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INFLUENCE OF LAND USE TYPES ON OCCURRENCE OF ARBUSCULAR MYCORRHIZAL FUNGI IN THE HIGH ALTITUDE REGIONS OF MT. KENYA

[INFLUENCIA DEL USO DEL SUELO SOBRE LA OCURRENCIA DE MICORRIZAS ARBUSCULARES EN REGIONES DE GRAN ALTITUD DEL MONTE KENYA]

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SUMMARY

A survey was carried out to establish the effects of Land Use Types (LUTs) on Arbuscular Mycorrhiza Fungi (AMF). AMF spore abundance and colonization were evaluated. The percentage root colonization was assessed in trap plants only. AMF were identified and enumerated from spores extracted directly from field soils. Soils were sampled from 60 points occurring in central Kenya. A total of 17 AMF species were isolated and 14 identified to species level. The spore community was dominated by Acaulosporaceae, and Glomaceae. Land use type had no significant ($p<0.05$) effect on AMF spore abundance or root colonization. However, trends were observed in soil under napier (*Pennisetum purpureum* Schumach) and tea (*Camellia sinensis* (L.) Kuntze) recording the highest AMF spore abundance; in fallow/pasture, maize (*Zea mays* L.) and coffee (*Coffea canephora* L. var. *robusta*) with intermediate spore abundance while natural forest and planted forest had the least spore abundance. The reverse was observed for root colonization where the highest colonization were soils under natural and planted forest but tea maintained both high spore abundance and slightly high colonization. The relationship between spore abundance and soil nutrients was not statistically significant ($p<0.05$) although phosphorus and acidity gave negative, coefficient correlation values of -1.29 and -0.48 respectively, with AMF spore abundance. The similarity of land use types was high ($r = 0.716$) though this did not have similar spore abundance or soil nutrient factors. This meant that other factors such as plant species and management played a major role in influencing AMF occurrence. The study maintains phosphorus and acidity to have negative influence on AMF, spore abundance and root colonization brought out similarities in land use intensities. There is a clear suggestion that spore abundance and AMF colonization were able to detect variations in land use intensity. There was also an indication that AMF species spore abundance was a response to stress with the Glomaceae and Acaulosporaceae responding to harsh conditions by producing spores, making them to persist and dominate disturbed landscapes longer.

Key words: Arbuscular mycorrhizae; spore abundance; root colonization; land use intensity; indicator taxa.

INTRODUCTION

Arbuscular mycorrhiza fungi associate with a broad range of species and are more widely distributed than other types of mycorrhizal associations. They are keystone organisms and form an interface between soils and plant roots, and are sensitive to changes in soil and plant conditions (Power and Mills, 1995). They are widespread in tropical soils and associate with a wide range of plant species, including most commercial crops (Sieverding, 1991) and trees (Atayese, *et al.,* 1993; Adjoud-Sadadou and Halli-Hargas 2000). Individual plant species and plant communities in natural and farming systems affect the distribution and diversity of AMF species (Tonin *et al.,* 2001; Dalpe *et al.,* 2000; Jefwa *et al.,* 2006). Land use intensity was observed to have an impact on AMF species diversity in agroecosystems of central Europe (Oehl *et al.* 2003), while pollution by prolonged phosphorus fertilizer application reduced the diversity of AMF (Renker *et al.,* 2005). The impact of agricultural management of ferrasols on AMF

communities was also observed with crop rotations (Castillo *et al*., 2006). There is emerging interest in the role of mycorrhizae in ecosystem processes (Rilling 2004). Management of landscapes is variable, ranging from intensive practices that are deleterious to soil processes to practices that conserve and maintain soil processes mediated by soil organisms. With increasing interference of landscape by man, it is vital to establish trends of AMF population. Loss of AMF species could lead to irreversible destruction of habitats and eventual loss of ecosystem services. Studies on AMF species diversity and their functions along land use gradient is therefore crucial in understanding the impact of land use on ecosystem services.

Site description

Embu study site lies in the Mount Kenya region, an extinct volcano with a vesuvian type of eruption. This region is divided into two main physiographic zones: the lower forest and cultivated zone and the upper zones of open moorland above 33550 (Wokabi, 1995). Embu District is in the Eastern Province of Kenya (latitude: 03º 30′ S, longitude: 37º 30′ E, and altitude 1480 m above sea level). The area receives a total annual rainfall varying between 1200 and 1500 mm in two rainy seasons, 'long rains' (March to June) and 'short rains' (October to December). Mean monthly temperature varies between 14º C and 19.5º C. The soils are mainly Humic Nitisols (FAO, 1989) derived from basic volcanic rocks (Jaetzold and Schmidt, 1982). They are deep, well weathered with friable clay texture and moderate fertility. The site has tropical moist highlands with temperature, soils and rainfall determining ecological regions that include: snow capped mountain tops, above 5,000 m where continuous vegetation stops. Between 2,300 and 2,500 m above the sea level, there is upland forest, while upland tea is dominantly found between 2,000 and 2,300 m. Pasture, coffee and annual crops are found on the volcanic footridges, lying between 1,500 and 2,000 m above the sea level. There is a wide range of management intensity from traditional, low-external-input systems to intensive monocultures and dairy cattle. In this respect, changes in agricultural biodiversity and its functions are associated with these gradients (Dounte *et al*., 1981).

Site selection

Allocation of the sample plots was done on a systematic grid fixed at an interval of 200 m in the main land use systems, namely: coffee, tea, maize-based systems, napier, horticulture, fallow, planted forest and natural forest. A total of 60 sampling points were pegged in each benchmark area and geo-referenced, using the grid points. From each point, samples were collected at the depth of 0-10, 10-20 and 20-30 cm for soil fertility determination and arbuscular mycorrhiza fungi (AMF) studies.

The predominant land use system were natural forest (Irangi forest), tea and coffee in the upper midland zones, mixed small-scale cultivation of food crops, dairy cattle rearing as well as semi-extensive livestock production. The main farms had approximately 30% of land under annual crops, 20% under perennial crops, and 20% under grazing, while forage production covers 6%. Three soil fertility management systems in the area included use of relatively high level of inputs such as manure, fertilizers and pesticides. These inputs were particularly used on maize, tea, coffee and irrigated horticultural crops.

Soil and water conservation practices included bench terraces "Fanya Juu", grass strips monocropping, intercropping, cover cropping to rotation involving legumes and cereals and agroforestry as well integrated arable-livestock systems (Table 1).

