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Full Length Research Paper

Mycorrhizal status of some indigenous tree species in the Takamanda rainforest, South West Region, Cameroon

Eneke Esoeyang Tambe Bechem[1*], Njoh Roland Ndah[1,2] and Egbe Enow Andrew[1]

[1]Department of Botany and Plant Physiology, University of Buea, P. O. Box 63 Buea, Cameroon.
[2]Forests, Resources and People, Limbe P. O. Box 111 Limbe, Cameroon.

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A survey was carried out to determine the type of mycorrhizal association formed by trees within the different habitat types of the disturbed and undisturbed sites of the Takamanda rainforest. Forty-eight tree species of commercial and cultural importance were selected from the two sites for this study. Root samples were collected from a total of 327 individual trees belonging to the 48 species; they were cleared, stained and examined microscopically for mycorrhizal colonization and type. All the forty-eight species examined harbored one or more mycorrhizal structures, which ranged from arbuscules, intercellular hyphae, intracellular hyphae, vesicles, and Hartig net. Thirty-nine species formed exclusively arbuscular mycorrhiza (81.25%), two species; *Uapaca guineensis* and *Angylocalyx oligophyllus* formed ectomycorrhiza only (4.17%), while seven species *Afzelia bipindensis*, *Baphia nitida*, *Anglylocalyx pynaertii*, *Cieba pentandra*, *Cylicodiscus gabunensis*, *Pterocarpus soyauxii* and *Terminalia ivorensis* formed both ecto- and arbuscular mycorrhiza (14.58%). In both forest sites and habitat types, arbuscular mycorrhiza was the most represented among the tree species. In the undisturbed site and in the plain 68% of tree species sampled formed arbuscular mycorrhiza, 12% formed ectomycorrhiza, 16% formed dual mycorrhiza and 4% were non-mycorrhiza. On ridge top, 81.8% of the tree species formed arbuscular mycorrhiza, 13.6% formed ectomycorrhiza with 4.6% being dual mycorrhiza. On hilly slopes, 82.8% of the tree species formed arbuscular mycorrhiza, 13.8% formed ectomycorrhiza and 3.5% were dual mycorrhiza. In the disturbed site, 100% of the tree species sampled on the plain, formed arbuscular mycorrhiza. On the ridge top, 73.3% of the tree species sampled formed arbuscular mycorrhiza, 13.3% formed ectomycorrhiza and 13.3% were non mycorrhizal. On hilly slopes, 83.3% formed arbuscular mycorrhiza, 8.3% formed ectomycorrhiza and 8.3% were non-mycorrhizal. Mycorrhizas are important factors in Takamanda and must be taken into consideration, when designing management strategies for this forest.

Key words: Arbuscular mycorrhiza, ectomycorrhiza, Takamanda forest.

INTRODUCTION

The management and conservation of forest biomes is a recognized priority on a global scale. Understanding the rhizosphere and the mycorrhizal associations in particular, is important for the proper management of forest ecosystems. Mycorrhizal relationship (mutualistic associations between specialized Basidio-, Asco-, and Glomeromycetous fungi and roots of higher plants) constitute the most efficient nutrient uptake facilitators particularly in nutrient deficient soils of tropical regions (Ike-Izundu, 2001; Onguene and Kuyper, 2001; Kernagham, 2005). Mycorrhizal symbioses are ubiquitous in terrestrial ecosystems and have been shown to exert significant influence on recruitment, species composition, richness and productivity of plant communities (Vander Heijden et al., 1998; Moyersoen and Fitter, 1999; Terwilliger and Pastor, 1999; Weber et al., 2005). However, the degree of this influence in the rainforest of Takamanda is yet to be unraveled.

A number of different types of mycorrhizas exist in nature and can be identified by the hyphal structures they form. Arbuscular mycorrhizas (AM), sometimes referred to as endomycorrhizas, are formed predominantly by the fungi of the Glomeromycota (Schubler et al., 2001). Their name is derived from structures they form within cells of plant root, arbuscules. Arbuscules are finely-branched structures that are formed within a cell and serve as a major metabolic exchange site between the plant and the fungus. Vesicles are formed by some species of AM fungi; they are sac-like structures, emerging from hyphae, which serve as storage organs for lipids (Smith and Read, 2008). AM are formed by a wide range of plant species, belonging to different life forms. AM colonization has no visible effect on root morphology (Brundrett, 2009). Ectomycorrhizas (EM), on the other hand, form an outer sheath (mantle) around the root, an internal, intercellular network of hyphae (Hartig net) and rhizomorphs. EM fungi have a visible effect on root morphology. Root tip branching often becomes dichotomous or irregular. The root tip also tends to swell and the mantle may colour the area of colonization (Hawley and Dames, 2004). It is widely accepted that most tropical tree species form mostly AM and limited species form EM associations (Onguene and Kuyper, 2000; Skinner, 2001; Bechem and Alexander, 2012; Bechem et al., 2014). EM associations have been observed in selected genera in the humid tropics, primarily from the Caesalpiniaceae, Fabaceae, Gnetaceae, Euphorbiaceae, Myrtaceae, Nyctaginaceae, Araucariaceae, and Polygonaceae (Alexander and Hogberg, 1986; Alexander, 1989; Henkel et al., 2002; Wang and Qiu, 2006). Substantive research has been done on EM associations in the Dipterocarpaceae of Asia (Alexander, 1989; Alexander et al., 1992; Lee et al., 1997), Caesalpiniaceae and the Uapacaceae of Africa (Hogberg and Piearce, 1986; Newbery et al., 1988; Torti and Coley, 1999).

