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An initial study of fallow periods on the nematode community in the Soudanese-Sahelian zone of Senegal

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Abstract

Observations were made on natural fallow areas, disturbed by human activity, located on shallow ferruginous soils in the Nioro du Rip region, Southern Senegal. Twelve important plant-parasitic nematodes occur in this region. Size of nematode populations and number of species decreased with the increase of the fallow period from 1-17 years. When human interference was prevented by fencing for the last 5 years of a 17 year fallow, the number of nematodes decreased at a slower rate than in an unfenced fallow and the number of species increased. Only *Helicotylenchus dihystera* and *Tylenchorhynchus gladiolatus* develop similarly under both conditions. *Xiphinema parasetariae* occurred mainly in older fallows whilst *Scutellonema cavenessi* was rare. Numbers of these harmful plant-parasitic species were reduced by fencing. Saprophyte populations remained stable under natural fallow conditions, but increased in the fenced area, especially associated with the greater deposition of organic matter near the woody plants. Amongst plant species, *Andropogon pseudapricus*, in contrast to *Pennisetum pedicellatum*, was usually associated with large nematode populations.

Keywords: Tropical Africa, Senegal, fallow, nematodes, *Scutellonema cavenessi*.

Résumé

Les observations ont été réalisées sur des jachères naturelles, sur sols ferrugineux peu profonds, dans la région de Nioro du Rip au Sud du Sénégal. Sur l'ensemble du site, 12 espèces de nématodes phytoparasites ont été identifiées. Dans les jachères anthropisées, l'effectif du peuplement ainsi que le nombre d'espèces observées diminuent lorsque l'âge de la jachère augmente de 1 à 17 ans. La mise en défens pendant 5 ans d'une jachère de 17 ans modifie ces tendances : le peuplement diminue moins vite et le nombre d'espèces est plus élevé que dans les zones anthropisées. Au plan qualitatif, seuls *Helicotylenchus dihystera* et *Tylenchorhynchus gladiolatus* se développent quelle que soit la situation de la jachère. Parmi les autres espèces, *Xiphinema parasetariae* est plus particulièrement présent sur les jachères âgées et inversement pour *Scutellonema cavenessi.* La mise en défens fait pratiquement disparaître cette espèce considérée comme très dangereuse pour les cultures de cette région. Le peuplement de nématodes saprophages reste pratiquement stable sur les jachères anthropisées. Il augmente sur la jachère en défens, notamment à proximité des ligneux. Parmi les espèces végétales, *Andropogon pseudapricus*, contrairement à *Pennisetum pedicellatum*, est généralement associé à des populations importantes de nématodes.

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INTRODUCTION

The abandoning of fields after many years of cropping is a common practice in tropical countries. Even if the reasons for this practice are not exclusively agronomic ones (Lericollais & Milleville, 1993; Jouve, 1993), abandonment often occurs at a time when yields are becoming very low. For instance, sugarcane yields in the cane area of Banfora in Burkina Faso decline from 100 t/ha, immediately after first cultivation of the savanna, to about 40 t/ha after 10 years of monoculture (Cadet, 1989). In Senegal, Siband (1972, 1974) studied the soil degradation of fields cultivated for different periods (between 2 and 50 years). He observed a rapid decrease of the organic matter content after clearing and a gradual decrease of the soil colloids in the top horizon. Whereas in general the mineral situation remained sufficient, the yields decreased slowly because of soil destructuration and the reduction of activity of the useful fauna. Depending on their distance from the village, these fields were more or less rapidly abandoned to fallow. A crop planted following a period of fallow generally yields more than previous ones from a field which formely supported several crop cycles.

In the Soudanese-Sahelian crop systems fewer and fewer inputs are available to compensate for this loss of fertility. Thus, fallowing appears to be a rational method for regenerating soil fertility (Greenland & Nye, 1959; Feller *et al.*, 1993). However, it is desirable that the fallow period and its potential uses are optimized. The fallow needs to be as short as possible in duration (a parameter, *a priori*, inversely proportional to its intrinsic efficiency) and where feasible should satisfy other human needs (e.g. source of wood, grazing, etc.).

