

Full Length Research Paper

Environmental behavior and biogeography of endemic types of the class Piper L. in Africa: An instance of the Guineo-Congolean area

*Ephraim Yang, E. V sadou and Mafany Inoni

Department of Plant Biology, Faculty of Science, University of Douala, Douala, Cameroon.

Accepted 01 March, 2015

The aim of this study was to establish the ecology and the distribution patterns of the endemics *Piper* L. in the Guineo-Congolean region including the Lower Guinea, the Higher Guinea, the Congo Basin and the Mosaic of Lake Victoria. The distribution stretches from Senegal to Tanzania. *Piper capensis* and *Piper guineense* are both represented in Lower Guinea and Congo Basin; these phytochoria are eco-regions of endemism in Africa. *P. guineense*, hemi-epiphyte liana, appears mostly in fragmented vegetations. Its distribution is extended up to 1,500 m. *P. capensis* is mostly abundant between 1,000 to 2,500 m where homogeneous populations are often made in the gaps. Members of *P. capensis* are dwarves at the level of the understory and rarely attain 1 m in height; however, those from gaps are often between 2 to 3 m. The variation in the height of individuals is closely related to light; a phytosociological study has shown an abundance of herbs within the population of *P. capensis*. The dwarfism of the individuals in the understory is assigned to an adaptation character of the species. This dwarfism is a consequence of its plagiotropic branches that is beneficial for photosynthesis. The “late turning green” of leaves save the individuals of the understory from leaf predators; in the gap where the sunlight boosts the process of photosynthesis, certain individuals establish “opportunistic” symbiosis with ants. The flowering is related to the humid periods of the year. Fruits are mostly abundant during the dry season.

Key words: Adaptation, distribution, Guineo-Congolean region, *Piper*, symbiosis.

INTRODUCTION

The vegetation of the high mountain of Centre Africa is almost exclusively composed of important and characteristic endemic groups. It was chosen to represent the insular Afro-mountain floristic region (White, 1979; Fischer, 1993). This region is composed of seven mountainous systems (White, 1983). Botanical exploration of this flora is not really effective due to its biological diversity and its area, in spite of many researchers' efforts (Berrie, 1989). *Piper* L. (*Piperaceae*) is a very

important group with nearly 2,000 species (Quijano-Abril et al., 2006), constituting an important element of mountain and lowland forests. Most species of *Piper* appear to be restricted to altitudes ranging from 0 to 2,500 m, and few occur above 3,000 m. *Piper* reaches its highest diversity in the lowlands of the Neotropical region (Gentry, 1990). *Piper* belongs to the most species-rich genera on earth and is distributed pantropically. Only New World and Asian species are currently within the focus of research (Jaramillo and Manos, 2001; Jaramillo and Callejas, 2004; Jaramillo 2004; Quijano-Abril et al., 2006). Africa is depauperate with an estimated 15 species, many of which are thought to be recent introductions such as *Piper umbellatum*, or

*Corresponding author. E-mail: Ephraim.yang2014@yahoo.com

escapes from cultivation such as *Piper betle*. Patterns of distribution of *Piper* species vary from being locally endemic to widespread. There are several species restricted to a specific centre of diversity while others occur throughout the Neotropics or the Paleotropics. Two species of *Piper* are known to be endemic to Africa, *Piper guineense* and *Piper capensis* (Jaramillo and Manos, 2001). *P. capensis* is mostly common in the understory of African mountain forests between 1,000 to 2,500 m where physiognomically homogeneous populations are often being made (Mangambu et al., 2010). The genus *Piper* has only been poorly studied in Africa. The most recent study dates back to the 1940s and was entirely based on morphology (Balle, 1942). The distribution patterns and ecology of *Piper* have not been studied in Africa due to the fact that African *Piper* has never drawn great botanical attraction and members of the genus are under collected.

The proposed study will take a more global comprehensive approach which will reveal new insights into the distribution of the endemic taxa especially with regard to African phytochoria of the Guineo-Congolese Region. For this purpose, we performed an inventory of *Piper* using herbarium data, phenological recordings, field data, geographical coordinates and ecological data.

MATERIALS AND METHODS

Ecology, flowering and fruiting

Flowering, fruiting and ecological data were obtained through informations provided by the labels of herbaria specimens from Burundi, Togo, DR Congo, Gabon, Cameroon, Central African Republic and Guinea Conakry. Data from the Paris herbarium (P) were used.