Nevertheless, there are many species for which mycorrhizal associations have to be examined (Skinner, 2001; Alexander and Lee, 2005). Mycorrhizal status, as well as the influence of mycorrhizal mutualism-parasitism continuum on rainforest diversity is poorly known compared to the wealth of botanical and ecological studies in these ecosystems (Alexander and Lee, 2005; Bechem and Alexander, 2012). The Takamanda rainforest is popularly known for being the home to the endangered cross river gorilla, besides this, it also harbors a diverse variety of plant species whose mycorrhiza status is still to be determined in this habitat. The determination of the mycorrhiza status of plants in this habitat will help in the elaboration of management strategies for the forest. This study was therefore undertaken to examine the mycorrhizal status of some indigenous tree species of the Takamanda rainforest Cameroon.

MATERIALS AND METHODS

Study area and tree selection

The Takamanda rainforest is situated on the Southern corner of the South West Region of Cameroon between 05º59' to 06º21'N and 09º11 to 09º30'E (Figure 1). This study was carried out in the undisturbed and disturbed sites of the Takamanda rainforest. The undisturbed site is located within the Takamanda National Park, thus access is restricted. The disturbed site is located outside the park and is very accessible to members of the community. The distance separating the two sites is about 3.5 km. The landscape of the area is undulating (ridge top, hilly slope and plain) in both undisturbed and disturbed forests sites (Figure 2). The undulating nature of the forest sites resulted to a variety of habitat types (plain, ridge top and hilly slope).

For the mycorrhizal screening, 48 tree species of economic and cultural importance were selected. The tree species listed in Table 1, comprise of 25 commercialized timber species (T) and 23 tree species that provide non-timber forest products (N). Some of the tree species such as *Pterocarpus* soyauxii, Annikia chlorantha and Cylicodiscus gabunensis offered multiple uses to the communities (Zapfack et al., 2001; Ndah et al., 2013). Out of the 48 tree species selected, 14 species occurred in both undisturbed and disturbed forest sites, 9 species solely in disturbed site and 25 species only in the undisturbed forest. In the undisturbed forest, the roots of 25 tree species were sampled in the plain, 22 were sampled in the ridge top and 29 in the hilly slope, while in the disturbed site, 9 species were sampled in the plain, 15 species in ridge top and 12 in hilly slope.

The 48 selected mature tree species for mycorrhizal evaluation were identified in the field, tagged and root samples were collected in the undisturbed and disturbed forest sites of the Takamanda rainforest. At least three individuals per species per site were sampled in order to ascertain the consistency of mycorrhizal type. In the sample collection process, soil at the base of each tree was dug-up using a hand fork and roots were followed from the base of the tree to the feeder roots to ensure accuracy of identification. Roots were collected from the four cardinal directions around each tree. Root samples were collected between June to July 2015 in both undisturbed and disturbed forest sites. Approximately 15 to 20 g (fresh weight) of fine root material was collected for each species in sites where they existed; soil was washed-off carefully

*Corresponding author. E-mail: tamenekeso@yahoo.co.uk.

