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The mycorrhizal soil infectivity and arbuscular mycorrhizal fungal spore communities in soils of different aged fallows in Senegal

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Abstract

This work was carried out to determine the influence of the duration of fallow and of physico-chemical components of soils on the distribution of endomycorrhizal fungal spores and the mycorrhizal soil infectivity. The mycorrhization of indigenous plants from the fallows was examined and it was concluded that, except for *Cassia obtusifolia*, fungal colonization was poorly developed. No correlation was established between spore populations and duration of fallow or between grazed and fenced areas. The relationships between abundance of mycorrhizal spores and the physico-chemical characteristics of the soils were markedly variable among species of mycorrhizal fungi. The results did not provide evidence of a beneficial effect of increased length of fallowing on mycorrhizal soil infectivity, but they did demonstrated the positive effect of preventing grazing on the re-establishment of vegetation during the fallow period.

Keywords: Arbuscular mycorrhiza; Sahelian zone; Mycorrhizal soil infectivity potential

1. Introduction

Dramatic deforestation has occurred in the Sahelian areas of West Africa following several decades of drought and over exploitation of the natural resources (Floret et al., 1993). Vegetation is now mainly dominated by shrubs and small woody plants (Donfack et al., 1995). Such vegetation does not prevent erosion from occurring with the subsequent loss of soil and organic matter. Moreover, soil erosion has, over a long time, been enhanced by other anthropogenic pressures, particularly by poor cattle grazing management (Maas, 1995).

Mixed farming systems with low inputs are widespread in West African savannahs (Ker, 1995). Their sustainability relies almost entirely on low human population density and on management of organic resources (manuring and fallowing). Under traditional shifting agriculture, a field would be cropped for a few years, then left in fallow for 15 to 20 years, depending on soil, climate and human need (Nye and Greenland, 1960). In the semiarid zone of Senegal fallow is a mean of replenishing soil fertility of the agro-ecosystems, and of providing food, wood and forage (Floret et al., 1993).

In recent years, there has been increasing evidence that the microbial communities of soil and plants have an important role in the development of sustainable agriculture. Among the microorganism living in the rhizosphere of plants, arbuscular mycorrhizal fungi

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have been found to be essential components of sustainable soil–plant systems (e.g. Bethlenfalvay and Linderman, 1992; Hooker and Black, 1995; Van der Heijden et al., 1998). Benefits derived by plants from arbuscular mycorrhizal (AM) symbiosis include (i) increased plant uptake not only of low mobility minerals such as phosphorus (Bolan, 1991; Plenchette and Fardeau, 1988; Sanders and Tinker, 1971) and micronutrients (Cooper, 1984; Kucey and Janzen, 1987; Bürkert and Robson, 1994), but also of nitrogen (Barea et al., 1991), (ii) enhanced water absorption (George et al., 1992; Sieverding, 1991), and (iii) improved plant health by providing protection against some pathogens (Dehne, 1982). Hyphae of AM fungi also play a role in the formation and stability of soil aggregates (Hamel et al., 1997; Wright and Upadhyaya, 1998) and contribute to the composition of plant community structures (Francis and Read, 1994).

In soils AM fungi are found as spores, hyphae or infected root pieces. All these propagules are sources of inoculum; extraradical mycelium is thought to be the main source (Sylvia and Jarstfer, 1992). Soil disturbance by grazing or erosion results in loss of AM propagules (Mosse, 1986), particularly in semiarid ecosystems (e.g. McGee, 1989), which decreases the mycorrhizal soil infectivity potential and thus limits the re-establishment of indigenous plants communities (Sylvia, 1990).

The aim of this work was to determine the influence of the duration of fallow on the distribution of AM fungal spores and mycorrhizal soil infectivity potential.

2. Materials and methods

2.1. Experimental area

The study was conducted in Senegal, in the Sine Saloum region (Fig. 1). The fallows were located near Thysse Kaymor (13°45′N–15°40′W), at Sonkorong, no more than 500 m from each other on the same ferruginous soil (Duchaufour, 1970). The 4-, 11- and 19-year-old fallow were selected based on local information on the duration of fallowing. The fallows were grazed and wood was regularly collected by the surrounding population. The 4-year-old fallow was situated in two areas, one previously cultivated for about 40 years (treatment T1) and the other for 10 years