MATERIAL AND METHODS

Sampling procedure

Soils were sampled from 60 sampling points in seven land use types: Tea (10), Coffee (9), Fallow/Pasture (8), Maize (8), Napier (8), Natural forest (8) and Tree plantations (9) at the soil depth of 0-10 and 10-20 cm depth using a soil auger. The four samples were collected at a radius of 3m and eight samples from 6m radius from the centre of a monolith at four cores per radius according to sampling layout adopted as described by Moreira *et al*., (2008). A total of 12 samples were collected from each point and the soils from the two depths were pooled together to make a composite sample of kilogramme. Samples were colleted only once in the dry season of February 2004. The soils were placed in polythene bags and stored at room temperature at the National Museums of Kenya (NMK). The soil samples were split for use in the establishment of soil trap cultures and 250 g for spore extraction.

Soil trap cultures

Since some species may not be in spore form at the time of sampling, a soil trap culture was established. Soil trap cultures also produce fresh viable spores that can be used for determination of species and the initiation of AMF pure cultures for use as inoculum and taxonomic purposes. To determine the composition of AMF in soils, a sample of 250 g soil from the field was mixed with sterile sandy soil at a ratio of 2:1 of soil: sand ratios and *Vigna unguiculata* (L.) and *Sorghum bicolor* (L.) Moenche mixture established in 1 litre pots as the trap plants. The

cultures were maintained under green house conditions. *Sorghum bicolor* and *Vigna unguiculata* mixture died from dumping off disease, hence an alternative trap plant *Mucuna puriens* (L.) DC was then established. The cultures were left to grow for a period of five months. Spores were extracted from the trap culture soils and evaluated for AMF species composition and abundance. The roots of *Mucuna* were processed (Gemma and Koske, 1988) for evaluation of AMF colonization using the slide method (McGoningle, 1990).

Spore extraction

Spores were extracted from 250 g soil sample at portions of 50 g per extraction by water and sucrose centrifugation method modified by using a 270 and 45 µm mesh sieves and 60w/v of sucrose (Jenkins, 1964). The spores were distinguished into morphotypes under reflected light stereomicroscope with color of spore, spore size, attachments on spore and surface appearance of spore used as the diagnostic features while the number of spores was counted for each morphotype. The Edinburgh Botanic Gardens color chart for fungi was used in the determination of spore color. Voucher specimens were prepared for each AMF morphotype and further described under a compound microscope with spore germination characteristics, spore wall characteristics, type of spore wall, size and number of layers and reaction to melzer's reagent used as diagnostic features. The spores were matched with species described by INVAM database and Schenck and Perez (1990). Spore cultures were made for final determination and confirmation of the species. Clean spores are being maintained as living collections at the National Museums of Kenya (NMK) for further verification.

RESULTS

Abundance of AMF spores in soils collected from different LUTs

Identification of spores was based on spore morphology distinguishing a total of 16 morphotypes. Analysis of variance (ANOVA) using Genstat showed no significant ($p = 0.30$) differences in spore abundance between LUTs (Table 2), however, the mean spore abundance was slightly variable with napier having the highest and Fallow/pasture and tree plantation the least spore abundance. Similarly, there were no significant differences ($p = 0.35$) in AMF colonization between LUTs. Correlation between AMF spore abundance and AMF colonization was negative (-0.917) though not significant ($p=0.394$). LUT with lower spore abundance such as natural forest and planted forest had higher root colonization compared to LUTs with coffee, napier and pasture/fallow while tea was exceptional in that it had both higher spore abundance and AMF colonization (Fig.1). Comparisons using student t-test showed significant ($p\leq0.05$) differences in spore abundance between land use types with tree plantation and napier significantly different. However, post ANOVA test for Bonferonni showed no significant differences between land use types.

Table 1. Nutrient characteristics in windows and land use types in Embu.

Land use	pH	Acidity	N	C	P	K	Ca	Mg	Mn	Cu	Fe	Zn	Na
			%		mg/kg			cmol/kg					
Coffee	4.0	1.5	0.3	3.4	10.8	0.3	1.8	0.6	0.6	10.3	35.51	7.97	0.20
Fallow/pasture	4.2	1.4	0.7	5.8	16.6	0.2	2.0	1.5	0.6	1.1	27.19	16.89	0.29
Maize	3.9	2.2	0.4	3.7	16.1	0.3	2.2	0.5	0.5	7.4	41.46	6.54	0.26
Napier	4.1	1.1	0.3	3.9	14.8	0.3	2.6	0.9	0.7	4.1	41.84	8.54	0.28
Natural forest	3.5	2.8	0.6	5.4	21.1	0.3	3.4	0.2	0.4	0.8	82.55	5.77	0.33
Tea	3.9	2.1	0.4	4.7	14.6	0.4	2.0	0.7	0.4	2.6	58.29	5.29	0.22
Tree plantation	4.2	1.7	0.9	6.6	12.4	0.2	1.6	1.9	0.2	3.1	43.34	6.24	0.26

Source: Muya et al., BGBD Annual report 2006

Table 2: AMF mean spore abundance, species richness and species diversity per 100 g of air dried soil seven LUTs in Embu.

	Spore abundance		
Land use type	Total	Mean	Jacknife estimate
Coffee	642	71.3	1213
Fallow/pasture	596	74.5	1118
Maize	579	72.4	1086
Napier	812	101.5	1523
natural forest	475	59.4	890
Tea	930	93.0	1767
Tree plantation	448	56.0	840
F-probability		1.18	
p-value		0.33	
Grand mean		75.97	
s.e		5.81	