Some data were also obtained during botanical expeditions carried out in Cameroon over a period of three years (2008 to 2010). For each individual of both species, samples of flowers and/or fruits were counted taking into account the month and the year of the collection. Several environmental factors including site characterization, surrounding vegetation and climate have been taken into account during the botanical explorations. Examination of herbarium specimens has also permitted to preselect areas of crops that can contain fragments of natural vegetation according to the information available on the herbarium labels (maps, description of landscape areas, national parks). The use of digital photography has allowed a more intensive and effective preparation of each trip.

Biogeography

The first goal of the trips was to verify the localities provided by the herbarium sheets. However, the most important was the identification of new localities so as to have better knowledge of the actual distribution of each species. Distribution data of taxa were obtained from the herbarium sheets, we used data from the field investigations as well. A total of 525 samples have been taken into account; a database of these samples was done and it is available upon request. The collection and compilation of current data of distribution and species abundance, as each individual species have been crucial to the project. To perform field trips, GPS and maps were used.

Phytosociology

Study site

Phytosociological surveys were carried out on Mount Oku in Cameroon according to a recent study conducted in the Kahuzi-Biega National Park in Democratic Republic of Congo (Mangambu et al., 2010). Mount Oku (3,011 m) forms one of the highest parts of the Bamenda highlands (Figure 1). Mount Oku, characterised by its crater lake, is predominantly of tertiary basaltic and trachytic lava, overlying the mainly granitic Basement complex rocks. The soils are uniform; there are humid ferralitic soils derived from tertiary lava parent material. These soils have a high organic matter content, due in part to the altitude and climate. The general climate is broadly the same as that of the rest of West Africa (Martin et al., 2000). With a rainy season between May and September and a dry season between October and April. The mean maximum of temperature is between 20 to 22°C and the minimum between 13 to 14°C. Rainfall varies from 1780 to 2290 mm per year. The monthly average of humidity exceeds 80% in July and August (Martin et al., 2000).

Sampling

Five surfaces of equal dimensions (20 × 20 m²) were made at different altitudes. These plots were demarcated using strings and compass. Within each established quadrant, sampling was done in areas of 5 × 5 m² where basic inventory of herbs has been easier (Figure 2). This method helps minimize errors and improves the inventory. Measurements were made in a crude table. According to Blaun (1932), a plant community requires for its normal development, a minimum area and a minimum number of species. Biological and morphological types were identified on the field through the observation of vegetative parts respectively bud and positions of regeneration of different species. The types of phytogeographic distributions were identified from references following a recent study of Mangambu et al. (2010).

Data analysis

Data were processed using Excel software. Taxa were identified by comparison with those available in the herbarium of Cameroon (YA), Laboratory of Plant Systematic and Ecology of the University of Yaoundé I and the Millennium Ecological Museum (MEM) of Pr. Dr. Bernard-Aloys Nkongmeneck. To facilitate the identification, floras and monographs have been consulted. The species distribution maps were prepared using Arcview 3.3[®] software and its extensions. Points with ambiguous coordinates were excluded. The abundance expressed in this case the number of individuals of species recorded per grid cell of 2°; the distribution area is divided into grid cell of 2° in the extension "Grid Analyst" of the software Arcview 3.3[®]. The extension "Count Points in Polygon" was used to assess species abundance.

RESULTS

Ecology

Two species are known to be endemic in Africa; *P. capensis* and *P. guineense*. Table 1 shows the different ecosystems and habitats in which individuals may be present. *P. capensis* is a shrublet of understory. *P. guineense* is a hemi-epiphytic liana of trunks of trees.