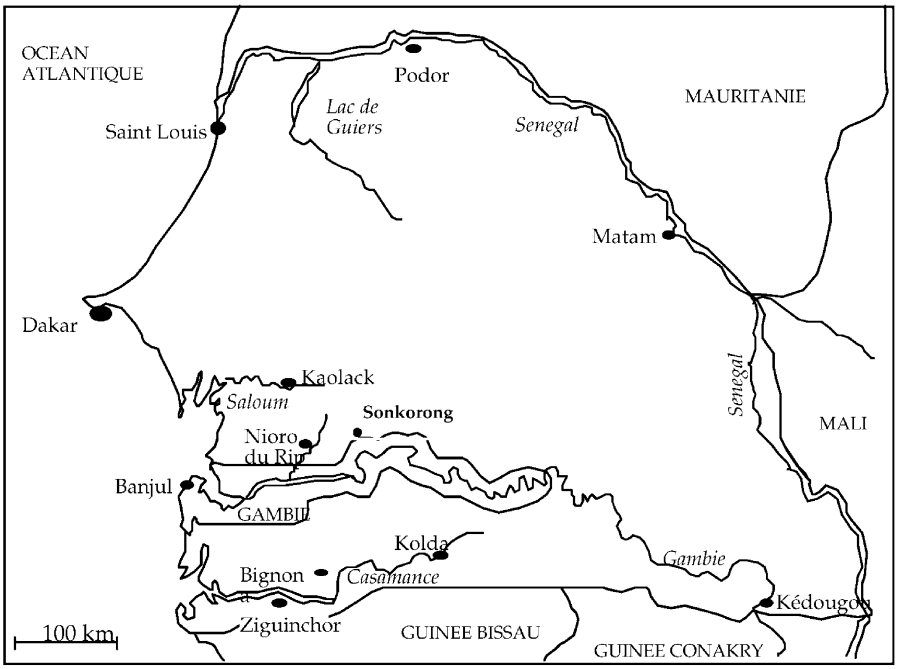

Fig. 1. Map of Senegal with the sampling location (village of Sonkorong).

Table 1
Cultural history of the soils studied

Transacts	Cultural system	Age (years)	Background	State
T1	Fallow (grasses + woody shoots)	4	>40 years cultivation	Grazed
T2	Fallow (grasses + woody shoots)	4	>40 years cultivation	Fenced
T3	Fallow (grasses + woody shoots)	4	>10 years cultivation	Grazed
T4	Fallow (grasses + woody shoots)	4	>10 years cultivation	Fenced
T5	Fallow (millet plantation)	11		Grazed
T6	Fallow (grasses + woody shoots)	11		Grazed
T7	Fallow (grasses + woody shoots)	19		Grazed
T8	Fallow (grasses + woody shoots)	19		Fenced
T9	Forest (trees, grasses + woody shoots)			Fenced

(treatment T3). A part (100 m × 100 m) of each area was fenced (treatment T2 and T4, respectively) at the beginning of fallowing to prevent soil and plant disturbance. The 11-year-old fallow (treatments T5 and T6) had no fenced area. The third fallow was 19-year-old (treatment T7) and included a 5-year-old fenced area (treatment T8). The other situation studied, as a reference treatment, was a fenced area in natural forest (treatment T9) situated 10 km from the fallowed areas. In each fallow system (Table 1), a representative transact (25 m) was marked out with 16 sampling points 1.5 m apart. In the case of the 11-year-old fallow (treatment T6), a transact was also selected in a nearby newly planted millet field (treatment T5). Physico-chemical characteristics of the soil are given in Table 2.

2.2. Field assessments

2.2.1. Soil and plant sampling

Soil and plant root systems were sampled in October, at the end of the growing season. Soil samples, 15 cm deep, were collected at the 16 sampling points along the transacts with an auger. Individual samples were used for enumerating AM fungal spores and for physico-chemical analyzes. For the mycorrhizal soil infectivity potential test, the 16 samples were pooled and a subsample was taken for analyzes. Only the root

Table 2
Physico-chemical characteristics of soils from the various fallow conditions

	Transacts								
	T1	T2	T3	T4	T5	T6	T7	T8	T9
Clay (%)	9.5	11.1	8.6	8.7	12.5	12.5	10.6	13.3	5.8
Fine silt	8.8	6.3	8.2	6.5	8.9	9.9	8.8	14.9	5.3
Coarse silt	17.0	14.3	15.4	17.6	17.4	17.8	18.6	19.4	16.0
Fine sand	39.4	39.4	35.8	40.8	34.0	31.4	30.3	29.8	35.1
Coarse sand	24.5	27.8	31.3	25.6	26.9	27.2	31.1	21.5	36.3
C, total (%)	5.30	5.53	5.83	4.44	7.00	7.84	6.53	7.50	4.73
N, total (%)	0.38	0.46	0.47	0.39	0.59	0.65	0.62	0.63	0.47
C/N	13.9	12.5	12.5	11.3	11.0	11.9	10.5	11.9	10.2
P, total (μg/g)	80.2	125.2	68.1	54.7	77.4	96.6	76.1	80.9	50.3
Ca, meq (%)	1.77	1.81	1.28	1.16	2.03	2.45	1.57	1.97	1.30
Mg, meq (%)	0.68	0.71	0.49	0.47	0.83	1.04	0.64	0.88	0.59
Na, meq (%)	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.04	0.01
K, meq (%)	0.04	0.07	0.06	0.04	0.06	0.08	0.16	0.09	0.11
CEC, meq (%)	3.36	3.50	3.15	2.55	1.17	4.48	3.05	4.30	2.23
Saturation rate (%)	75.9	75.3	61.7	70.7	72.4	82.9	70.3	70.4	72.2
Wilting point (4.2%)	3.6	4.1	3.1	3.3	4.0	4.8	3.7	5.2	2.1

systems of the more dominant plants along each transact were collected to ensure a sample size which was representative and sufficient for staining and observation. Each sample was composed of root systems of at least three plants.