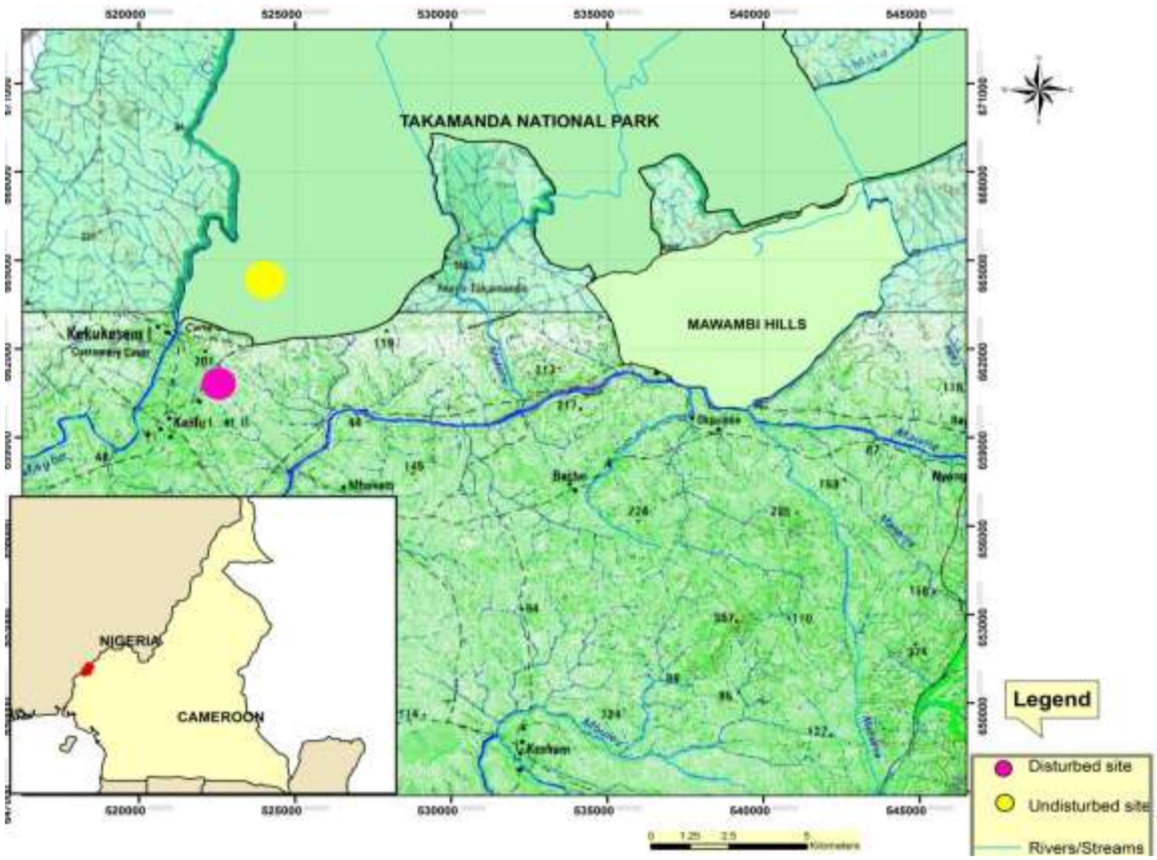

Figure 1. Map of Akwaya showing the study sites (CIFOR landscape map).

with fresh water and the samples were stored in labeled vials containing 50% alcohol (Brundrett et al., 1996) for onward transportation to the life sciences laboratory at the University of Buea. Whilst in the laboratory, samples were stored in the refrigerator at 4°C and were processed within 72 h from collection.

Processing and examination of root samples for mycorrhizal structures

For detailed microscopic examination, representative root samples were washed carefully with tap water to remove alcohol; soil particles and adhering organic matter were removed with the aid of a fine brush, forceps and under a dissecting microscope. A sub-sample of the roots was then cleared and stained using the procedure described by Brundrett et al., (1996). Root samples were cleared by immersing them in 10% KOH for 2 days. They were then rinsed several times in tap water to remove the clearing solution (Brundrett et al., 1996; Onguene and Kuyper 2001; Hawley and Dames, 2004). They were stained in a 0.05% trypan blue in lactoglycerol for 2 to 3 days. Stained roots were rinsed in tap water and cut with a razor blade into approximately 2 cm long pieces. For each species, five slides were prepared, such that 25 root fragments of up to 50 cm were placed on a glass slide and gently squashed under a cover slip to observe the presence and type of mycorrhiza structures under a compound microscope (Olympus BX 41). Arbuscular mycorrhiza was characterized by the presence of intracellular hyphae, hyphal and arbusculate coils and arbuscules, while ectomycorrhiza were recorded by the presence of intercellular hyphae, mantle and Hartig net (Brundrett, 2008; Onguene, 2000). In the categorization of the type of mycorrhiza that occurred in a plant, a plant species was scored as EM when ectomycorrhiza structures only were observed in sampled individuals, it was AM when arbuscular mycorrhiza structures only were observed, it was AM_EM when both ecto- and arbuscular mycorrhiza structures were observed in the roots of plants of the same species. Photographs of mycorrhizal structures observed were captured with an Olympus DP 20 camera attached to the microscope.

Data analysis

Information gathered here on the occurrence of mycorrhiza types on the different species was compared to data from other forest habitats in order to draw conclusions on mycorrhiza habits of each of the species studied. The effect of habitat types and sites on mycorrhizal colonization of tree species was also evaluated using a two way analysis of variance.

RESULTS

Mycorrhizal status of tree species in the disturbed and undisturbed rainforest

All 48 tree species in both undisturbed and disturbed forests formed mycorrhizas (Tables 2 and 3). Out of the 48 tree species in the two sites, tree species formed