To reach this goal, it is necessary to understand how fallowing affects the biological and the other soil components which influence fertility (Floret *et al.*, 1994). The herbaceous and woody plants which grow during fallowing, and especially their roots, are of primary importance in restoring fertility (Pieri, 1991), because they will increase organic matter, restore soil structure, help circulate water and enhance the multiplication of soil organisms.

However, fallowing can also maintain populations of harmful organisms, such as plant parasitic nematodes. Where populations are high, the growth of the fallow plants and thus the competition between species may be affected. Moreover, field crop yields following the fallow may decrease, bringing into question the principle of fallowing. In the Soudanese-Sahel area, the nematode community which has a damaging effect on the peanut rotation crops (millet, maize, sorghum, peanut, etc.) is composed of many species, generally dominated by *Scutellonema cavenessi* (Germani, 1981; Germani *et al.*, 1984). Many surveys of nematode communities associated with natural vegetation have been made (Rashid *et al.*, 1988; Cadet & Van Den Berg, 1992; Coleman *et al.*, 1991). However, nematode population dynamics have never been studied, especially in relation to long-term fallow. The available results indicate that after fallowing, the number of plant parasitic nematodes is usually very low and subsequently progressively increases as the land is cropped (Mateille *et al.*, 1992). This result provides indirect evidence that fallowing is associated with a decrease in the capacity of the soil to support plant parasitic nematodes. The present study aims at analysing the impact of the duration of fallowing on the quantitative and qualitative aspects of nematode populations.

MATERIAL AND METHODS

Observations were made in Senegal, in the Sine Saloum region. The four fallow areas are located near Thyssé Kaymor, at Sonkorong, no more than 500 m from each other, on the same ferruginous soil according to the French soil classification (Duchaufour, 1970). There is a hardpan at about 35 to 45 cm deep. The carbon content in the top horizon (0 to 10 cm) varied from 4 to 6.5°/₀₀, depending on the age of the fallow; the clay content from 15 to 20%. pH (H_2O) was 5.5 whatever fallow age. The annual rainfall was 796.2 mm in 1993. Three of the fallows, 1, 9 and 17 years old respectively, were not protected. The duration of fallowing was determined by asking local people and by ring counts of the cross-sections of the woody species that show stump sprouting the first year after cutting or burning (Donfack, 1993). The three fallow areas are grazed and wood is regularly cut by the surrounding village populations. The fourth fallow is a 1 hectare plot located in the 17-year-old area, but fenced for the last 5 years. The 1 year fallow was previously cultivated with fertilized millet or groundnut for about 40 years. The last crop was millet.

In each fallow, six 10 × 10 m undelimited plots were selected in a one hectare area representative of the vegetation. Two series of samples were collected from each plot: one in the woody areas, the other, a few metres away, in the open herbaceous areas. The main plant species located in the vicinity of the 12 sampling places were listed. In the 1 year fallow, samples were collected alternatively near the two dominant species: *Eragrostis tremula* and *Hibiscus sabdarifla* (table I).

Samples were collected at the end of October-beginning of November (end of the rainy season) from the 0-30 cm soil layer. Nematodes were separated from soil by Seinhorst's (1962) method. Their number was calculated per dm^3 of soil. The numbers of the most important plant parasitic nematodes species (*Tylenchida* or *Dorylaimida*), capable of damaging the cultivated plants were counted. Free-living nematodes were grouped together. Mycophagous nematodes were not taken into account because of their very low numbers.

The effect of vegetation type on nematode population densities was compared by the Mann Whitney U test. The nematological characteristics of each type were studied by correspondence analysis (Thioulouse, 1989) of faunistic data with, in rows, the samples in the different fallows and in columns the nematode species. Before computation, densities (x) were converted into log ($x+1$).

RESULTS

1°) Influence of fallow period on the nematode communities

A) Quantitative aspects

a) Plant parasitic nematodes

In the unfenced fallows, the average plant parasitic nematode population densities decreased significantly with fallow age ($r=0.68$; $p=0.0001$; fig. 1). Between 1 and 17 years, this decline can be considered as linear. The community would thus theoretically disappear after 21 years.