2.2.2. Recovery of AM fungal spores

For each transect, spores were recovered from a 100 g subsample of soil from each of the 16 soil samples by wet sieving and decanting (Gerdemann and Nicolson, 1963). Spores were then counted under a compound microscope (40×).

2.2.3. AM colonization of indigenous and cultivated plants

The main plant species of the fallows in the experimental area were identified by Pate (1997). The method used for assessing AM colonization was described by Giovannetti and Mosse (1980). After clearing and staining, as described below, root fragments were randomly re-distributed in a 10 cm diameter Petri-dish which has a grid with lines spaced at 1.27 cm. Each intersect of a root fragment and the gridline corresponded to 1 cm. The presence of fungal structures at each intersect was recorded which gave a frequency of root colonization (length (%)). A total of 100 root/gridline intersects were observed for each sample.

2.3. Mycorrhizal soil infectivity determination

The method used was described by Plenchette et al. (1989). The bioassay is based on a dose (quantity of non-disinfected soil)-response (mycorhizal status of test plants) relationship according to the biological assay principle (Finney, 1971). The method involves cultivation of a population of mycotrophic plantlets on a range of concentrations of natural soil diluted with the same disinfected soil. Six dilutions were made of each soil by thoroughly mixing the original soil in various quantities (100, 48, 24, 12, 6, and 3%) with the same autoclaved soil (140°C, 40 min) to provide a range of concentrations. Five replicates were prepared for each dilution. Seeds of millet (*Pennisetum typhoides* L.) were pre-germinated for two days in Petri-dishes on humid filter paper. Ten germinated seeds were then transplanted into small plastics pots (5.5 cm diameter; 6 cm high) containing 100 g of each soil dilutions. Pots were then placed in a greenhouse for 2 weeks with temperatures ranging from 20 to 35°C and 12 h light. Plants were watered daily with deionized water without the addition of nutrients.

After 2 weeks of growth the entire root system of each seedling was collected, carefully washed under tap water, cleared in 10% KOH for 30 min at 90°C and stained for 15 min with acid fuchsin (0.05% in lactoglycerol). Each entire root system was mounted on a microscope slide and observed at a 250× magnification under a compound microscope. A single AM hyphal entry point was considered as a record of mycorrhizal infection to give an all or nothing quantitative response. The number of infected plants was recorded and results were expressed as the percentage of mycorrhizal plants per pot.

For each soil treatment, percentage of mycorrhizal plants was plotted against the logarithm of unsterilized soil concentrations. Linear regressions (model $Y = BX + A$) were calculated for each soil. Soil infectivity was expressed as mycorrhizal soil infectivity (MSI) units/100 g soil. An MSI unit is defined as the minimum dry weight (g) of soil required to infect 50% (MSI_{50}) of a plant population under the bioassay conditions and calculated for $Y = 50\%$.

2.4. Analytical and statistical methods

Analyses of variance were performed and treatments spore count means were compared using LSD values. Anovas were also carried out to compare the slopes of the regression lines between non-sterile soil concentrations and percentage of mycorrhizal plantlets. For soils with statistically similar regression slopes the *Y*-intercepts were compared using a *t*-test (the program used was written in Fortran by André Carteron, Station de Génétique et d'amélioration des plantes, INRA, Dijon, France).

Number of spores and physico-chemical characteristics of soils were compared with a Principal Component Analysis (PCA) (Thioulouse et al., 1997) with a one way analysis of variance. The PCA was performed for the soil characteristics on a matrix table with in row variables corresponding with the 9×16 sampling points on the field transects and in column variables corresponding to the 15 physico-chemical soil characteristics. The factorial map of the variables, drawn with the first two factors, which describe the most important

part of the variability, highlight the relationships between the variables and their importance, through their correlation with the factors. In the corresponding first factorial plane, the stars represent the sampling points on the transects of the fallowed sites and are located on the map according to their soil characteristics. The main trends revealed by the PCA were illustrated with boxs and whisker plots of the variable values for each treatment. Centered and normed values of the fungal spore matrix table with the same row variables as the soil matrix and four columns for the three types and total numbers of spores, were projected on the corresponding points on the first factorial plan issued from the soil PCA. The plane was split according to fallow sites and spore types.