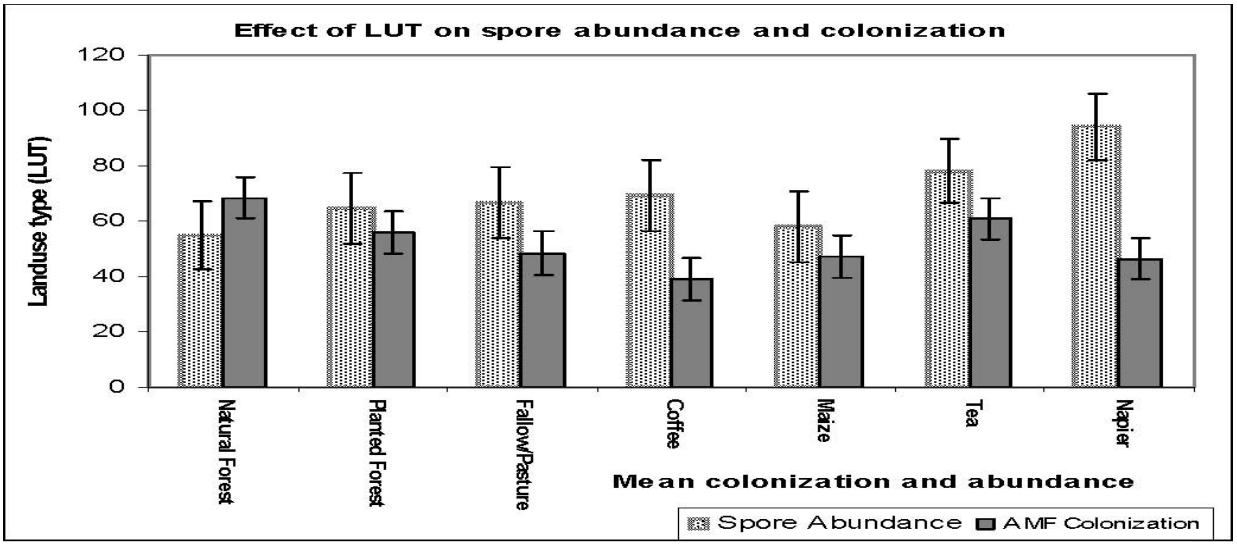
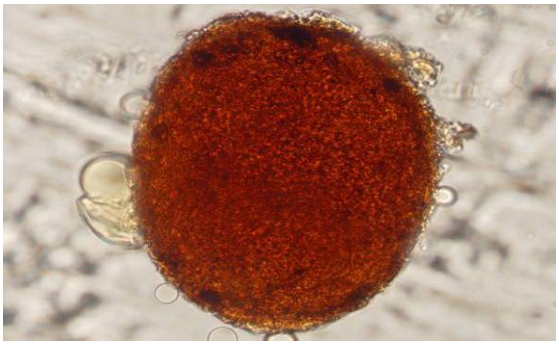


Figure 1. Impact of land use type (LUT) in order of less to high intensity on spore abundance and colonization.

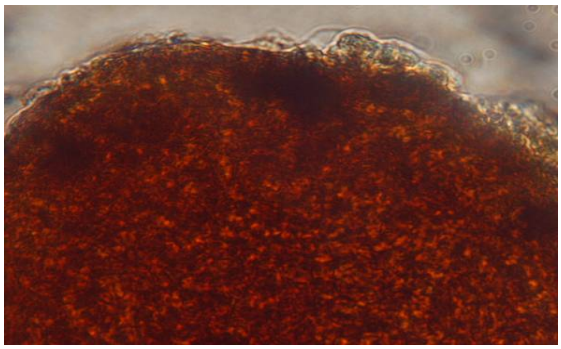
Composition of AMF species in soils from different LUT

Fourteen species could be distinguished morphologically according to Schenck and Perez (1990) and INVAM (International Culture Collection of Arbuscular and Vesicular-Arbuscular Mycorrhizal Fungi) spore description data base and with an aggregate of four morphotypes referred to as Myc (Myc 16, Myc 17 and Myc 3) could not be matched with any known species. The majority of species were identified as Acaulosporaceae (5), Glomaceae (4), Gigasporaceae (5) and others (3) (Plate 1). Only four AMF species could be assigned to specific taxa. The remaining taxa, though distinguished to species level, it could not be assigned species epithets and were named based on distinct morphological characters such as color. There were variations in spore proportions of individual species in soils (Table 3). *Acaulospora* spp. had the highest spore proportion of 50% followed by *Glomus* spp. with 33.9%, *Gigaspora* sp. (7.8%), *Scutellospora* spp. (4.6%) and others (2.9%). The two genera, *Glomus* and *Acaulospora* formed the highest proportions of spores. The spores of *Glomus* sp. 1 and *Acaulospora* sp. 2 were dominant in most LUTs. Most species were present in all land use types but variable in mean spore abundance (Table 4). Two species, *Glomus* sp. Cream (*G. aggregatum*) and *Scutellospora* hyaline (*Scutellospora aff. pellucida* (Nicol & Schenck) C. Walker & F.E Sanders, 1986) were detected only in trap cultures, while *Glomus* Sienna, *Glomus* sporocarpic, Myc 3b, Myc 16 and Myc 17 occurred only in field soils. The distribution of species can be presented in two groups namely;

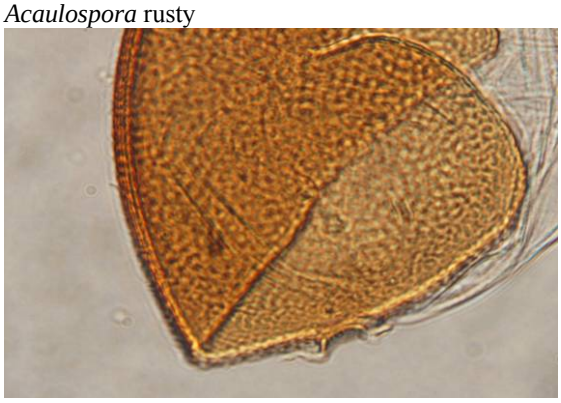
widespread which comprised of species in all LUTs such as *Glomus* sp. 1, *Glomus* sp. 3, *Acaulospora* rusty, *Acaulospora* sienna, *Acaulospora* hyaline, *Acaulospora* sp. 2, *Acaulospora scrobiculata*, *Scutellospora* yellow and *Gigaspora* and, the restricted species which were *Glomus* sporocarpic, *Glomus aggregatum* (cream), *Scutellospora* brown, *Scutellospora* yellow *Scutellospora nigra* and *Scutellospora pellucida*. Eight species had the highest numbers of spore under napier, followed by five in tea, two in tree plantation and one in maize. Species with highest spore abundance in napier were *Glomus* spp (4), *Scutellospora* spp (4) and the *Gigaspora* spp (1). Species with the highest spore abundance in tea were *Acaulospora* spp. (5). The two species most abundant with tree plantation were *Acaulospora* sp. (1) and *Glomus* sp. (1) while *Scutellospora* hyaline was only found from soils under maize crop.