During the first year of fallow, *Hibiscus sabdarifla* and *Eragrostis tremula*, as well as herbaceous plants growing in the vicinity, maintained similar nematode populations. In the 9 and 17 year unprotected fallows, there are no differences in infestation between herbaceous areas and woody areas where these herbaceous plants also grow (fig. 2). The number of nematodes is lower in the 17 year fallow than in the one-year fallow. However, fencing of the 17 year fallow significantly increased the nematode numbers as compared with the same age unfenced fallow,

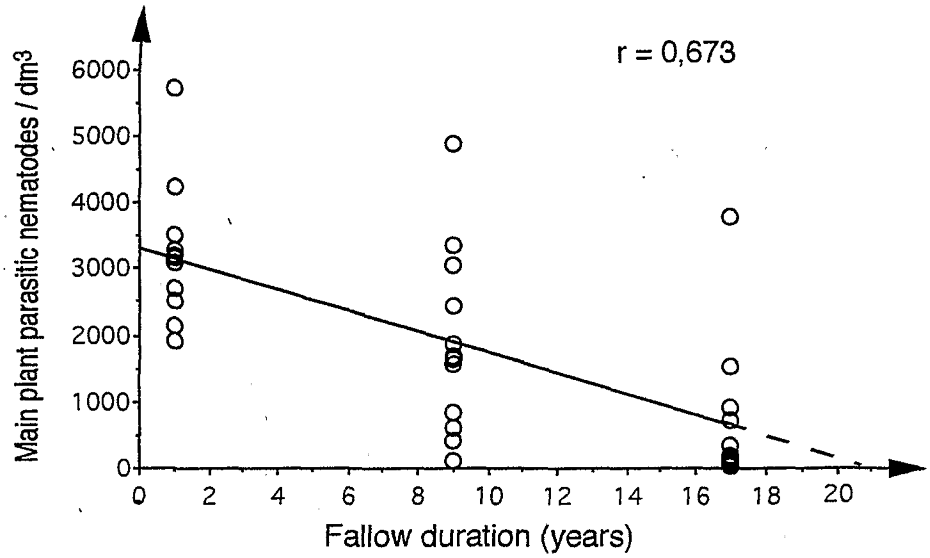

FIG. 1. – Evolution of nematode community with increasing duration of natural fallow. Circles represent the average number of plant parasitic nematodes in the twelve samples collected in each fallow.

up to about the level for the 9 year fallow population (fig. 2). As before, the presence of a woody plant did not modify size of the community.

b) Free-living nematodes

Populations of free-living nematodes in the fenced area were larger than those in the 17 year disturbed area. In both cases, there were significantly more nematodes in the woody than in the herbaceous areas (fig. 2). Again, in the fenced plot, populations of this trophic group are comparable to populations observed in the 9 year fallows.

B) Qualitative aspects

Twelve species of plant parasitic nematodes were identified in the samples collected in the different areas: *Xiphinema parasetariae, Tylenchorhynchus gladiolatus, Helicotylenchus dihystera, Scutellonema cavenessi, Pratylenchus sefaensis, Aorolaimus macbethi, Telotylenchus ventralis, Paratrichodorus minor, Criconemella sp., Ditylenchus sp., Gracilachus sp., Paratylenchus sp.*

Only two of them, *H. dihystera* and *T. gladiolatus*, were present in all situations. All the others, including *S. cavenessi*, were absent from one or more of the sets of conditions studied. For a given fallow period, the most frequent species are often the most abundant (fig. 3).