Soil mineral particles of clay, fine and coarse silt, and fine and coarse sand were collected by mechanical analysis after the destruction of organic cement by hydrogen peroxide and the total dispersion of the soil in a 1 M NH_4Cl solution (Duchaufour, 1970). Total carbon (C) and nitrogen (N) content of samples were determined by the Walkley and Black (1934), and Bremner (1965) methods, respectively. Total P (Dabin, 1967), cation exchange capacity (CEC); exchangeable calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), as well as saturation rate (Sat) and wilting point 4.2 (pF4) were also analyzed.

3. Results

AM colonization (Table 3) varied greatly within and between plant species. Since the number of samples varied greatly among species harvested, it was not possible to make statistical comparisons. The range of mycorrhizal development was very wide, from 0% for some *Brachiaria ramosa* samples to 99% for some *Cassia obtusifolia* samples which showed the highest level of mycorrhization. Introduced plants, such as cultivated millet *Pennisetum typhoides*, *Andropogon gayanus* or *Acacia holosericea* exhibited also a wide range of mycorrhizal development. Fungal structures observed both in indigenous and introduced plants were typical of the genus *Glomus*.

AM fungal spores were recovered from all soil transacts (Table 4). Two species were identified as *Scutellospora* (*S.*) *verrucosa* (white to yellow, round, diameter <400 μm, bulbous subtending hyphae) and as *S. gregaria* (black colored, round, diameter <500 μm, bulbous subtending hyphae). These species had already been found in soil from this area (Duponnois and Bâ, 1998). Both species were always present, but were not very abundant. The main genus encountered was *Glomus* representing more than 93% of the total number of spores. The spores were brown to dark brown with a diameter around 100 μm. As species were not identified, only the genus has been taken into account. The total number of AM fungal spores varied greatly among the treatments, from 116.4 (T5) to 418.8 (T2) spores per 100 g of soil (Table 4). For *Glomus* and the total number of spores the highest levels were found in the 4-year-old fallows (T1, T2, T4) and the lowest in the 11-year-old

Table 3
AM colonization (standard deviation in parenthesis) of dominant plants from different fallow treatments

	Number of samples[a]	Length (%)
Indigenous plants		
Brachiaria ramosa	12	14.7 (5.6)
Cassia obtusifolia	2	92.0 (7)
Killinga debilis	5	5.6 (1.6)
Merremia aegyptiaca	1	9.0
Pennisetum pedicellatum	22	20.3 (4.3)
Spermacocea stachydea	5	27.2 (8.5)
Tephrosia pedicellata	1	6.0
Triumfetta pendrata	1	58.0
Introduced plants		
Andropogon gayanus	4	30.5 (3.9)
Acacia holosericea	3	29.0 (12.7)
Pennisetum thyphoïdes	32	18.3 (2.2)

[a] Composed of at least three root systems.

Table 4
Numbers of AM fungal spores (per 100 g of soil) recovered in each transact (means of 16 samples)[a]

Transacts	*Scutellospora verrucosa*	*Scutellospora gregaria*	*Glomus* sp.	Total
T1	12.3 cd	21.6 c	373 cd	406.9 d
T2	18.9 de	17.5 bc	382.4 cd	418.8 d
T3	24.6 e	6.2 a	224 ab	254.8 bc
T4	13.2 cd	7.0 a	379.2 d	399.4 d
T5	3.2 ab	2.8 a	110.4 a	116.4 a
T6	9.8 bc	15.7 b	339.2 bcd	364.7 bc
T8	1.6 a	5.5 a	313.6 bcd	320.7 bcd
T9	53.9 f	17 bc	125.2 a	196.1 ab

[a] In column values followed by the same letters are not significantly different (Fischer's protected LSD $P < 0.05$).