Acaulospora rusty

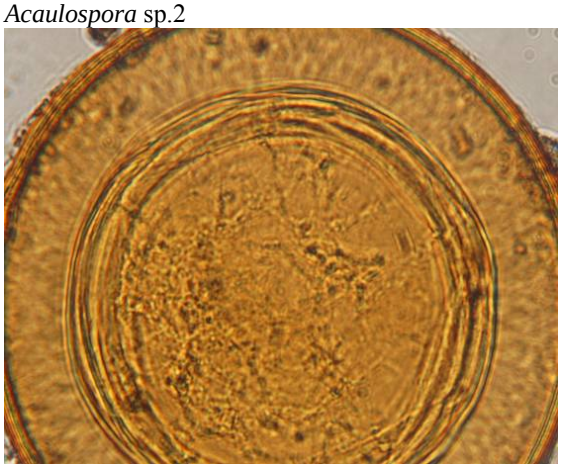


Acaulospora rusty



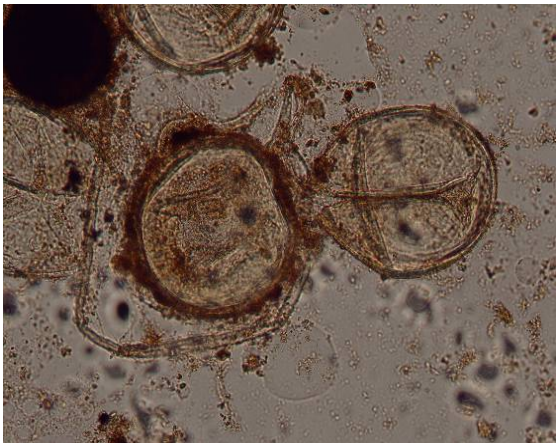
Acaulospora sp.2

Acaulospora sp. 2

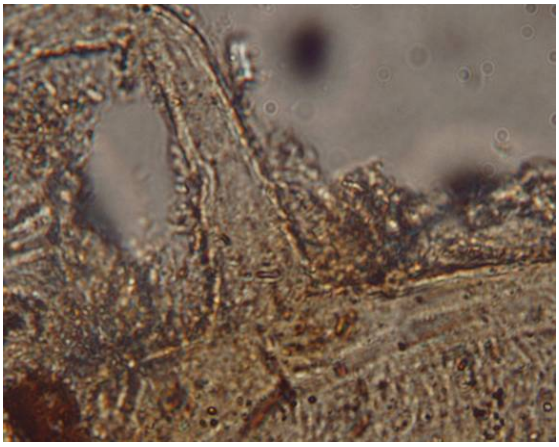


Acaulospora mellea

Acaulospora mellea

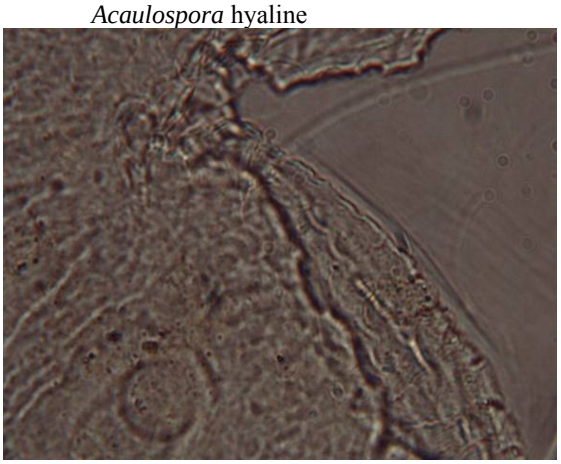


Acaulospora hyaline

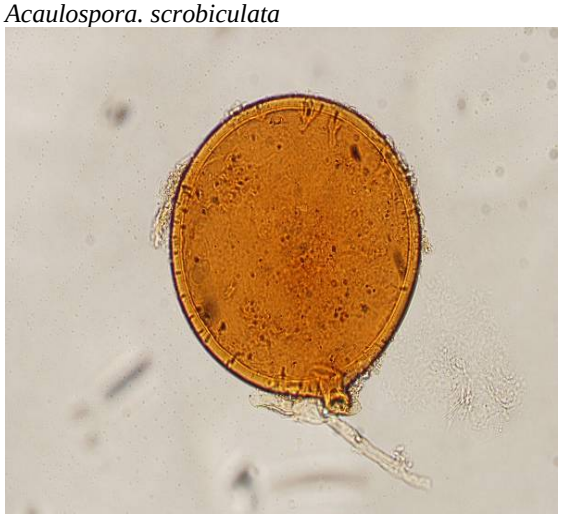


Acaulospora hyaline

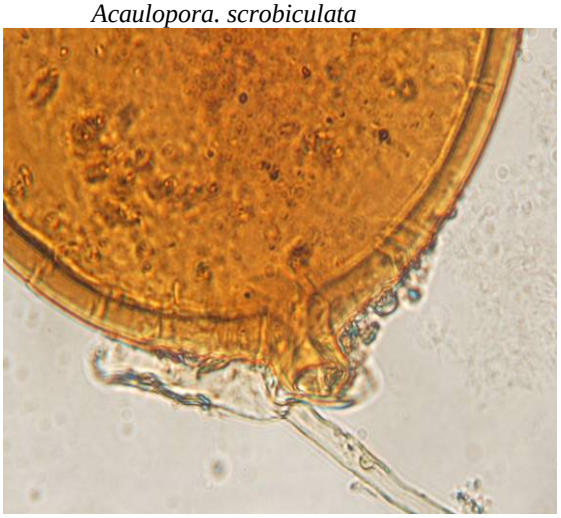
Acaulospora. scrobiculata



Acaulopora. scrobiculata



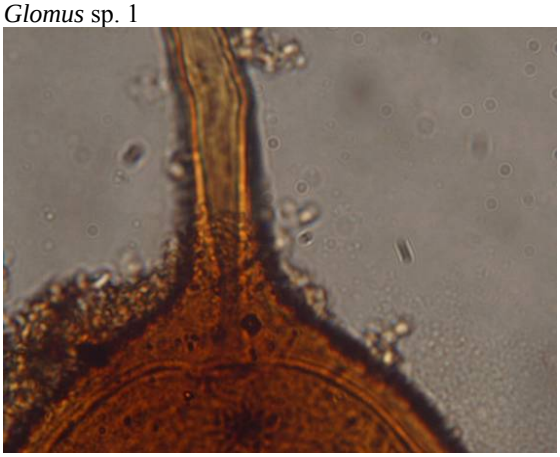
Glomus sienna



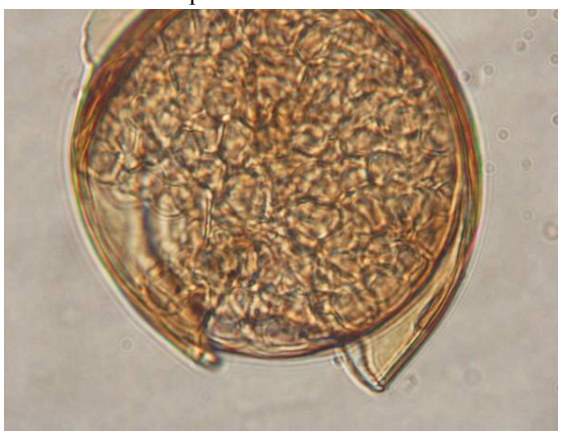
Glomus sienna

Glomus sp. 1

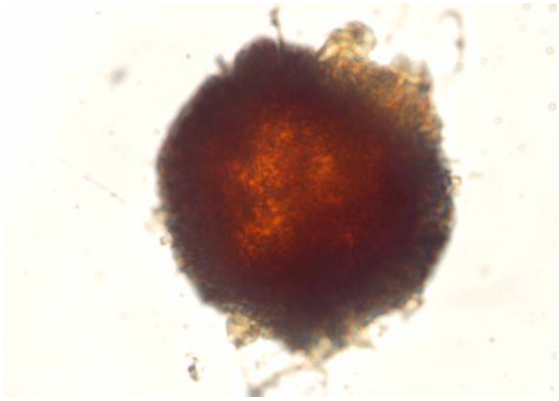
Glomus sp. 1



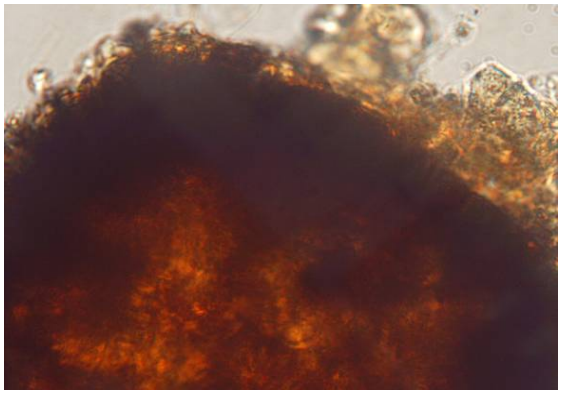
Glomus sp. 1



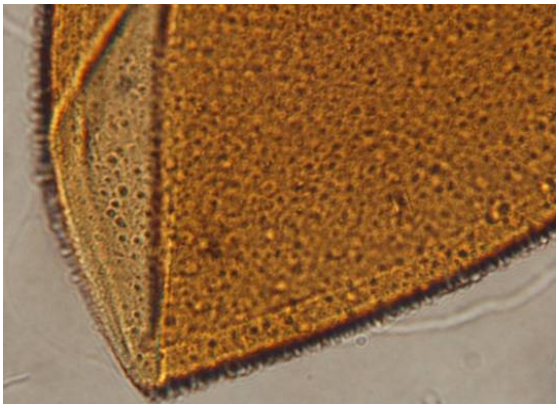
Glomus cream (aggregatum)



Glomus sporocarpic

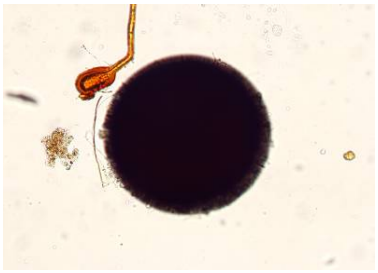


Glomus sporocarpic

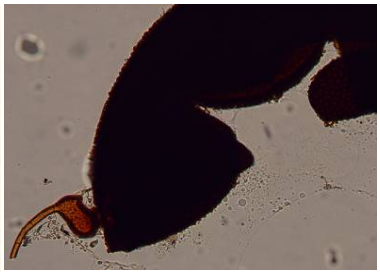


Scutellospora brown

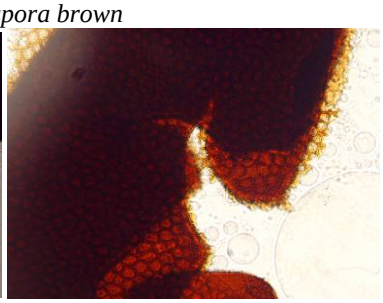
Scutellospora brown



Scutellospora nigra



Scutellospora nigra



Scutellospora nigra