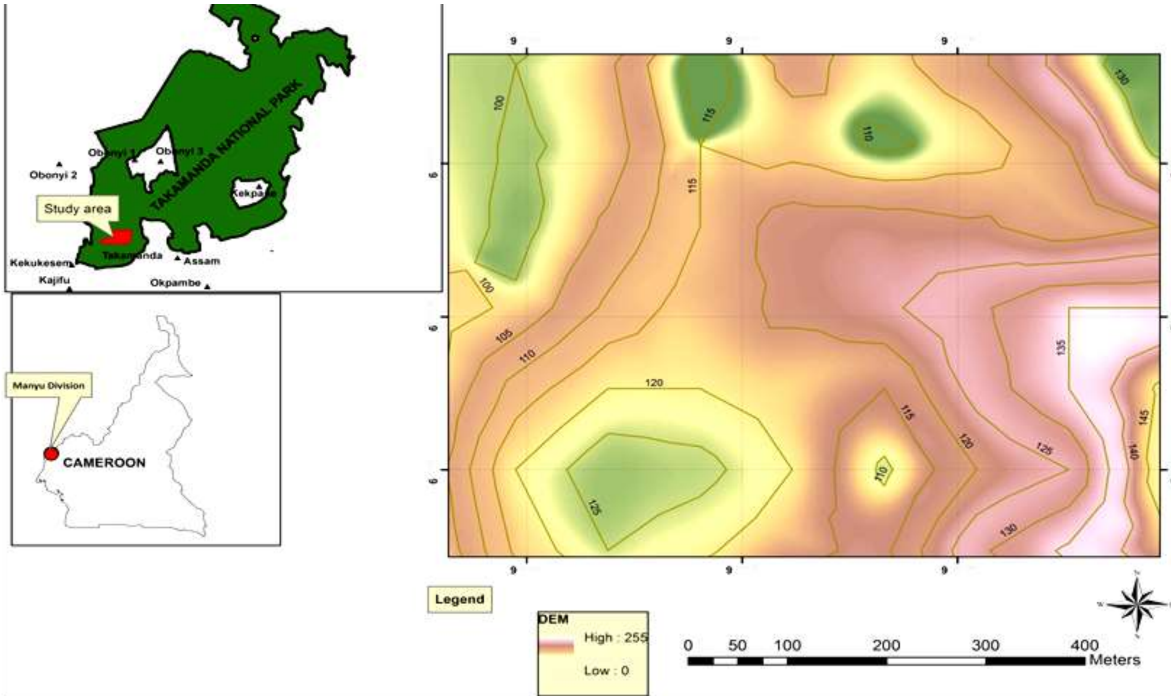

Figure 2. Study site, showing the undulating nature of the terrain (CIFOR landscape map).

arbuscular mycorrhiza (81.25%), only two species (*Uapaca guineensis* and *Angylocalyx oligophyllus*) formed ectomycorrhiza (4.16%) (Tables 2, 3) and seven of them (*Afzelia bipindensis*, *Baphia nitida*, *Anglylocalyx pynaertii*, *Ceiba pentandra*, *Cylicodiscus gabunensis*, *Pterocarpus soyauxii* and *Terminalia ivorensis*) formed both ecto- and arbuscular mycorrhizas (14.58%) in roots of the same individuals or on different individuals of the same species. This was characterized by the presence of intracellular hyphae, intercellular hyphae; arbuscules and Hartig net (Tables 2 and 3; Figure 3a to d).

In both forest sites and in all habitat types, AM was the most prevalent mycorrhiza formed by the tree species in this study. At the undisturbed site, AM was recorded in 17 (68%) species in plain, 18 (81.8%) on ridge top and 24 (82.8%) on hilly slope while in the disturbed site AM was observed in 9 (100%) species in the plain, 11 (73.3%) on ridge top and 10 (83.3%) species in hilly slope (Tables 2 and 3). This was closely followed by EM at undisturbed site with 3 (12%) species in plain, 3 (13.6%) species in ridge top and 4 (13.8%) species on hilly slope. In the disturbed site EM was observed in 2 (13.3%) of species on ridge top and in 1 (8.3%) in the hilly slope (Table 3). Generally, dual mycorrhizal (AM_EM) colonization was lowest in both sites and habitats. At the undisturbed site AM_EM was seen in 4 (16%) species in the plain, 1 (4.6%) species in the ridge top and in 1 (3.5%) species on hilly slope (Table 2). Dual mycorrhiza colonization was observed in 1 (8.3%) species sampled in the hilly slope in the disturbed forest. From the results of the two way ANOVA, there was no significant (P>0.05) difference in mycorrhiza occurrence for the species in both forest sites and in the different habitat types. In the undisturbed forest, all plants sampled in the different habitat types formed mycorrhizas except in the plain, where 1 out of the 25 plant species was non-mycorrhizal, giving a 96% mycorrhiza occurrence. Similarly, in the disturbed site, all plants sampled in the different habitats harbored mycorrhizal structures, resulting to a 100% mycorrhiza occurrence, except in the ridge top where 2 out of the 15 plants sampled were non-mycorrhizal with 86.7% occurrence.

Some inconsistencies in mycorrhiza types were observed for some tree species at both sites and in the different habitat types (Table 4). *Afzelia bipindensis* formed dual mycorrhizas and harbored both AM and EM structures on roots of the same plant as well as from different plants collected from plain and hilly slopes. *Angylocalyx pynaertii* and *Pterocarpus soyauxii* also formed dual mycorrhizal associations with individual root samples collected from the plain (low land) showing both AM and EM structures (Table 4). Five of the seven species with dual mycorrhiza associations were Fabaceae (Table 4). Figures 3a to d shows some of the mycorrhizal structures observed on sampled plants. This included intracellular hyphae, arbuscules and intercellular hyphae.

DISCUSSION

All tree species studied were mycorrhizal. We observed

Table 1. Tree species selected for evaluation of mycorrhizal status in the Takamanda rainforest.