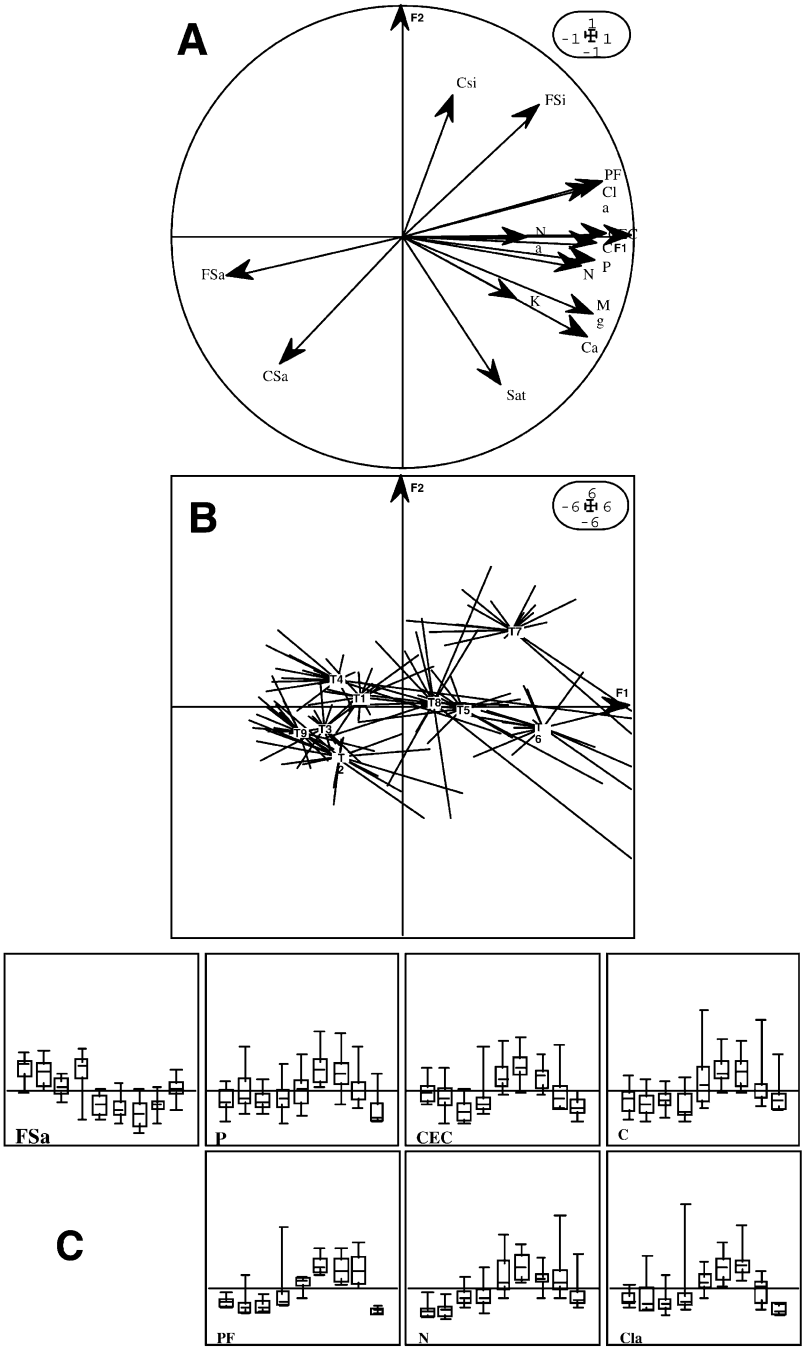

Fig. 2. PCA analysis of the physico-chemical characteristics of the different aged fallows: (A) factorial map (F1 × F2) of the variables corresponding to the physio-chemical characteristics. Soil mineral particles of clay (cla), fine (Fsi) and coarse (Csi) silt, fine (Fsa) and coarse (Csa) sand. Total carbon (C), nitrogen (N), and phosphorus (P). Cationic exchangeable capacity (CEC). Calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), saturation rate (Sat), Wilting point 4.2 (pF4); (B) position of points corresponding to the sampling points projected in he same factorial plane and grouped according to the treatments listed in Table1; (C) box and whisker plots of the deciding variables along F1.

fallow (T5), with the 19-year-old site (T8) giving intermediate counts. Forest soil (T9) contained the greatest number of *S. verrucosa*, but few glomelean spores. The proportions of fungal species recovered were not constant from one treatment to another. For instance, spore populations were highest in T9 for *S. verrucosa*, in T1 for *S. gregaria* and in T2 for *Glomus* sp.

The PCA performed on the physico-chemical characteristics of the fallow soils showed that the sites with the highest clay content (T5, T6 and T8) were grouped in the positive area of F1 and those with a high sand content (T1, T2, T3, T4 and T9) in the negative area (Fig. 2). The sites with a high silt percentage and those with high base saturation rates are separated along F2.

When the abundances of the different fungal types were projected on the factorial plane resulting from soil analysis (Fig. 3), *S. verrucosa* appeared mostly in the negative part of F1 (and of F2). These points were characterized by more sandy soil. *S. gregaria* showed more or less the same tendency, but was found in significant numbers in other soils types. The others types of spores were found everywhere and did not seem related to specific soil characteristics. When split by sites (Fig. 4), *S. verrucosa* was mainly found in the forest and not only in the other sandy sites, but also in some locations in the 11-year-old fallow. *S. gregaria*