As regards the qualitative aspect, longer duration of the fallow is associated with a decrease in species diversity; from seven or eight species in the 1 and 9 year fallows, to five or six in the 17 year unfenced fallow (table I). However, these differences concern rare species (*Aorolaimus, Ditylenchus*). Conversely, in

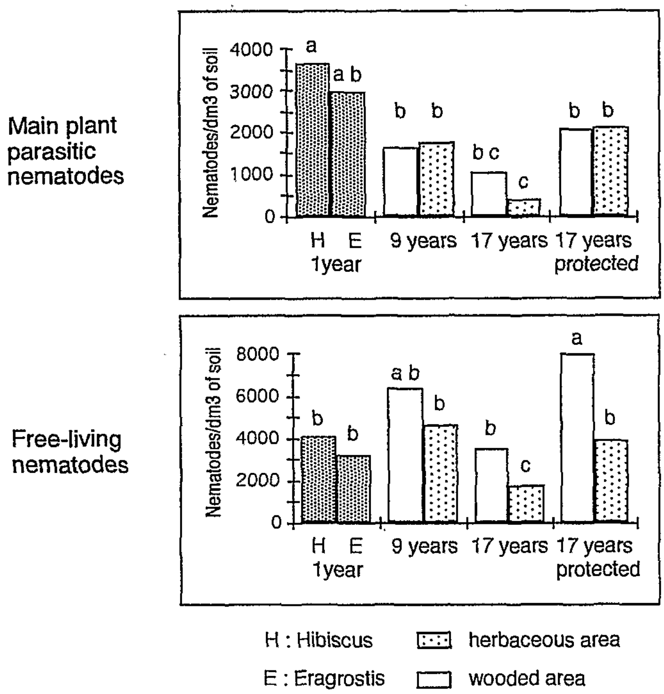

FIG. 2. – Comparison of plant parasitic nematode communities observed in the herbaceous and wooded areas of each fallow. (Bars with a letter in common are not significantly different according to Mann Whitney U-test, $p = 0.05$.)

the protected fallow, species are again as numerous as in the youngest fallow. For a given fallow period, there are usually fewer species (1 or 2 units) in the open areas than in the wooded areas (or between *Eragrostis* and *Hibiscus*). Again, this usually involves the less frequently occurring species, viz. *Xiphinema* (1 year), *Ditylenchus* and *Pratylenchus* (9 years), *Pratylenchus* (17 years) and *Scutellonema* and *Paratylenchus* (17 years protected).

The correspondence analysis allowed determination of the main characteristics of the fauna in the different fallow periods. Three groups can be identified in the first and second levels which account for 50% of the total variability (fig. 4). The ellipses corresponding to the data derived from the samples collected in the protected area are located in the first quadrant (fig. 4B). In the positive areas of F1 are grouped the values corresponding to the 9 and 17 year fallow samples, whereas in the negative part of F2, values for the 1 year fallows are represented.

Respective ellipse locations are explained by the position of the variables projected in the same factorial plane. The 17 year protected area is characterized by low populations of *S. cavenessi*, whereas this species is particularly abundant in the 1 year fallow. The one-year fallows are characterized by low populations of *Xiphinema* compared with oldest fallows. Numbers of *Xiphinema* are greater in the 9 year fallow and smaller in the 17 year fallow, especially when fenced. *Scutellonema*, which appears in the twelve samples collected in the 1 year fallow,