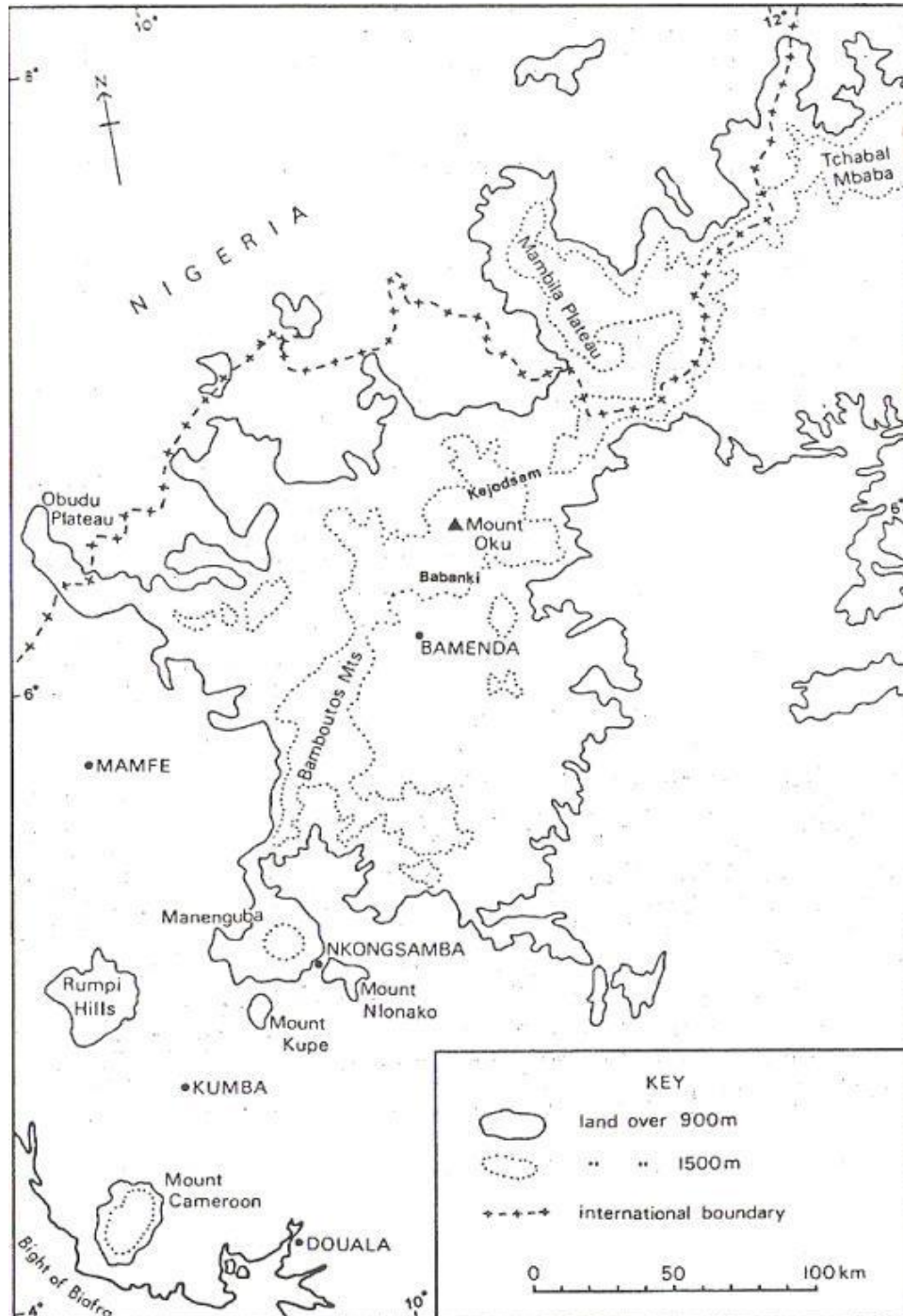


Figure 1. Geographical situation of the site (in Martin Cheek et al., 2000).

Many collections were done in the forests (Figure 3).

Individuals from gaps can attain 2 to 3 m of height in *P. capensis* while those from understory rarely exceed 1 m of height; the species is represented by dwarf individuals. At the level of gaps, *P. capensis* forms physiognomically homogeneous population. Individuals in the understory have more developed leaves compared to those individuals encountered in gaps. The branches of these

individuals are more spread to enable them to raise good amounts of light that appear in different spots in the understory.

In *P. guineense*, the main stem grips trunks of phorophytes using root spikes that bloom at the nodes. This robust stem is often as high as the phorophytes. At the same nodes, secondary branches appear laterally giving a plagiotropic part of the adult individual. Both species