Family	Species	Category
Anacardiaceae	*Lannea welwitschii* (Hiern) Engl.	T
	Pseudospondias microcarpa (A. Rich.) Engl.	T
Annonaceae	*Annickia chlorantha* (Oliv.) Setten & Maas.	N
	Anonidium mannii (Oliv.)	N
Apocynaceae	*Funtumia elastica* (Preuss) Stapf	T
	Rauvolfia vomitoria Afzel	N
Bombacaceae	*Ceiba pentandra* (L.) Gaertn.	T
Burseraceae	*Dacryodes edulis* (G. Don) H. J. Lam	N
Cecropiaceae	*Musanga cecropioides* R. Br.	N
Clusiaceae	*Garcinia kola* Heckel	N
Combretaceae	*Terminalia ivorensis* A. Chev.	T
Dichapetalaceae	*Tapura africana* Engl.	T
Ebenaceae	*Diospyros preussii* Gürke	N
Euphorbiaceae	*Mallotus oppositifolius* (Geisel.) Müll.-Arg.	N
	Plagiostyles africana (Müll.Arg.) Prain	T
	Ricinodendron heudelottii (Baill.) Pierre	N
	Uapaca guineensis Müll.-Arg.	N
Fabaceae	*Afzelia bipindensis* Harms.	T
	Albizia zygia (DC.) J.F. Macbr.	T
	Amphimas pterocarpoides Harms	T
	Angylocalyx oligophyllus (Baker) Baker f.	N
	Angylocalyx pynaertii De Wild.	N
	Anthonotha macrophylla P.Beauv.	N
	Baphia nitida Lodd.	N
	Cylicodiscus gabunensis Harms.	T
	Distemonanthus benthamianus Baill.	T
	Hylodendron gabunense Taub.	T
	Parkia bicolor A. Chev.	T
	Piptadeniastrum africanum (Hook.f.) Brenan	T
	Calpocalyx dinklagei Harms.	N
	Pterocarpus soyauxii Taub.	T
Flacourtiaceae	*Homalium logistylum* Alex.	T
Irvingiaceae	*Irvingia gabonensis* (Aubrey-Lecomte ex O. Rorke). Baill.	N
Meliaceae	*Lovoa trichilioides* Harms.	T
Moraceae	*Ficus exasperate* Vahl.	N
	Milicia excelsa (Welw.) C.C.Berg	T

Table 1. Contd.

Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb.	T
	Staudtia stipitata Warb.	T
Olacaceae	*Strombosia grandifolia* Hook. f.	N
Polygalaceae	*Carpolobia lutea* (G. Don)	N
Pandaceae	*Microdesmis puberula* Hook. f. ex Planch.	N
Passifloraceae	*Barteria fistulosa* Mast.	N
Rubiaceae	*Mitragyna ciliata* (Aubrev. & Pellegr)	T
Sapindaceae	*Blighia welwitschii* (Hiern) Radlk.	T
Sterculiaceae	*Cola millenii* K. Schum	N
	Eribroma oblogum Mast.	T
	Sterculia tragacantha Lindl.	T
Violaceae	*Rinorea dentata* (P Beauv.) Kuntze	N

T: Commercialized Timber species and N: Non timber forest products.

that majority of the tree species examined harbored AM fungal structures. The high AM status could probably be attributed to the production of large quantities of viable spores and large spore sizes containing substantial energy during adverse conditions, thus AM inoculum might rapidly build up in the system than EM. Our observations were similar to those of other surveys in Africa, which showed most or all of the woody species being mycorrhizal with a majority forming AM. Hawley and Dames (2004) assessed mycorrhizal status of 15 indigenous tree species in South Africa and all were AM. In a similar survey carried out in Tanzania, out of the forty-seven indigenous trees and shrubs species investigated, forty of them were reported to be AM and the remaining seven species EM (Hogberg, 1982). Onguene and Kuyper (2001) assessed the mycorrhizal status of 100 tree species in a rainforest of South Cameroon. All the species were mycorrhizal, with 26 species forming EM and the remaining species being AM. Newbery et al. (1988) in Korup National Park, Cameroon also reported that, out of the 56 species investigated, 55 turned out to be mycorrhizal with only one species, Wareneckea memecyloides, which is a Meslastomataceae being non-mycorrhizal. Bechem et al., (2014) also reported a similar finding in a lowland rainforest of Cameroon with a 92.06% of species studied being AM and 3.97% forming EM. The results in this study further confirm the fact that trees forming AM dominate tropical rainforests. Arbuscular mycorrhiza fungi thrive in P deficient soils in the tropics. They have the ability to access insoluble P, making it available to their host plant, in addition to other benefits (Smith and Read, 2008). AM fungi demonstrate little specificity with respect to host plant, thus AM plants dominate tropical forests.