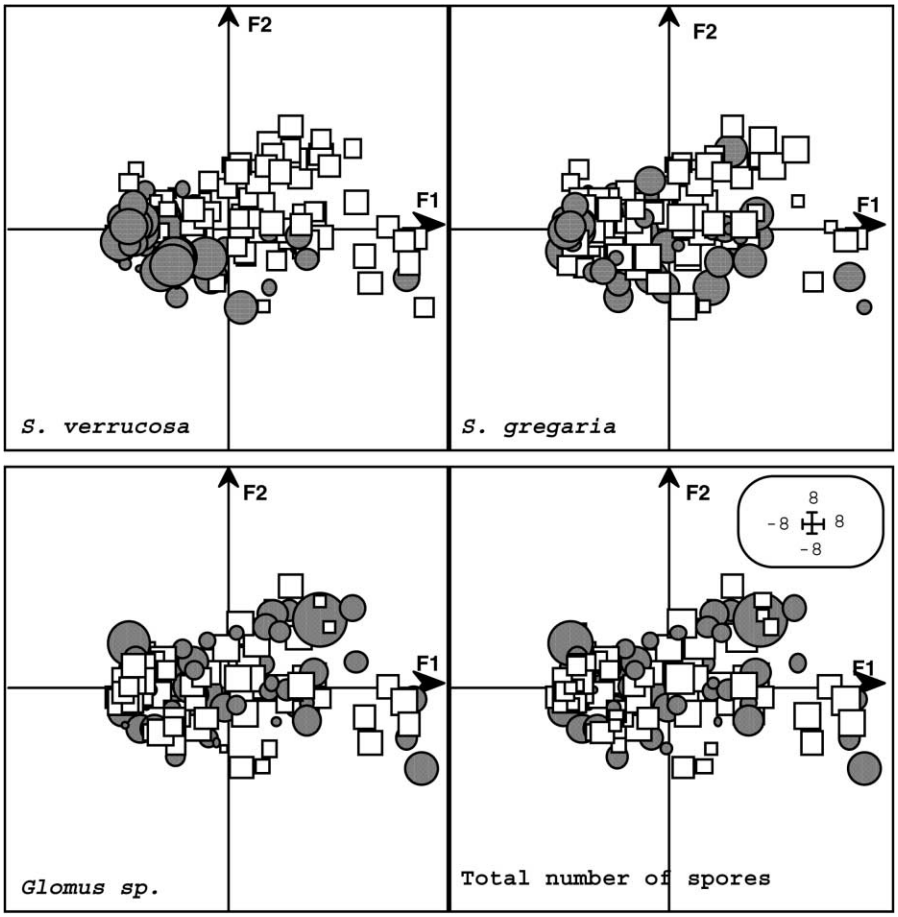

Fig. 3. Projection of the centered and normed values of the abundances of the different spore types on the corresponding sampling points on the first factorial plane of the soil data PCA. Circles represented values above average and square values below average. The size of the figure is proportional to the initial value.