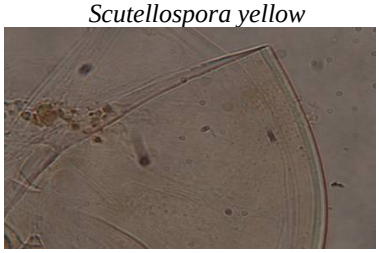
Scutellospora yellow

Scutellospora yellow

Scutellospora yellow

Scutellospora pellucida

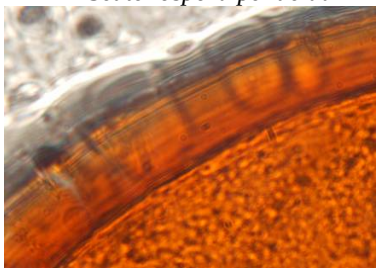
Scutellospora pellucida



Scutellospora pellucida

Gigaspora sp

Gigaspora sp



Gigaspora sp.

Plate 1. Pictures of Morphotypes of AMF species comprising 4 *Glomus* spp., 5 *Acaulospora* spp, 4 *Scutellospora* spp. and 1 *Gigaspora* sp.and non-defined AMF taxa.

Table 3. Arbuscular mycorrhizae species rank abundance in field soils.

Rank Abundance	AMF species	Proportion (%)
1	*Glomus* sp. 1	20.4
2	*Acaulospora* sp 2	15.9
3	*Glomus* sienna.brown	13.6
4	*Glomus* sp. 3	13.2
5	*Acaulospora mellea*	7.4
6	*Acaulospora* hyaline	5.6
7	*Acaulospora* rusty	5.6
8	*Scutellospora* yellow	4.1
9	*Gigaspora* (11 &12)	7.8
10	Undefined	2.9
11	*Acaulospora. Scrobiculata*	1.9
12	*Scutellospora* brown	0.4
13	*Glomus* sporocarpic	0.3
14	*Scutellosora nigra*	0.3
15	*Scutellospora pellucid*	0
16	*Glomus aggregatum (Cream)*	0

Table 4. Mean spore abundance of AMF species community in field per 250 g dry weight soil.