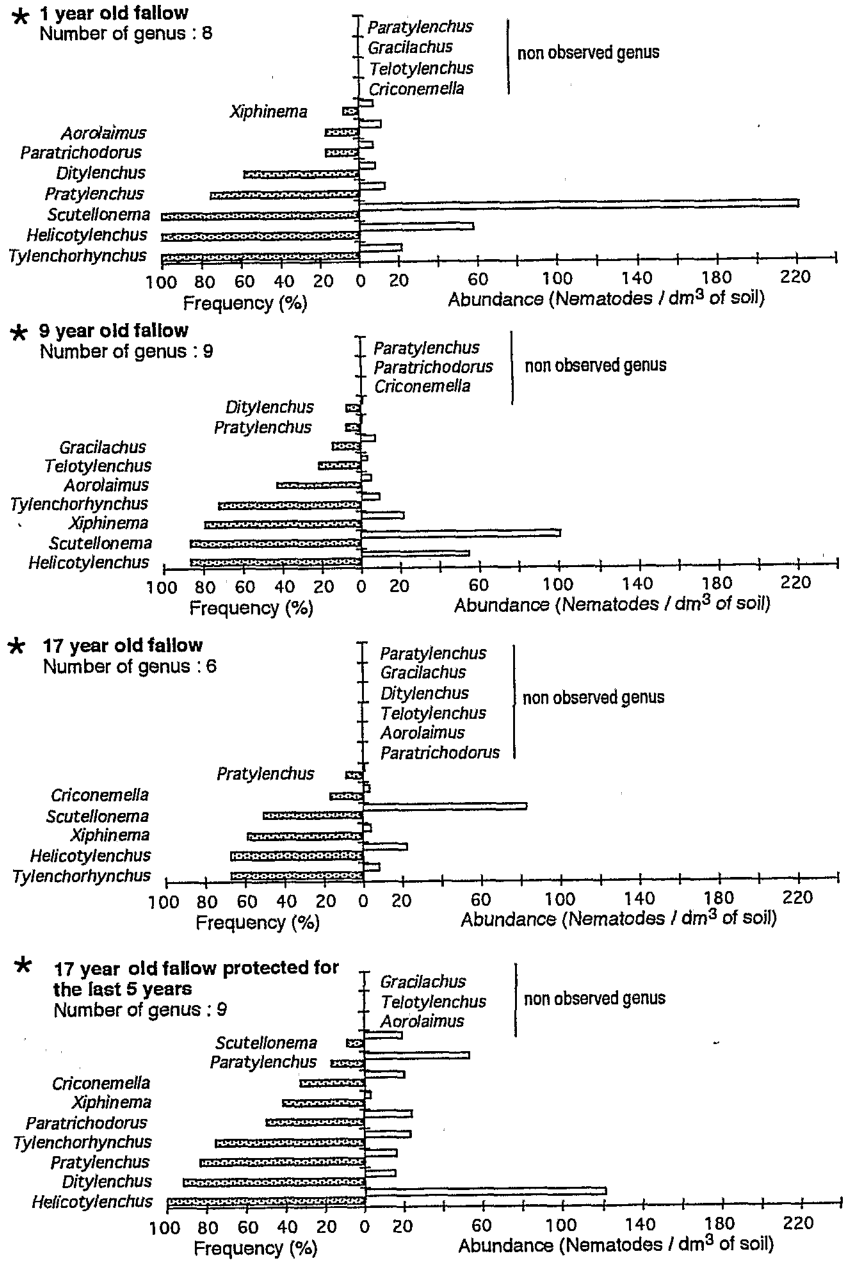

FIG. 3. – Comparison of frequencies and abundances of the main plant parasitic nematode genera observed in the disturbed and protected fallows. (Frequency: percentage of samples where the genera is present.) (Abundance: average density of the samples where the genera is present.) (Left: genus present; centre: facultative genus; right: genus absent.)

TABLE I. – *Genus observed in the different non-protected and protected fallows.* *(W: woody area; H: open herbaceous area; +: presence; O: absence).*

	1 year		9 years		17 years		17 years fenced	
	Eragrostis	*Hibiscus*	W	H	W	H	W	H
Xiphinema	+	O	+	+	+	+	+	+
Tylenchorhynchus	+	+	+	+	+	+	+	+
Helicotylenchus	+	+	+	+	+	+	+	+
Scutellonema	+	+	+	+	+	+	+	+
Pratylenchus	+	+	O	+	+	O	+	+
Criconemella	O	O	O	O	+	+	+	+
Paratrichodorus	+	+	O	O	O	O	+	+
Aorolaimus	+	+	+	+	O	O	O	O
Telotylenchus	O	O	+	+	O	O	O	O
Ditylenchus	+	+	+	O	O	O	+	+
Gracilachus	O	O	+	+	O	O	O	O
Paratylenchus	O	O	O	O	O	O	+	O
Total	8	7	8	8	6	5	9	7

was observed only once in the protected area. The separation of the data points corresponding to the young and the 17 year fallows is emphasized by *Aorolaimus*, present in the 1 and 9 fallows but absent from the fenced 17 year fallow, and conversely for *Criconemella. Ditylenchus, Pratylenchus* and *Paratrichodorus* were more frequent and abundant in the 17 year protected plot than in the 1 year fallow and increase the separation in the factorial analysis. Species which are widespread in the 1 year fallow contribute to the elongation of the corresponding ellipses into the negative part of F1. It was possible to distinguish between the open and woody areas of the fenced fallow and the *Hibiscus* or *Eragrostis* samples of the 1 year fallow. In particular this was due to more *Ditylenchus* and fewer *Scutellonema* in the herbaceous areas and in the vicinity of *Hibiscus.*