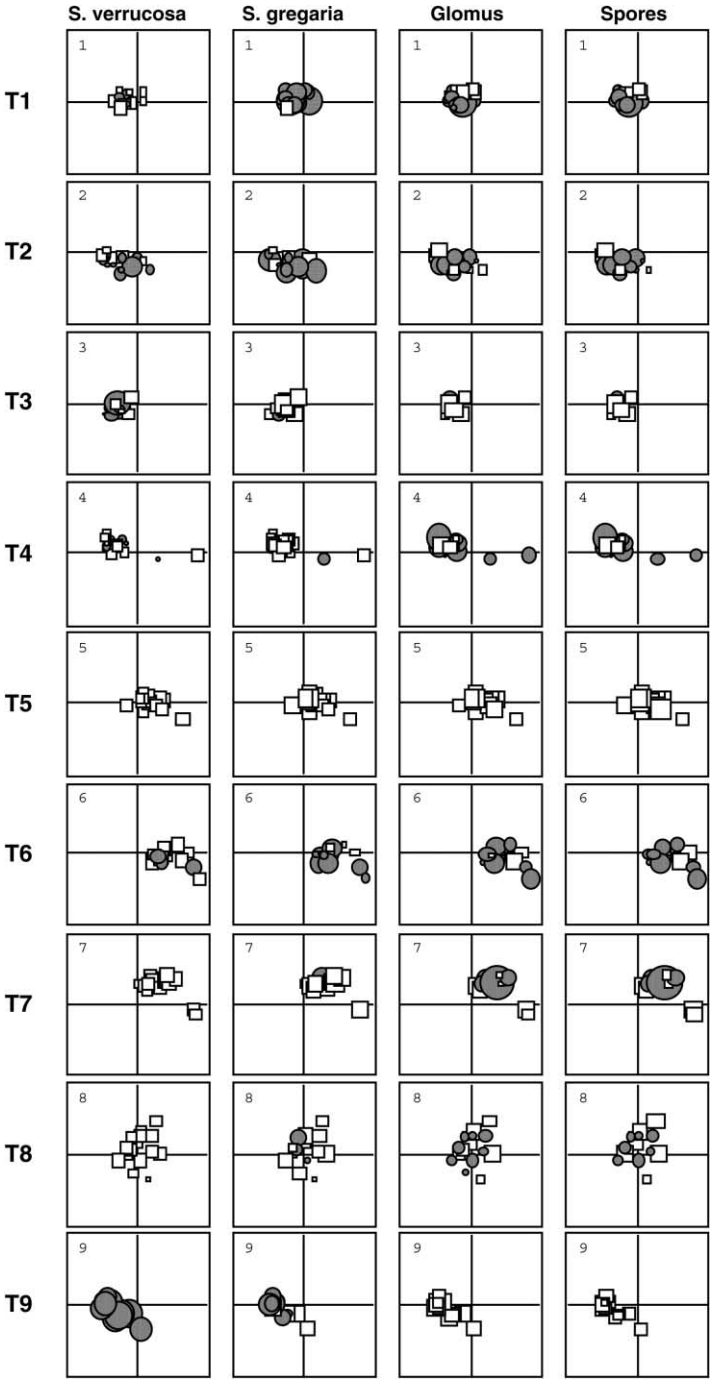

Fig. 4. First factorial plane of the soil data PCA with the fungi type abundances split according to fallow age.

Table 5
Percentages of mycorrhizal plantlets of *Pennisetum typhoïdes* growing on a range of non-disinfected soil dilutions (means of five replicates)

Transacts	Soil dilutions (%)					
	3	6	12	24	48	100
T1	6	14	14	26	30	36
T2	20	12	22	46	58	62
T3	6	10	12	26	42	60
T4	12	20	48	50	68	58
T5	2	4	8	14	52	68
T6	16	16	26	48	60	72
T7	6	12	16	24	48	54
T8	10	18	28	36	52	66
T9	4	8	14	20	36	60

seemed more strongly linked with fallow age than with human disturbance. This species was observed in fallows following a long cropping period whatever the management, but hardly at all the fallows after a short cropping period. It was also abundant in the 11-year-old fallow (but not on the millet) and in the forest.

The percentages of AM plantlets recorded in the bioassay test to determine the mycorrhizal soil infectivity are given in Table 5. None of them reached the level of 100% mycorrhizal infection and at the opposite end of the scale there were always a few mycorrhizal plantlets at the highest dilution level. Characteristics of the regression curves relating percentages of mycorrhizal plantlets and dilution levels are shown in Table 6. Since no statistical differences were observed between regression slopes by variance analysis the curves were considered as parallel with a common slope ($B = 0.335$) to calculate *Y*-intercepts. Their comparison with a *t*-test permitted three groups of soils to be distinguished as having significantly different levels of mycorrhizal soil infectivity ($P < 0.05$). The value of a MSI_{50} unit varied among the soils, the lower showing the higher soil infectivity. For the purpose of easier comparison the number of MSI_{50} units per 100 g of soil was obtained by dividing 100 by the value (g) of an MSI_{50} unit (Table 6). For T1, T5 and T9, the calculated quantities of soil necessary to obtain 50% of mycorrhizal plantlets, were respectively, 160.6, 113.9 and 109.3 g of non-disinfected soil. These quantities are greater than the amount of soil tested, i.e. 100 g. This means that there were not enough propagules of mycorrhizal fungi in 100 g of non-disinfected soil to obtain 50% of mycorrhizal plantlets, and the number of MSI_{50} units per 100 g was <1. Five soils (T1, T3, T5, T7, T9) had a similar mycorrhizal soil infectivity of plus or minus one MSI_{50} unit. In this group of sites, the three different ages of fallow and the forest were found. The second group (T2, T6 and T8) had significantly higher mycorrhizal soil infectivity and comprised three different aged fallows with grasses dominating (T2, T6, T8) and two fenced areas (T2, T8). The treatment T4, a fenced area on a 4-years-old fallow, showed the highest mycorrhizal soil infectivity.

Table 6
Relationships between soil dilutions and percentage of mycorrhizal plantlets of *Pennisetum typhoïdes*, and values of the MSI_{50} units[a] (quantity of non-desinfected soil)

Transacts	*Y*-intercept	Regression coefficient	MSI_{50} units g per 100 g	Nb MSI_{50} units per 100 g
T1	−0.209 a	0.57	>100 a	<1 a
T5	−0.189 a	0.57	>100 a	<1 a
T9	−0.183 a	0.67	>100 a	<1 a
T3	−0.159 a	0.64	92.7 a	1.07 a
T7	−0.153 a	0.55	88.9 a	1.12 a
T8	−0.069 b	0.75	49.9 b	2.00 b
T2	−0.053 b	0.45	44.7 b	2.23 b
T6	−0.023 bc	0.65	36.4 bc	2.74 bc
T4	+0.007 c	0.46	29.6 c	3.37 c

[a] Comparison of the *Y*-intercept determine three groups of treatments. Values not followed by the same letters are significantly different ($P < 0.05$).