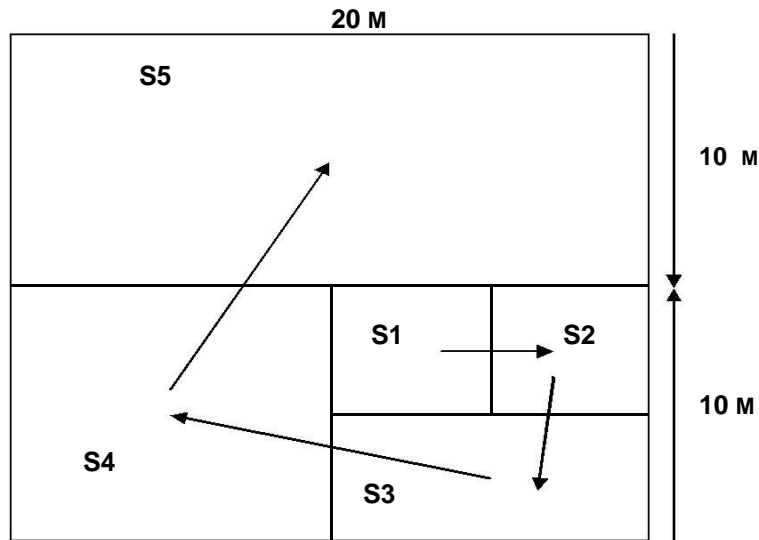


Figure 2. Quadrant of sampling (20 x 20 m²).
 S = surface, S1 = 5 x 5 m²; S2 = 10 x 5 m²; S3 = 10 x 10 m²; S4 = 20 x 10 m² and S5 = 20 x 20 m² → Progression.

Table 1. Summarize of the ecological data.

Taxa	Vegetations	Habitats	Morphology	Status
<i>P. capensis</i>	- Primary and secondary forests ; -Gallery; -Raphiales ; -Sub-mountain and mountain forests ; -Old secondary forests.	-Understory ; -Deep gully ; -Edges of road ; -Gradient of gully ; -Old cocoa ; -Gaps ; -Plantations ; -Fallow lands.	Shrublet	Terrestrial
<i>P. guineense</i>	-Primary and secondary forests ; -Gallery; -Raphiales ; -Sub-mountain and mountain forests ; -Old secondary forests.	-Understory ; -Deep gully ; -Edges of road ; -Gradient of gully ; -Old cocoa ; -Gaps ; -Plantations ; Fallow lands; -Base of huge; -forest trees; -Trunks of trees.	Liana	Hemi-epiphyte

are very abundant in the understory of tropical forests (Figure 4).

Flowering and fruiting

Herbaria specimens in flower and/or in fruit were

observed. The botanical expeditions have provided additional data. Figure 5 shows the patterns of flowering of both species; it is likely to find individuals of *P. capensis* in flower as well as in fruits all year in *P. capensis*. In contrast, in *P. guineense*, flowering and fruiting are not always observed year round (Figure 6). But, however there are large fruiting period equivalent to

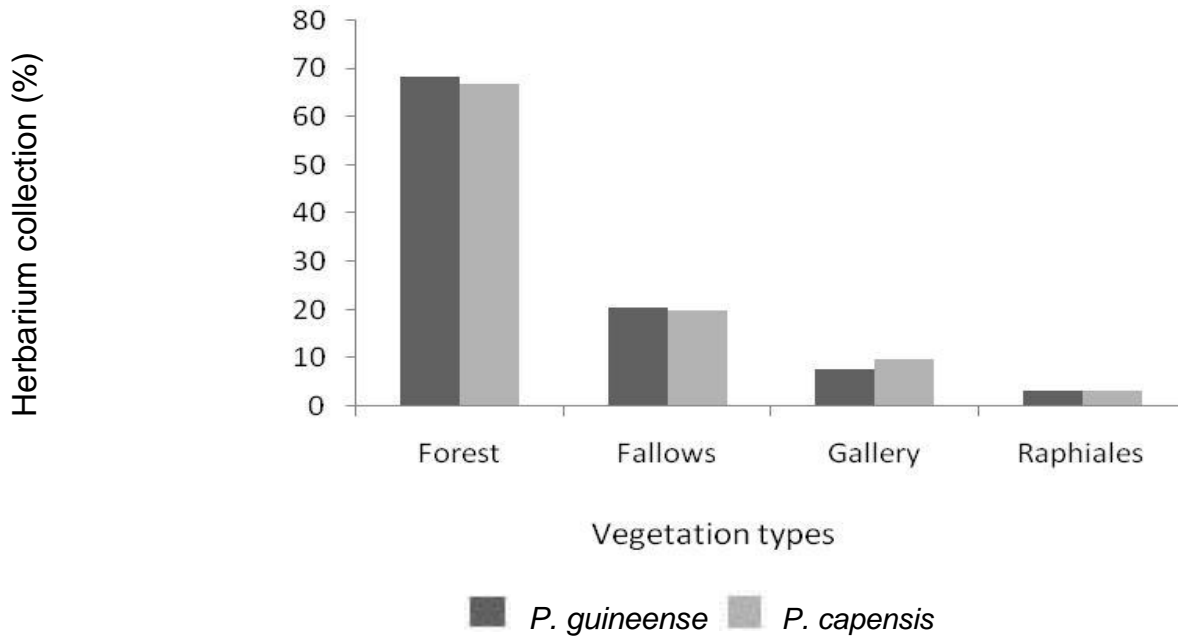


Figure 3. Proportion of the herbarium samples following the types of vegetation.