2°) Relations between plant species and nematode communities

The main plant species dominant around the different sampling areas were: *Combretum glutinosum* (open areas), *Andropogon pseudapricus, Pennisetum pedicellatum, Spermacoce stachydea, Eragrostis tremula, Hibiscus sabdarifla, Acacia macrostachya, Guiera senegalensis, Sporobolus festivus.* For the first four species, which were present near to many sample points (respectively 19/50; 16/50; 22/50 and 19/50), it was possible to compare (by t-test) the nematode community in their presence or absence (fig. 5). Presence or absence of *C. glutinosum* did not significantly affect plant parasitic nematode populations in the wooded areas where it was abundant. Similarly, *S. stachydea* did not influence the nematode community. In contrast, free-living nematodes were much more numerous under the trees ($p=0.011$). Parasitic nematodes tended to be more abundant in the vicinity of *A. pseudapricus* ($p=0.033$) and less abundant in the vicinity of *P. pedicellatum* ($p=0.039$). The first species is mainly observed in the open areas of the 9 and 17 year unfenced fallows, the second was uniformly distributed.

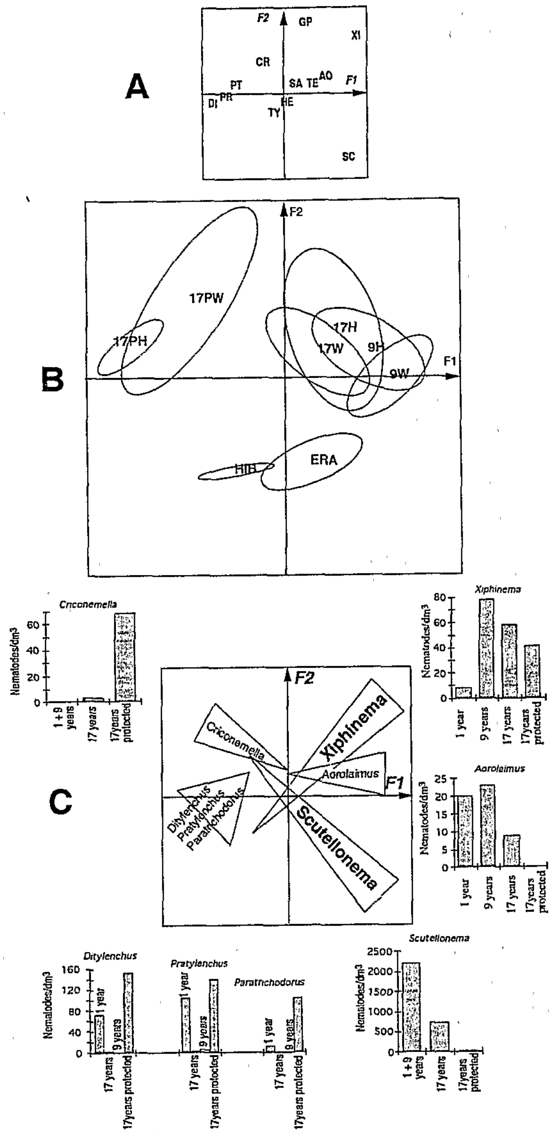

FIG. 4. – Study of the nematological characteristics of the natural and protected fallows, by means of correspondence analysis. {A: factorial map of the variables corresponding to the nematode genera (XI: *Xiphinema*, TY: *Tylenchorhynchus*; HE: *Helicotylenchus*; SC: *Scutellonema*; PR: *Pratylenchus*; CR: *Criconemella*; PA: *Paratrichodorus*; AO: *Aorolaimus*; TE: *Telotylenchus*; DI: *Ditylenchus*; GP: *Gracilachus* and *Paratylenchus*). **B**: Representation of the ellipses corresponding to the two situations of each fallow period, in the factorial plane F1 × F2, (HIB: *Hibiscus* (1 year); ERA: *Eragrostis* (1 year); 9: 9-year-old fallow; 17: 17-year-old fallow; P: protected fallow; H: herbaceous area; W: wooded area). C: schematic representation of the faunal tendencies in the fallow areas studied.}

