Her Majesty's Stationary Office: 5-30.

HOOPER, D.J. (1990). Extraction and processing of plant and soil nematodes. *In*: Luc, M., Sikora, R.A. & Bridge, J. (Eds). *Plant parasitic nematodes in subtropical and tropical agriculture.* Wallingford, UK, CAB International: 45-68.

JOHNSON, D.E. (1995). Weed management strategies for smallholder rice production. *Proc. 1995 Brighton Crop Protect. Conf.*: 1171-1180.

KARIAGA, M.G.O. & AGAMA, P.E. (1994). Plant parasitic nematodes associated with rainfed rice in Western Kenya. *Afr. Crop Sci. Conf. Proc.*, 1: 310-311.

LUC, M., MERNY, G. & NETSCHER, C. (1964). Enquête sur les nématodes parasites des cultures de la République Centrafricaine et du Congo-Brazzaville. *Agron. trop., Nogent*, 19: 723-746.

MARTIN, G.C. (1972). Rhodesia. A nematode affecting rice. *FAO Pl. Protect. Bull.*, 20: 40-41.

MERNY, G. (1970). Les nématodes phytoparasites des rizières inondées en Côte d'Ivoire. I. Les espèces observées. *Cah. ORSTOM, sér. Biol.*, 11: 3-20.

NAITO, H. (1994). Effects of crop intensification on pathogen evolution. *In*: Teng, P.S., Heong, K.L. & Moody, K. (Eds). *Rice pest science and management.* Los Baños, Philippines, International Rice Research Institute: 71-88.

NORTON, D.C. (1989). Abiotic soil factors and plant-parasitic nematode communities. *J. Nematol.*, 21: 299-307.

PLOWRIGHT, R.A., MATIAS, D., AUNG, T. & MEW, T.W. (1989). The effect of *Pratylenchus zeae* on the growth and yield of upland rice. *Revue Nématol.*, 13: 283-292.

PLOWRIGHT, R.A. & HUNT, D.J. (1994). Plant parasitic nematodes of upland, hydromorphic and inland swamp rice ecosystems in Côte d'Ivoire. *Afro-Asian J. Nematol.*, 4: 61-67.

PROT, J.C., HERMAN, M. & AHMADIN, A. (1992). Plant parasitic nematodes associated with upland rice in Sitiung, West Sumatra, Indonesia. *Int. Rice Res. Newsl.*, 17: 1.

PROT, J.C. & RAHMAN, M.L. (1994). Nematode ecology, economic importance, and management in rice ecosystems in South and Southeast Asia. *In*: Teng, P.S., Heong, K.L. & Moody, K. (Eds). *Rice pest science and management.* Los Baños, Philippines, International Rice Research Institute: 129-144.