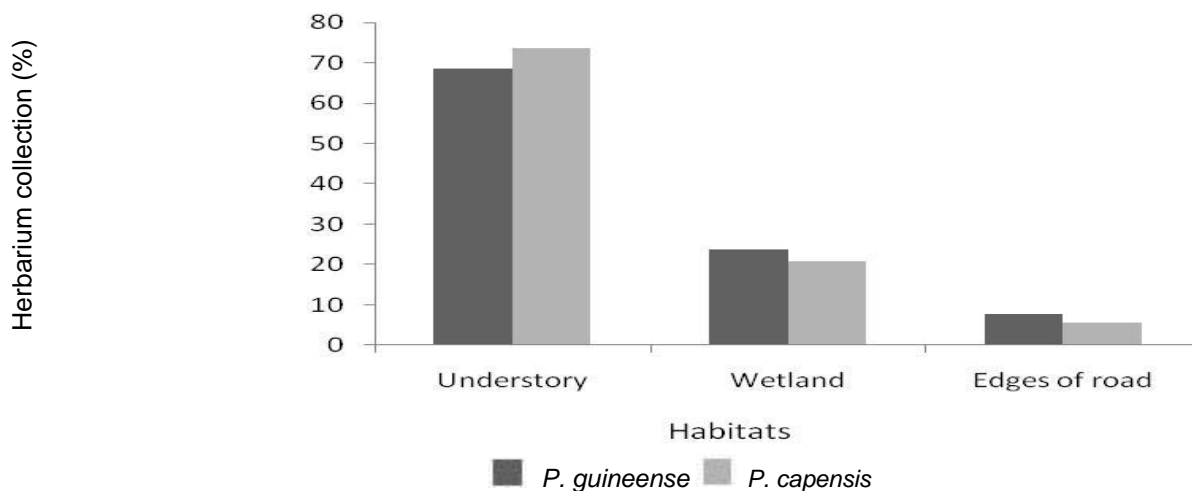


Figure 4. Proportion of the herbarium samples following the habitats.

both species, and this period is situated from November to March and also corresponds to the period of fruit abundance in the markets. In both species, the greatest flowering period occurs from August to October.

Phytogeography

Altitudinal distribution

Although *P. capensis* is present in several habitats, it spans great altitudes. It is very abundant in the

understory of sub-mountain and mountain forests between 1000 and 2500 m (Figure 7) especially in gaps where individuals most often form a physiognomically homogeneous stand.

The effect of altitude seems to influence distribution in *P. guineense*; the abundance decreases with altitude. During explorations in the forests of Cameroon, very few individuals of this species were observed above 1500 m. This level is similar to the pattern of distribution in *Piper umbellatum*. When *P. umbellatum* encountered at high altitudes, it is present only in clearings or cultivated