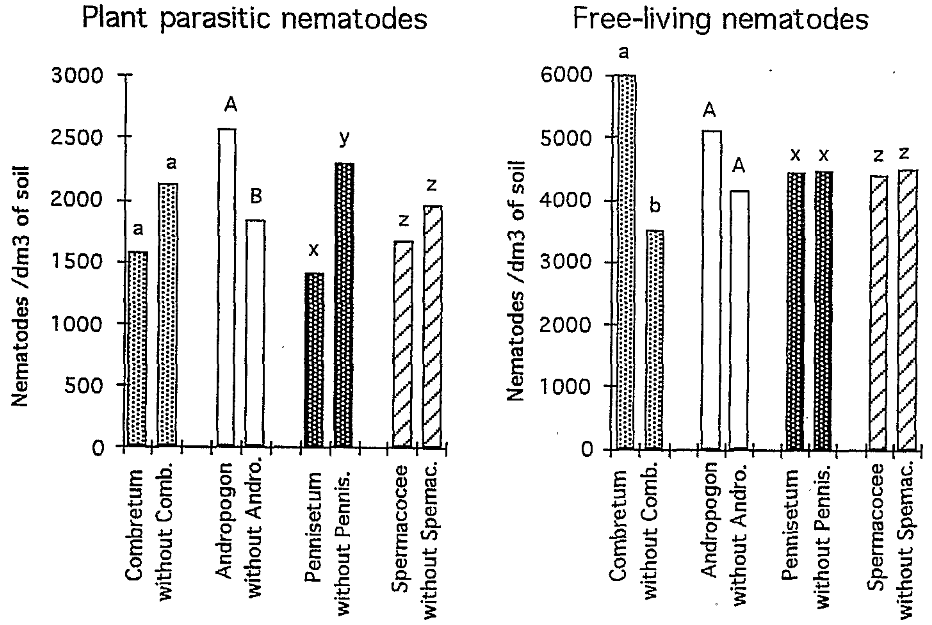

FIG. 5. – Comparison of the nematode communities observed in the vicinity of the main plant species and in places where these plants were not growing. (Pairs of bars with a letter in common are not significantly different according to *t*-test, $p = 0.05$.)

DISCUSSION

Surveys have shown that the main crops in the groundnut producing basin of Senegal are associated with a plant parasitic nematode community, dominated by *S. cavenessi* (GERMANI *et al.*, 1984). All fallow areas investigated in this study were situated on the same shallow ferruginous soil and have been previously cultivated. Thus, we can assume that the initial infestation of the oldest fallows was similar to that of the 1 year old fallow. Observation of the nematode communities associated with fallows of increasing ages confirms that fallowing progressively and proportionally leads to decreases in the population densities of plant parasitic nematodes. However, even after 17 years without cultivation, there is no extinction of the community, because some genera, such as *Helicotylenchus* and *Tylenchorhynchus*, are polyphagous and seem able to maintain a minimum community whatever the composition of the flora in the fallow plots. Moreover the potential diversity of the nematode community is continuously increased by repeated introduction from other sites (e.g. by running water, human and animal movements). The vegetation, and thus the potential hosts, are in constant evolution. By deduction, the minimum community, in the studied area, should be reached around the twentieth year of fallow.

On a quantitative basis, protection by fencing reduced the effect of fallowing as the average nematode community was about twice that in the same age unfenced fallow. This was probably due to the 5-fold greater vegetation biomass in the protected area (DIATTA, 1994), compared to the unprotected one where bare areas were common because of the effect of the passage of animals and of bush fires in the dry season. Not surprisingly, bare fallow is an effective means of eradicating plant parasitic nematodes (DUNCAN, 1986; SARAH *et al.*, 1983).