Mycorrhizas structures were absent in some individuals of *Cylicodiscus gabunensis*, *Lovoa trichiliodes*, *Staudtia stiapitata*, *Albizia zygia*, *Barteria fistulosa* and *Ceiba pentandra* in some habitat types in this study. However, some of these species showed mycorrhizas association in other habitats. Birhance et al. (2010) mentioned that environmental characteristics can influence colonization therefore our observations may be due to the differences in characteristics of the different habitat types, since elevation changed from plain to hilly slopes to ridge tops. *Uapacca guineensis* was the only species which formed EM in both forest sites. This is in conformity with findings of Onguene and Kuyper (2001) and Bechem et al. (2014) who also observed EM structures on roots of these species. This could be attributed to species specificity to particular types of mycorrhiza. Other species of this genus *Uapaca* have been reported to show dual mycorrhizal status (Onguene and Kuyper, 2001). Seven tree species formed dual mycorrhizal associations; but four of the species *Afzelia bipindensis*, *Baphia nitida*, *Cylicodiscus gabunensis* and *Pterocarpus soyauxii* all belonging to the Fabaceae, harbored both AM and EM structures in the same root sample. This observation was similar to that of studies carried out in Central western Guyana (McGuire et al., 2008); South Cameroon (Onguene and Kuyper, 2001) Korup National Park

Table 2. Mycorrhizal status of tree species at different habitat types in the undisturbed Takamanda rainforest.

Family	Species	Plain				Ridge tops				Hilly slopes			
		AM	**EM**	**AM_EM**	**NM**	**AM**	**EM**	**AM_EM**	**NM**	**AM**	**EM**	**AM_EM**	**NM**
Anacardiaceae	*Lannea welwischii*	-	-	-	-	-	-	-	-	X	0	0	0
	Pseudospondias microcarpa	-	-	-	-	-	-	-	-	X	0	0	0
Annonaceae	*Annickia chlorantha*	X	0	0	0	-	-	-	-	X	0	0	0
	Anonidium mannii	-	-	-	-	-	-	-	-	X	0	0	0
Apocynaceae	*Funtumia elastica*	X	0	0	0	X	0	0	0	X	0	0	0
	Rauvolfia vomitoria	X	0	0	0	X	0	0	0	X	0	0	0
Bombacaceae	*Ceiba pentandra*	0	X	0	0	X	0	0	0	-	-	-	-
Cecropiaceae	*Musanga cecropioides*	X	0	0	0	-	-	-	-	X	0	0	0
Combretaceae	*Terminalia ivorensis*	X	0	0	0	X	X	0	0	0	X		0
Dichapetalaceae	*Tapura africana*	X	0	0	0	X	0	0	0	X	0	0	0
Ebenaceae	*Diosoyros preussi*	X	0	0	0	-	-	-	-	-	-	-	-
Euphorbiaceae	*Ricinodendron heudeloti*	-	-	-	-	X	0	0	0	X	0	0	0
	Uapaca guineensis	0	X	0	0	-	-	-	-	0	X	0	0
Fabaceae	*Afzelia bipindensis*	0	X	X	0	X	0	0	0	X	0	X	0
	Albizia zygia	-	-	-	-	-	-	-	-	0	X	0	0
	Amphimas pterocarpoides	-	-	-	-	X	0	0	0	-	-	-	-
	Angylocalyx oligophyllus	0	X	0	0	-	-	-	-	-	-	-	-
	Angylocalyx pynaertii	0	X	X	0	0	X	0	0	-	-	-	-
	Anthonotha macrophylla	-	-	-	-	0	X	0	0	-	-	-	-

AM: Arbuscular mycorrhiza, EM: Ectomycorrhiza, AM_EM: Both ecto and arbuscular mycorrhiza, NM: Non mycorrhiza, X: Presence of mycorrhizal type(s), and 0: Absence of mycorrhizal type - = not sampled in habitat.

(Bechem et al., 2014). *Terminalia ivorensis* was AM in plain and EM in ridge top; *Ceiba pentandra* was EM in plain and AM in ridge top. These inconsistencies could be attributed to environmental variability and availability of inocula in these micro habitat types. Mycorrhizal status was generally consistent for most tree species in the same habitats and forest sites. Similar consistent observations have been reported by Nandakwang et al. (2008); Evelin et al. (2009); Birhane et al. (2010). Tree root colonization consisted of intercellular and intracellular hyphae,

Table 2. Contd.

Family	Species	Plain				Ridge tops				Hilly slopes			
		AM	EM	AM-EM	NM	AM	EM	AM-EM	NM	AM	EM	AM-EM	NM
Fabaceae	*Calpocalyx dinklagei*	-	-	-	-	0	X	0	0	0	X	0	0
	Cylicodiscus gabunensis	X	0	X	X	-	-	-	-	-	-	-	-
	Distemonanthus benthamianus	X	0	0	0	X	0	0	0	X	0	0	0
	Hylodendron gabunense	X	0	0	0	X	0	0	0	X	0	0	0
	Parkia bicolor	-	-	-	-	-	-	-	-	X	0	0	0
	Piptademastrum africana	X	0	0	0	-	-	-	-	X	0	0	0
	Pterocarpus soyauxii	X	X	X	0	X	0	0	0	X	0	0	0
Flacourtiaceae	*Homalium logistylum*	-	-	-	-	-	-	-	-	X	0	0	0
Icacinaceae	*Lasianthera africana*	-	-	-	-	-	-	-	-	X	0	0	0
Irvingiaceae	*Irvingia gabonensis*	X	0	0	0	-	-	-	-	-	-	-	-
Meliaceae	*Lovoa trichliodes*	0	0	0	X	-	-	-	-	X	0	0	0
Myristicaceae	*Pycnanthus angolensis*	X	0	0	0	X	0	0	0	X	0	0	0
	Staudtia stipitata	-	-	-	-	X	0	0	X	-	-	-	-
Olacaceae	*Strombosia grandifolia*	X	0	0	0	-	-	-	-	-	-	-	-
Pandaceae	*Microdesmis puberula*	X	0	0	0	X	0	0	0	X	0	0	0
Polygalaceae	*Carpolobia lutea*	-	-	-	-	X	0	0	0	X	0	0	0
Rubiaceae	*Mitragyna ciliata*	-	-	-	-	-	-	-	-	X	0	0	0
Sapindaceae	*Blighia welwitschii*	-	-	-	-	X	0	0	0	X	0	0	0
Sterculiaceae	*Eribroma oblogum*	X	0	0	0	X	0	0	0	X	0	0	0
	Sterculia tragacantha	X	0	0	0	X	0	0	0	X	0	0	0
Violaceae	*Rinorea dentata*	X	0	0	0	X	0	0	0	-	-	-	-