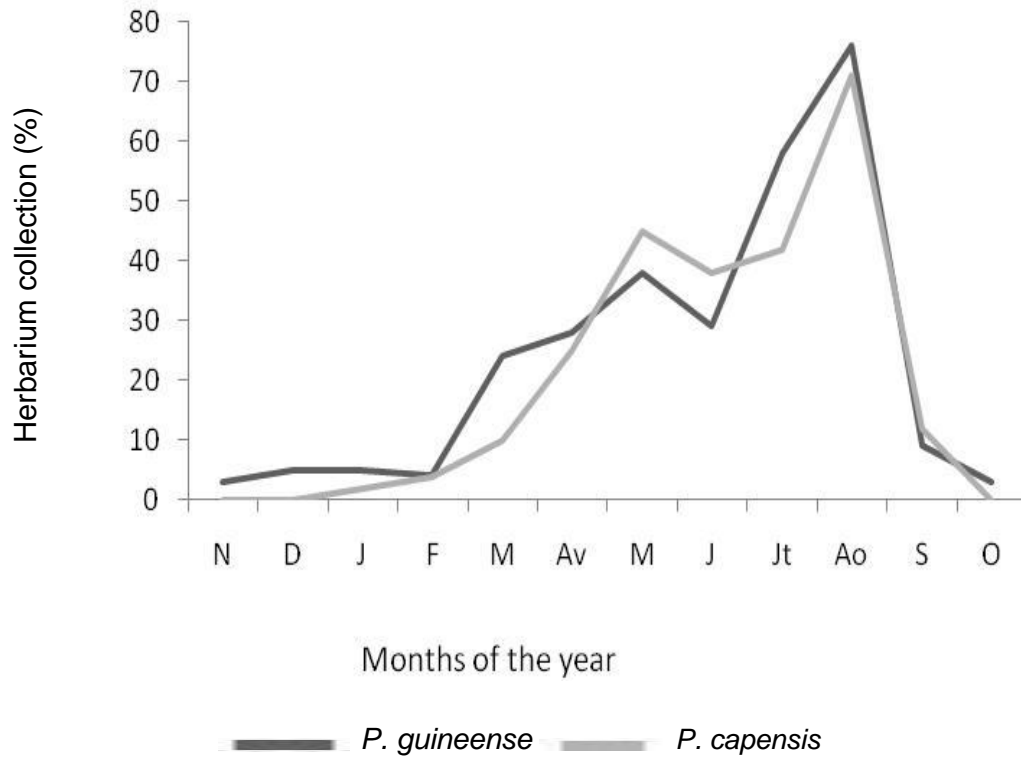


Figure 5. Patterns of flowering in both *Pipers*.

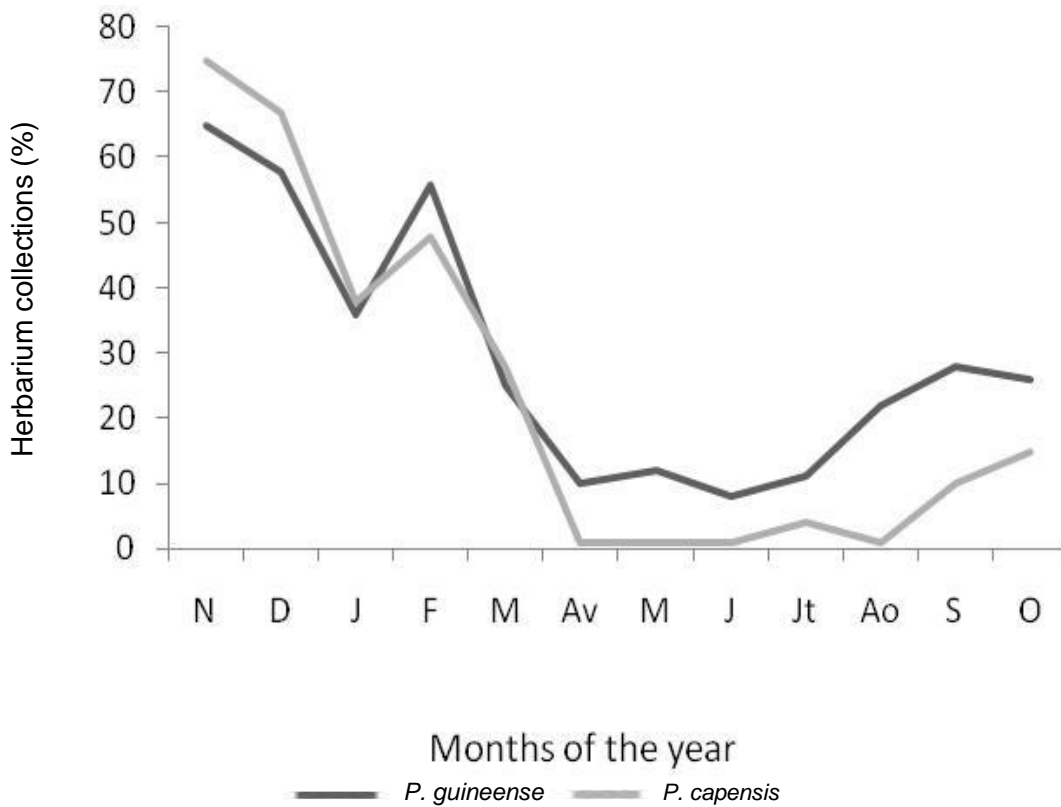


Figure 6. Patterns of fruiting in both *Pipers*.