Important modifications in the nematode community structure were associated with increasing duration of fallowing. *X. parasetariae* occurrence characterizes an intermediate soil-plant environment between young fallow, previously highly disturbed by cultivation, and the long duration stabilized fallow. Consequently it is an indicator of the re-establishment of a natural ecosystem. Conversely, the numbers of *S. cavenessi* decrease with increasing duration of fallow. Increase of the areas without vegetation in the unprotected fallow may contribute to this process (bare fallow effect; DUNCAN, 1986). However, the complete disappearance of *S. cavenessi* in the protected fallow, where vegetation was well developed, shows that other factors are involved. They are, for instance, soil factors (CADET *et al.*, 1994), or biological factors, such as nematode-antagonistic organisms (fungi, bacteria; CAYROL, 1983; GOWEN *et al.*, 1989), or the depletion of *Scutellonema* host plants. Besides, if the number of plants does not increase after fencing, the diversity index (Shannon) is smaller in the unprotected area due to the dominance of some plant species, such as *Guiera senegalensis*, associated with the highly disturbed environment (table II). *S. cavenessi* is considered to be the most pathogenic species of the Soudano-Sahelian crops (GERMANI, 1981). Development of subsequent crops should benefit from the decrease in the population densities of this species under fallowing. However, this positive effect could be attenuated because protection favours the occurrence of other species, such as *Ditylenchus, Pratylenchus* and *Paratrichodorus*, also pathogenic to crops.

TABLE II. – *Influence of fencing on the number of herbaceous and ligneous species and on the corresponding plant diversity index (Shannon); (from* BODIAN*, 1993).*

	Ligneous plants		Herbaceous plants	
	Number	diversity index	Number	diversity index
17 years fallow protected for last 5 years	17	1.97	55	1.30
Non-protected 17 year fallow	15	1.66	62	0.98

For a given fallow period (9 or 17 years), plant parasitic nematode communities which develop near a ligneous plant, such as *Combretum glutinosum*, have the same size as those evolving in a herbaceous area, although the amount of roots available for parasitic nematodes is greater in the first case; but the nematode species are different. However, the amount of root is not the only factor that can regulate communities; e.g. some plants are less attractive for parasitic nematodes, especially *Pennisetum* whose presence appears to decrease soil infestation.

Saprophagous nematodes have a different pattern of occurrence. On the oldest fallows, they are more abundant in the vicinity of ligneous plants than in the herbaceous areas, a situation probably resulting from the greater rate of organic matter deposition around the latter (BACHELIER, 1978; COLEMAN *et al.*, 1991). On this basis, the population density of saprophagous nematodes could be used as an "agronomic fertility" index. This suggestion is supported by the data from the protected fallow, where organic matter accumulation is obviously more important than in the natural area. The carbon content in the top horizon (0 to 10 cm) increased from 6 to 10% respectively in the 17-year-old protected and non-protected fallows (MANLAY, 1994). Saprophagous nematodes are significantly more abundant there, mainly near the trees, confirming the role of ligneous plants in restoring soil fertility (YOUNG, 1989; PELTIER, 1993).

CONCLUSION

The results show that fallowing induces, with time, a progressive decrease in the level of nematode infestation. Because nematode damage is proportional to the number of individuals, this observation is important for good growth of the crops following the fallow. Elimination of species by fallow reinforced this cleaning effect, especially for *Scutellonema cavenessi*, the most pathogenic species in this region. Identification of the floristic or edaphic factory causing the change in nematode community structures would certainly contribute to a better understanding of the overall fallow fertilizing effect. Research is under way to identify plant species important as poor or non-hosts for nematodes, as they could be used to maximize the increase in fertility. This study is based on results obtained with relatively old fallows (9 to 17 years). However, the fallow period now tends to decrease according to a progressive increase of cultivated areas. A similar research programme should be started on crop-fallow cycles with fallow periods of 3-4 years which seem to be more realistic.

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