AMF species	Land use types						
	Coffee	Falow/ pasture	Maize	Napier	Natural forest	Tea	Tree plantation
Glomus sp. 1	21.9	17.9	21.4	23.4	12.6	8.2	4.3
Glomus sporocarp	0.22	0.38	0.63	0.63	0	0	0
Glomus sp. 3	11	1.9	3.6	3.6	7.3	2.0	14.6
Glomus cream	0	0	0	0	0	0	0
A. mellea	0.44	7.1	3.6	0	5.4	14.1	7.0
Acaulospora rusty	5.8	2.5	4.0	4.8	2.5	7.6	1.6
Glomus Sienna	6.4	15.1	5.9	24.6	8.5	7.7	5.1
Acaulospora hyaline	5.8	2.3	4.0	4.9	2.8	7.6	1.6
Acaulospora sp. 2	13.1	8.1	7.6	9.8	11.3	19.3	13.3
A. scrobiculata	0.3	3.1	1.5	0.3	0.8	4.4	4.6
Scutellospora yellow	0.7	5.3	2.5	9.6	2.3	1.4	0.8
Scutellospora brown	0.3	0.1	0.6	1.3	0	0.1	0
S. nigra	0.1	0.1	0	0.3	0	0	0
Scutellospora hyaline	0	0	0	0	0	0	0
Gigaspora	2	9.4	7	15.4	4.3	0.9	2.5
Myc 3	0.3	0	0	0.1	0	0	0.9
Myc 16	2.3	0	4.8	0	1.6	0.6	0.6
Myc 17	0.7	0	0	3	0	0.2	0

Distribution patterns of AMF in different LUTs

Soil nutrient factors were significantly ($p \leq 0.05$) different in the LUTs (Table 5). Carbon was highest in soils under planted forest, fallow/pasture, natural forest and tea in descending order. Iron content was highest in soils collected from natural forest and tea, nitrogen was highest in planted forest, fallow/pasture and natural forest; phosphorus was highest in natural forest, fallow/pasture and maize; and potassium was highest in tea. Linear regression models for soil properties showed variable relationship between spore abundance and nutrients (Table 6). The relationships were not statistically significant ($p \leq 0.05$) although there was slight evidence of positive effects on carbon, nitrogen and potassium and negative effects on phosphorus and acidity. Increase in P and acidity resulted in a decline in spore abundance and vis versa and the increase and decrease in carbon, nitrogen and potassium resulted to increase and decrease in spore

abundance respectively. The LUTs were evaluated for similarities based on spore abundance. Land use similarity analysis using Bray-curtis distances to generate the distance matrix and presented in a dendogram showed that the similarities in LUTs were not due to chance ($p< 0.01$) (Fig 2). Land use types can be classified into two categories A (Coffee, Maize, natural forest, fallow/pasture and Napier) and B (Tea and tree plantation); the A group could further be split into Ia (Maize and natural forest) and Ib (Coffee) and II (fallow/pasture and Napier).

Table 5. Mean soil nutrients across windows and land use type.

Land use type	Soil nutrients					
	Carbon (%)	Acidity (%)	Iron (%)	Nitrogen (%)	Phosphorus (ppm)	Potassium (%)
Coffee	3.4	1.5	35.5	0.3	10.8	0.3
Fallow/pasture	5.8	1.4	27.2	0.7	16.6	0.2
Maize	3.7	2.2	41.5	0.4	16.1	0.3
Napier	3.9	1.1	41.8	0.3	14.8	0.3
Natural forest	5.4	2.8	82.6	0.6	21.1	0.3
Tea	4.7	2.1	58.3	0.4	14.6	0.4
Planted forest	6.4	1.8	47.4	0.8	12.3	0.2
Grand mean	4.8	1.8	47.9	0.51	15.05	0.28
F-statistic	7.15	2.58	3.80	3.94	1.86	1.37
p-value	0.001	0.03	0.003	0.002	0.11	0.24
s.e	0.21	0.14	3.89	0.05	0.95	0.02

Table 6. Relationship between soil nutrients and AMF spore abundance.

Soil nutrients	Carbon	Acidity	Nitrogen	Phosphorus	Potassium
Intercept estimate	66.7	78.3	74.7	83.2	60.4
Coefficient estimate	1.99	-1.29	2.52	-0.48	55.58
F-statistic	0.30	0.06	0.02	0.36	2.69
p-value	0.59	0.81	0.88	0.55	0.11

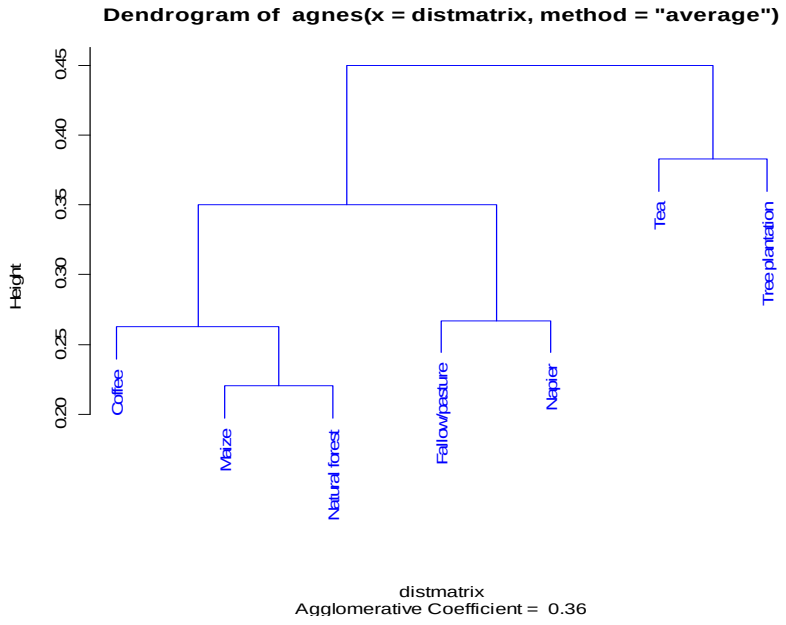


Figure 2. Similarities in Land use types based on AMF spore abundance.