AM: Arbuscular mycorrhiza, EM: Ectomycorrhiza, AM_EM: Both ecto and arbuscular mycorrhiza, NM: Non mycorrhiza, X: presence of mycorrhizal type (s) and 0: Absence of mycorrhizal type - =not sampled in habitat.

Table 3. Mycorrhizal status of tree species at different habitats in the disturbed Takamanda rainforest.

Family	Species	Plain				Ridge tops				Hilly slopes			
		AM	EM	AM_EM	NM	AM	EM	AM_EM	NM	AM	EM	AM_EM	NM
Anacardiaceae	*Lannea welwischii*	-	-	-	-	X	0	0	0	-	-	-	-
Bombacaceae	*Cieba pentandra*	-	-	-	-	X	0	0	0	X	0	0	0
Burseraceae	*Dacryodes edulis*	X	0	0	0	-	-	-	-	-	-	-	-
Cecropiaceae	*Musanga cecropioides*	-	-	-	-	X	0	0	0	X	0	0	0
Clusiaceae	*Garcinia Kola*	X	0	0	0	-	-	-	-	-	-	-	-
Combretaceae	*Terminalia ivorensis*	-	-	-	-	-	-	-	-	0	X	0	0
	Mallotus oppositifolius	-	-	-	-	X	0	0	0	-	-	-	-
Euphorbiaceae	*Ricinodendron heudeloti*	X	0	0	0	X	0	0	0	X	0	0	0
	Uapaca guineensis	-	-	-	-	0	X	0	0	0	X	0	0
	Albizia zygia	X	0	0	X	X	0	0	0	X	0	0	0
	Amphimas pterocarpoides	-	-	-	-	0	0	0	X	-	-	-	-
Fabaceae	*Baphia nitida*	X	0	0	0	X	0	0	0	X	0	X	0
	Distemonanthus benthamianus	-	-	-	-	X	0	0	0	X	0	0	0
	Pterocarpus soyauxii	X	0	0	0	0	X	0	0	-	-	-	-
Irvingiaceae	*Irvingia gabonensis*	X	0	0	0	-	-	-	-	X	0	0	0
Moraceae	*Ficus exaspirata*	-	-	-	-	-	-	-	-	X	0	0	0
	Milicia excelsa	X	0	0	0	-	-	-	-	X	0	0	0
Myristicaceae	*Pycnanthus angolensis*	X	0	0	0	X	0	0	0	-	-	-	-
Sterculiaceae	*Cola millenii*	-	-	-	-	-	-	-	-	X	0	0	0
	Eribroma Oblogum	-	-	-	-	X	0	0	0	-	-	-	-
Pandaceae	*Microdesmis puberula*	-	-	-	-	X	0	0	0	-	-	-	-

AM: Arbuscular mycorrhiza, EM: Ectomycorrhiza, AM_EM: both ecto and arbuscular mycorrhiza, NM: Non mycorrhiza, X: presence of mycorrhizal type (s), and 0: Absence of mycorrhizal type - =not sampled in habitat.

Table 4. Inconsistency in mycorrhizal types in the different habitats of the Takamanda Rainforest.

Family	Species	Plain	Ridge tops	Hilly slopes
Bombacaceae	*Cieba pentandra*	EM	AM	-
Combretaceae	*Terminalia ivorensis*	AM	AM, EM	EM
	Afzelia bipindensis	EM, AM_EM	AM	AM, AM_EM
	Angylocalyx pynaertii	EM, AM_EM	EM	-
Fabaceae	*Baphia nitida*	AM	AM	AM_EM
	Cylicodiscus gabunensis	AM	AM_EM	-
	Pterocarpus soyauxii	AM, EM, AM_EM	AM	AM

AM_EM: AM and EM Structures on roots of same individual; AM, EM: Structures on roots of different individuals of same species; - tree species not sampled in the habitat hilly slope.