4. Discussion

In tropical countries after many years of cropping, yields becomes very low and it is common practice to abandon fields to fallow. The yield decreases are mainly attributed to a loss of fertility and fallow appears to be the most rational method to regenerate soil fertility (Greenland and Nye, 1959; Feller et al., 1993). The duration of fallow is a matter of conflict between agronomic requirements and human needs. In practice village people tend to keep it as short as possible. Since the herbaceous and woody plants which grow during the fallow are the main agents for restoring soil fertility (Piéri, 1991), it is necessary to improve the re-establishment of vegetation. Among the biotic factors that could favour rapid plant establishment, faster plant growth and alleviate abiotic stress, arbuscular mycorrhizal symbiosis has been shown to be the most effective (see Smith and Read, 1997) in the successful establishment of plants in re-vegetation strategies.

Under semi-arid conditions, it has already been shown that AM inoculation of plants is very efficient in establishing plants on disturbed soils (Estaùn et al., 1997). But, this practice needs production of AM fungal inoculum, which must be efficient in particular environments. Alternatively, one can use the natural indigenous population of AM fungi if available. For this purpose, the first step is to study the existing vegetation and to determine the mycorrhizal soil infectivity. In our study, we observed that AM colonization of the plants examined varied greatly from one plant to another of the same species, and with the exception of *Cassia obtusifolia*, colonization was not well developed. It is not surprising that *Cassia obtusifolia* exhibited the highest level of AM colonization, since it belongs to the legume family which is known to be highly mycotrophic (Asai, 1944). The intensity of AM colonization was also low which suggests that indigenous fungi have a low infectious capacity and a slow rate of development. However, the spore population ranging from 1 to 4 spores/g of soil was comparable to that found in most temperate soils, but far from the 28 spores/g found with cassava on tropical soil (Sieverding et al., 1989). These results indicate that extensive cultural practices, in low fertility soils, and intensive cultural practices in high fertility soils may lead to impoverishment of soil fungal biodiversity.

All the root systems of the plants observed showed internal vesicles typical of *Glomus*. These observations reflected the preponderance of chlamydospores from *Glomus* species. No correlation could be established between spore population and duration of fallowing. In the situations, where it was possible to compare spore populations of grazed and fenced areas, only the 4-year-old fallow following a short cultivation period showed a significant increase compared to the corresponding fenced area. No effect of fencing was observed for the same fallow period, but following a long cropping period. The abundance of *Glomus* sp. corroborate some results obtained in different parts of Africa, namely Cameroon (Musoko et al., 1994), Senegal (Diop et al., 1994), Nigeria (Redhead, 1977) and Burkina Faso (cited in Bâ et al., 1996).

The relationships between the number of mycorrhizal spores and soil chemical and physical properties vary (Newman et al., 1981). It has been observed that large number of spores can occur over a wide range of soil pH (Read et al., 1976), soil phosphate levels (Jeffries et al., 1988) and salinity (Gerdemann, 1968). There are also marked differences among species and strains of AM fungi in the effects of soil properties on their distribution and abundance (Robson and Abbott, 1989). The results obtained in this study confirm this variability.

Our results show that populations of AM fungi in the different soils were very similar in their ability to infect plants (no significant differences between slopes of regression lines). In fact, the spore counts had already shown quite similar composition of populations, while the relationships between the percentages of mycorrhizal plantlets indicate similar behavior patterns in the expression of the inoculum potential. The values recorded for the number of MSI_{50} units per 100 g of soil are quite low (<4) compared to results obtained in cultivated soil in Burgundy, viz. 6–7 (Plenchette et al., 1989), or >11 in a fallowed plot of the long term experiment of Deherain (INRA, Research Center of Versailles, France) (Plenchette, 1989). Since the number of spores is rather high one could have expected higher soil infectivity, but this can be explained by observations which show that there are only very low numbers of viable spores in soils of disturbed ecosystems (Brundrett and Abbott, 1994; Diop et al., 1994; McGee, 1989). The results obtained in our study do not provide evidence for a beneficial effect of

increased duration of fallow on mycorrhizal soil infectivity, but they clearly demonstrate the benefit of protecting the fallow from grazing during reestablishment of vegetation. Of the four treatments having significantly higher soil infectivity, grazing was excluded for three of them. The exception, treatment T9, was a fenced area in a forest with low mycorrhizal soil infectivity, where the dominating plants were trees with deep root systems that contribute poorly to the mycorrhizal soil infectivity of the cultivated layer of the soil.

Long lasting fallow leads to a decrease in plant biodiversity and it has been shown that "long fallow disorder" decreases the number of mycorrhizal propagules in the soil and the extend of AM colonization of plants (Thompson, 1994). Our results suggest that mycorrhizal soil infectivity may benefit from a short period of fallowing if the fallow is protected against grazing. Since AM fungi are obligatory symbionts, it is not surprising that deleterious antropogenic pressure on vegetation reduces the development of AM fungi. To improve success in the restoration of soil fertility, including biodiversity of AM fungi, the results suggest that attention be given to legumes having a high mycorrhizal dependency (Plenchette et al., 1983) which could greatly enhance the AM fungal communities and the mycorrhizal infectivity of soil.

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