DISCUSSION

The seventeen AMF species isolated from this tropical moist highland is low compared to 40 species recorded in the Cameroon tropical rainforest (Mason, *et al.,* 1992) but similar to 15-18 species recorded in the acid soils of western Kenya and in agroforestry systems in the miombo ecozone of Malawi (Mathimaran *et al.,* 2007; Shepherd *et al.,* 1996; Jefwa *et al*., 2006). Land use classes were ordered in respect to agricultural intensification—as follows: natural forest, planted forest, fallow/pasture, coffee, maize, tea and napier (Moreira *et al.,* 2008). Spore abundance was highest in LUTs with high intensity (Tea and Napier) and less abundant in less intense LUTs. Land use types such as natural forest and tree plantation had fewer spores and high root colonization indicating that there was a high percentage of infective vegetative propagules. Soils from tea had both high spore abundance and high root colonization since tea is a perennial crop with continuous root growth but is highly fertilized. With the exception of coffee, the rest of the LUTs were dominated by perennial plants which had the highest root colonization that may be attributed to continuous root growth throughout and less disturbance through cultivation. Coffee, another perennial crop is often intercropped with food crops and receives frequent manual weeding coupled by high application of agrochemicals, while napier, a fodder crop, is subjected to frequent cutting as fodder for the zero-grazed dairy cows. This form of interference may explain the high sporulation and disruption of mycelia manifested in slightly low AMF colonization. Disturbance eliminates or severely reduces mycorrhizal diversity (Xavier and Germida, 1998). The hyphal network which contributes to biogeochemical cycling of nutrients ceases to function under adverse conditions or disturbance (Jeffries and Barea, 1994; Linderman and Pfleger, 1994; McNaughton *et al*., 1990). Baylis (1969) suggested that intermittent root growth may stimulate sporulation as may be the case in conditions of disturbance. Spores are reproductive propagules that are produced for propagation of the fungus and as survival propagules particularly when conditions are harsh. Either way this is an advantage to the fungus as it guarantees survival. It is evident from this study that disturbance contributes to high sporulation, of the less infective propagules. Under low disturbance and continuous root growth, mycelia are the most dominant infective propagules. This may explain the low spore abundance and high colonization in soils under natural forest. Spore abundance was used as the measure of dominance with species in Acaulosporaceae followed by Glomaceae being the most prevalent. Three *Scutellospora* spp. and one *Gigaspora* sp were also recorded though in very low abundance. These observations are inconsistent with Mathimaran (2007) who observed low dominance of *Glomus* spp. in a tropical agricultural soil, and consistent with reports, where *Glomus* spp. was recorded as the most prevalent in cropping systems (Oehl *et al.,* 2003, Jansa *et al.,* 2002, Diallo *et al.,* 1999). Acaulosporaceae and Glomaceae were also more prevalent in natural forest, than Gigasporaceae species with only *Scutellospora* spp. yellow recorded. Gigasporaceae is associated with undisturbed conditions although in this study, it occurred in cropping systems. *Scutellospora* spp. and *Gigaspora* spp. have been reported in cultivated systems (Shepherd *et al.,* 1996, Jefwa *et al.,* 2006) while they were reported to be absent in disturbed soils with *Glomus*, *Acaulospora* and *Entrophospora* recorded as the most dominant (Dodd *et al*., 2000). With so much contradicting reports on AMF species occurrence, there is still need to evaluate AMF functioning under different systems and host plants. Trap culture was effective in stimulating sporulation of *Scutellospora* aff. *pellucida (Scutellospora hyaline)* and *Glomus* aff.*aggregutum (Glomus cream)*. The two species were not recovered from field soils. Four AMF species (sporocarpic *Glomus* sp. and three morphotypes) failed to produce spores under trap culture. Oehl *et al.,* (2004) reported three out of 35 species recorded at a field site failing to produce spores in traps. This was explained by different environmental conditions and different composition of plant cover (Bever *et al.,* 1996; Jansa *et al.,* 2002). Most of the species were not exclusive to a particular LUT as they were commonly found in all LUTs. AMF species seemed to be prevalent in most LUTs with differences in only spore production. Spore production is partly a clear response to stress. A high number of spores in areas of anthropic impact was a response of AMF to physiological impact that fire caused to trees, as a reaction to a stress situation and to guarantee high survival rates (Moreira *et al*., 2006). Occurrence of high spore counts is therefore an indicator of disturbance. Species that sporulate more seem to be more sensitive to disturbance. It was evedent that species in the Glomaceae and Acaulosporaceae were more responsive to soil disturbance.

CONCLUSION

Phosphorus and acidity still stand out as major soil conditions that affect AMF spore abundance and colonization negatively. The similarities amongst LUTs could not be explained by soil nutrient factors or spore abundance. However, spore abundance and root colonization seemed to bring out similarities in LUTs more strongly based on the types of plants (perennial vs annuals) and conventional management practices in these LUTs. Natural forest and tree plantation which both have the least spore abundance and high colonization have perennial plants with less interference in soil management. The two with

minimum interference could be classified as least disturbed. The next category of land use type was fallow/pasture, maize and coffee in descending order. The period of Fallow/pasture in this region, where population density is highest in Kenya was a duration of only one cropping season followed by an annual crop of maize and bean intercrop and or horticultural crops. The three LUT are characterized by fertilizer and pesticide inputs and frequent tillage to sustain production. Coffee production requires more input compared to the two LUTs. The low spore abundance and low colonization is a clear indication of high intensity that affects all AMF infective propagules, including spores which are supposed to withstand harsh conditions. Napier and tea which were permanent crops (perennial) maintained continuous root growth, and sustained AMF in vegetative form, but due to application of fertilizers and the frequent harvest of fodder grass some degree of disturbance occurred resulting in high spore production. However, the LUTs with tea, like natural forest and planted forest is still able to maintain high colonization. Spores abundance and AMF colonization were good indicators of land use intensity. Based on observations made in this study, when spore density is high and root colonization low, disturbance is high, but the response to disturbance will depend on the types of plants (annual vs perennials).

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REFERENCES

Adjoud-Sadadou, D., Halli-Hargas, R. 2000. Occurrence of arburscular mycorrhizae on aged Eucalyptus. Mycorrhiza. 9:287-290.

Atayese, M.O., Awotoye, O.O., Osonubi, O., Mulongo, K. 1993. Comparison of the influence of hedgerow woody legumes and cassava at the top and base of a hillslope in alley cropping system. Biology and Fertility. of Soils. 16:198-204.

Baylis, G.T.S. 1969. Host treatment and spore production by Endogone. New Zealand Journal of Botany. 7:155-160.

Bever, J.D., Morton, J.B., Antonovics, J., Schultz, P.A. 1996. Host-dependent sporulation and species diversity of arbuscular mycorrhizal fungi in mown grassland. Journal of Ecology. 84: 71-82

Castillo, C.G., Rubio, R., Rouanet, J.L., and Borie, F. 2006. Early effects of tillage and crop rotation on arburscular mycorrhizal fungal propagules in an ultisol. Plant and Soil. 43: 83-92.

Dalpe, Y., Plenchette, C., Gueye, M. 2000. Glomales species associated with surface and deep rhizosphere of *Faidherbia albida* in Senegal. Mycorrhiza. 10, 125-129.