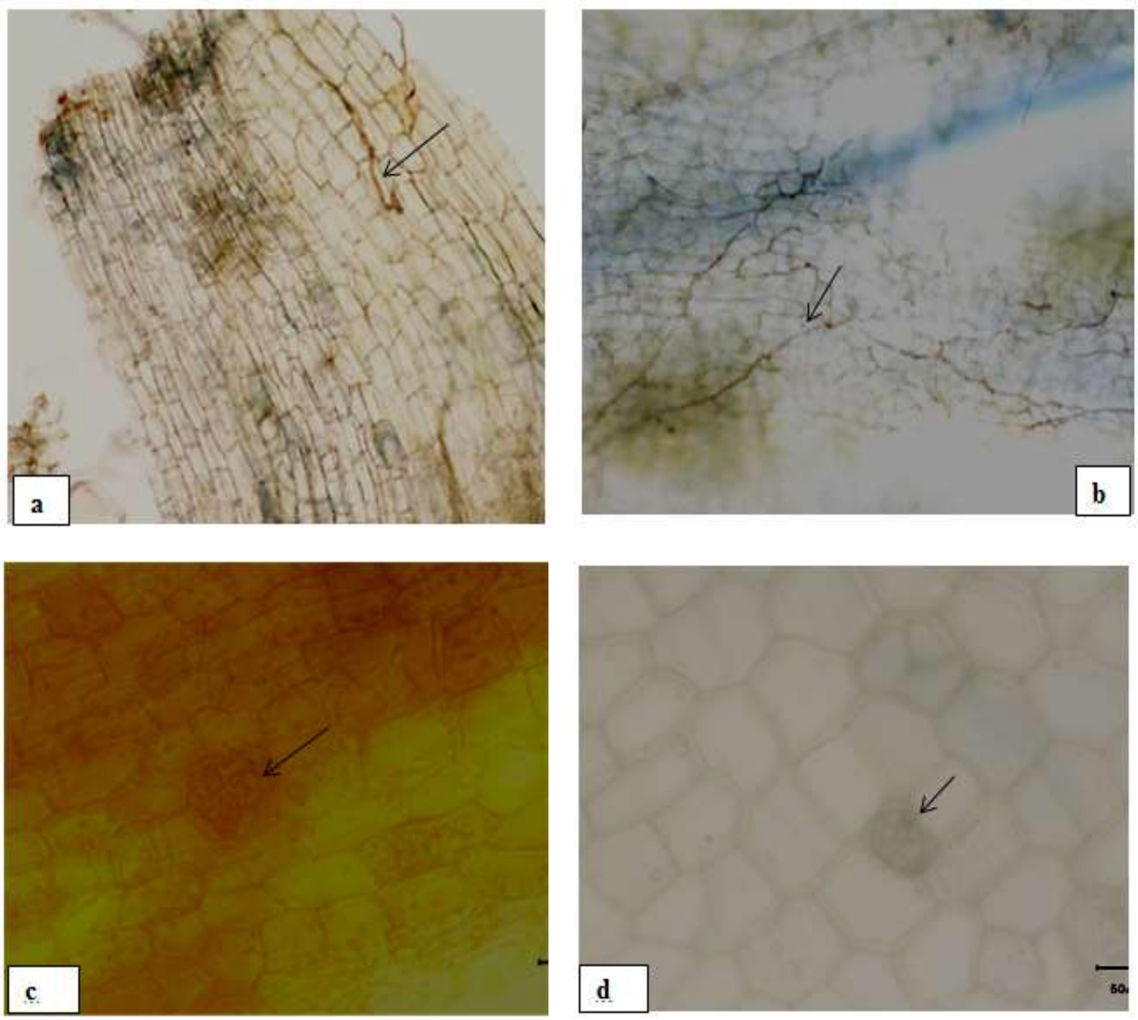

Figure 3. Sections of roots showing intercellular hyphae (i and ii), arbuscules (iii) and endophytes (iv).

arbuscules, and Hartig net. The dominance of intracellular and intercellular hypha structures in the different habitats and forest types indicated the presence of favourable environmental conditions which promoted the growth of the mycelia (Brundrett et al., 1996; Hawley and Dames, 2004; Becerra et al., 2007; Nandakwang et al., 2008). Birhane et al. (2010); Becerra et al. (2007); Brundrett (2009) an d Moyersoen et al. (1998) mentioned that environmental conditions may influence the colonization and development of mycorrhizal structures. Studies have shown that anthropogenic activities resulting to the removal and replacement of species has an effect on the fungal diversity of the soil (Paillet et al., 2010). Management measures for the different forest sites must therefore be designed such that below ground diversity is protected. In the study reported here more of the plant species sampled occurred in the undisturbed site. It would be interesting to know whether this above ground diversity in the undisturbed site is proportional to the below ground diversity.

Conclusions

This study provides the first account of mycorrhizal status of tree species in the Takamanda rainforest. AM was the most prevalent mycorrhizal type in the Takamanda rainforest. Dual colonization of tree species in this rainforest was reported with species belonging to the Fabaceae and Combretaceae. Mycorrhizal colonization did not show great differences across habitat types and the forest sites of the Takamanda rainforest. Proper management of the forest ecosystem will improve mycorrhizal colonization, thus enhance nutrient uptake, circulation, resistance to diseases and would encourage the growth of tree species. Management strategies for the Takamanda National Park must be designed in such a way as to promote mycorrhiza formation and guarantee the continuous existence of the inoculum.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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