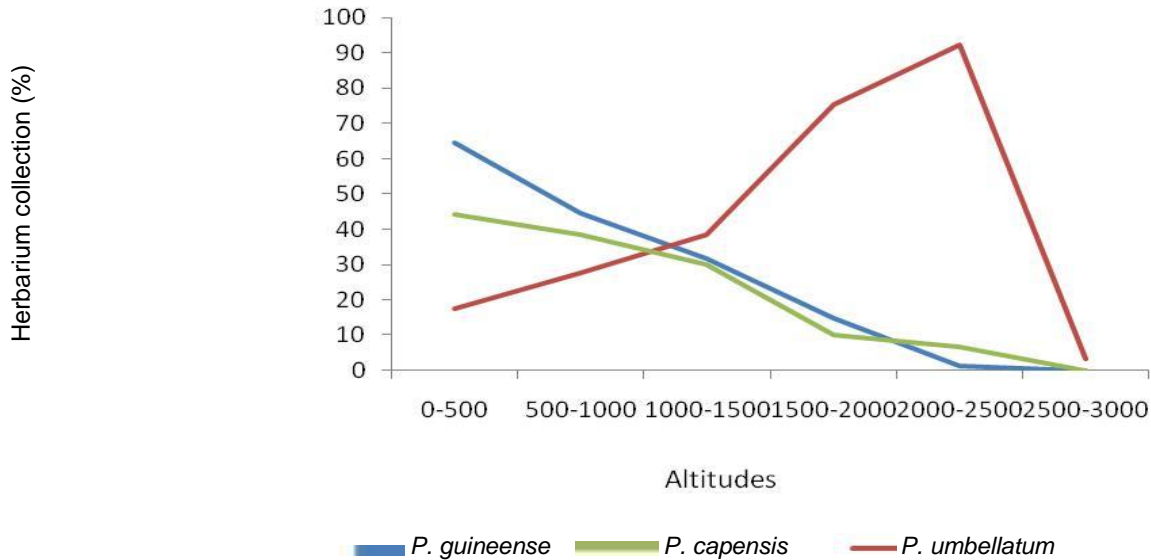


Figure 7. Altitudinal distribution.

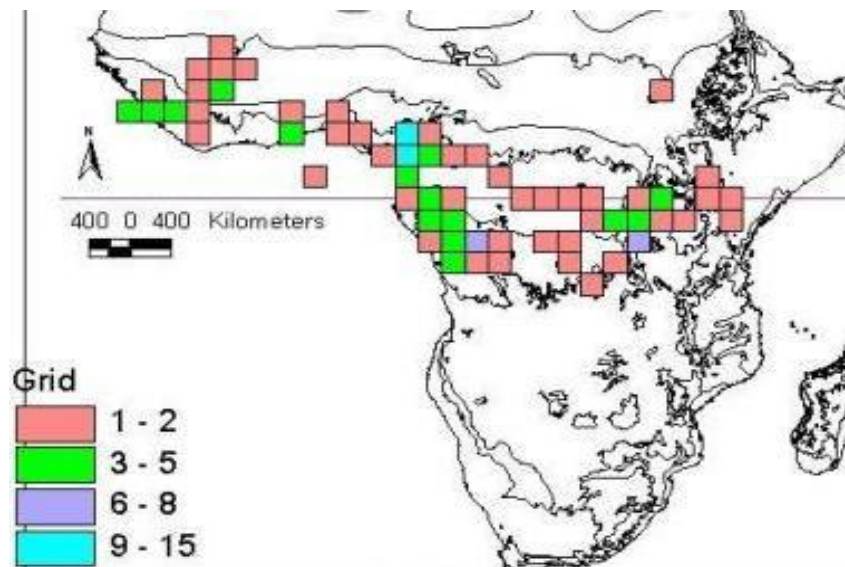


Figure 8a. Distribution in the Guineo-Congolese Region in *P. capensis*. The digits indicate the number of collections in a grid cell of 2°.

areas. In fact, *P. umbellatum* is a species of open and fallow lands. It emerges thoroughly between 0-1000 m in the fields and fallows only. In contrast, *P. guineense*, which is one of the native species of African forests, normally emerges both in the undisturbed ecosystems and fallow lands. Compared to *P. umbellatum*, the species is very abundant in the understory of secondary forest.