Dodd, J C., Arias, I., Koomen, I., Hayman, D S. 1990. The management of vesiculararbuscular mycorrhizal populations in acid infertile soils of a savanna ecosystem. The effect of precropping and VAMF inoculation on plant growth and nutrition in the field. Plant and Soil. 122: 229-240.

Dounte, R., Ochanda, N., Epp I T. 1981. Forest cover mapping in Kenya, using remote sensing techniques. KREMU, Nairobi.

FAO. 1989. Forestry and food security. FAO forestry paper, FAO (UN) 90: 1-2.

FAO-UNESCO. 1987. Soil map of the world. Revised legends with corrections and updates. World Soil Resources Report 60, FAO, Rome. Reprinted with updates as Technical paper 20, ISRIC, Wageningen.

Gemma, J.M., Koske, R.E. 1988. Seasonal variation in spore abundance and dormancy of *Gigaspora gigantea* and in mycorrhizal inoculum potential of a dune soil. Mycologia. 80: 211-216.

Diallo, A.T., Samb, P.I., Duucousso, M. 1999. Arbuscular mycorrhizal fungi in the semiarid areas of Senegal. European Journal of Soil Biology. 35: 65-75.

Jansa, J., Mozfar, A., Anken, T., Ruh, R., Sanders, I R., Frossard, E. 2002. Diversity and structure of AMF communities as affected by tillage in a temperate soil. Mycorrhiza. 12:225-234.

Jaetzold, R.H., Schmidt, H. 1983. Farm Management Handbook of Kenya, Vol. II/B, Central Kenya. Ministry of Agriculture, Nairobi, Kenya.

Jeffries, P., Barea, J.M. 1994. Biogeochemical cycling and arbuscular mycorrhizas in sustainability of plant-soil systems. In: Impact of arburscular mycorrhizas on sustainable agriculture and natural ecosystems. S. Gianinazzi., Schüepp. H. pp.101-116.

Jefwa, J.M. Sinclair, R., Maghembe, JA. (2006). Diversity of glomale mycorrhizal fungi in maize/sesbania intercrops and maize monocrop systems in southern Malawi. Agroforestry Systems. 67: 107-114.

Jenkins, W.R. 1964. A rapid centrifugal-floatation technique for separating nematodes from soil. Plant Disease Report. 48, 692.

Lindermann, R.G., Pfleger, F.L. 1994. General summary: In: Pfleger, F.L., Linderman, R.G (eds.) Mycorrhiza and plant health. APS press, St Paul Minnesota. pp. 337-344.

Mason, P.A., Musoko, M.O., Last, F.T. 1992. Short-term changes in vesicular-arbuscular mycorrhizal spore populations in *Terminali*a plantations in Cameroon. In: Read, D.J., Lewis, D.H., Fitter, AH., Alexander, I.J (eds.). Mycorrhizas in ecosystems. Wallingford: CAB International. Pp.261-267.

Mathimaran, N., Ruh, R., Jama, B., Verchont, L., Frossard. 2007. Impact of agricultural management on arbuscular mycorrhizal fungal communities in Kenyan ferrasol. Agriculture Ecosystems and Environment. 119: 22-32.

McGonigle, T.P., Evans, D.G., Miller, M.H. 1990. Effect of degree of soil disturbance on mycorrhizal colonisation and phosphorus absorption by maize in growth chamber and field experiments. New Phytologist. 116, 629-636.

McNaughton, S.J., Oesterheld, M. 1990. Extramatrical mycorrhizal abundance and grass nutrition in tropical grazing ecosystems in Serengeti National Park, Tanzania. Oikos. 59: 92-96.

Moreira, F.M., Huising, E.J., Bignell, D.E., 2008. A handbook of tropical soil biology. Sampling and characterization of below-ground biodiversity. pp.202-212. earthscan publishers.

Moreira, M., Baretta, D., Tsai, S.M., H., Jurandy, E., Cardoso, B.N. 2006. Spore density and root colonization by arburscular mycorrhizal fungi in preserved or disturbed Aracauria angustifolia (Bert.) O. Ktze. Ecosystems. Scientia Agricola (Piracicaba, Brazil.). 63: (40) 380-385.

Oehl, F., Siverding, E., Mäder, P., Dubois, D., Ineichen, K., Boller, T., Wiemken, A. 2004. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. Oecologia. 138: 574-583.

Oehl, F., Sieverding, E., Ineichen, K., Mäder, P., Boller, T., Wiemken, A. 2003. Impact of land use intensity on the species diversity of arbuscular mycorrhizal fungi in agroecosystems of central Europe. Applied Enviromental Microbiology. 69: 2816-2824.

Power, M.E., Mills, L.S. 1995. The keystone cops meet in Hilo. Tree. 10: 182-184.

Renker, C., Blanke, V., Buscot, F. 2005. Diversity of arbuscular mycorrhizal fungi in grassland sponteneously developed on area polluted by a fertilizer plant. Environmental pollution. 135: 255-256.

Rilling, C.M., 2004. Arburscular Mycorrhizae and terrrestial ecosystem process. Ecology letters. 7: 740 754.

Schenck N.C., Perez Y., 1990. Manual for the identification of VA mycorrhizal fungi (eds.). Synergistic Publ., Gainesville Florida, pp 286.

Shepherd, K.D., Jefwa, J., Wilson, J., Ndufa, J.K., Ingleby, K., Mbuthia, K.W. 1996. Infection potential of farm soils as mycorrhizal inocula fo Leuceana leucocephala. Biology and Fertility of Soils. 22:16-21.

Sieverding E. 1991. Vesicular-arbuscular mycorrhiza management in tropical agro systems. German Technical cooperation (GTZ) Eschborn, pp 371.

Tonin, C., Vandenkoornhuyse, P., Joner, E.J., Stracek, J., Leyval, C. 2001. Assessment of arburscular mycorrhizal fungi diversity in the rhizosphere of viola calaminaria and the effect of these fungi on heavy metal uptake by clover. Mycorrhiza. 10: 161-168.

Wokabi, S M. 1995. Yield Gap analysis in Embu District. Ph.D. Thesis. University of Ghent, Belgium.

Xavier, L.J.C., Germida, J.J. 1998. Impact of human activities on mycorrhiza: Impact of humans in soil microorganisms: In Microbial biosystems: New Frotiers. Proceedings of the 8th International symposium on microbial ecology. Bell, C.R., Brylinsky, M., Johnson-Green, P (eds.). Atlantic Canada society for microbial ecology, Halifax, Canada, 1999.

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