Above 2500 m, the distribution curves straighten up, showing a considerable decrease of individuals of the studied species in very high altitudes. *P. capensis* is very

low encountered at 2500 m, beyond which it is almost impossible to find the species. Over 90% of individuals of *P. capensis* emerge between 1000 and 2500 m.

Phytochoria

Figures 8a and b shows phytochoria of the studied species in the Central African region. Species distribution extends from Senegal to Tanzania. Individuals are highly prevalent in the region of Lower Guinea, the Congo Basin

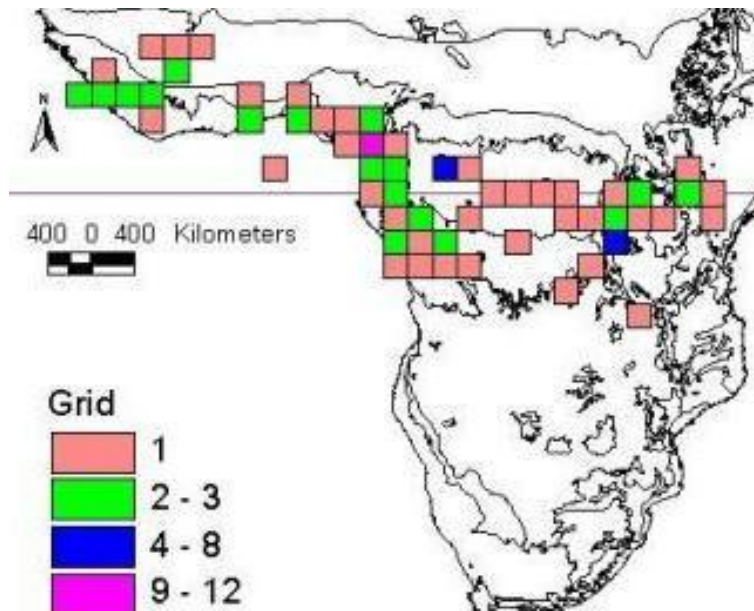


Figure 8b. Distribution in the Guineo-Congolese Region in *P. guineense*. The digits indicate the number of collections in a grid cell of 2°.

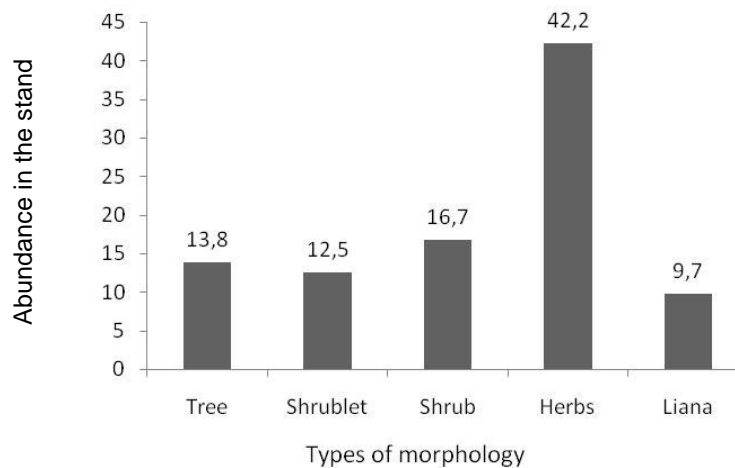


Figure 9. Types of morphology.

and in the Mosaic of Lake Victoria in Burundi. There is a transition on the one hand between Guineo-Congolese/Sudanian sub-regions and on the other hand between Guineo-Congolese/Zambezi sub-regions.

Phytosociological study of altitudinal group of *P. capensis*

Ecological diagrams

The surveys have been conducted in mountain forests between 2000 to 2500 m (Table 2). Five types of morphology were identified during the investigation

(Figure 9), trees (13.8%), shrublets (12.5%), shrubs (16.7%), lianas (9.7%) and herbs (42.2%). There is a dominance of grasses.

Eleven types of phytogeography were identified (Figure 10) with the three major types, namely: species of the mountains of tropical Africa (Mo (Aftrop)), species along the Cameroonian dorsal with the Sudanese and Guinean districts encompassing among other species of Mount Oku, Cameroon and mount Bamboutos, Obudu plateau, the massive Korup and Bioko, oceanic islands Sao Tome and Principe (Mo (OC)) and species of tropical Africa (Aftrop) with respectively 28.4; 22.4 and 21% of species. Species of afro-mountain are predominant with about 56.7%.

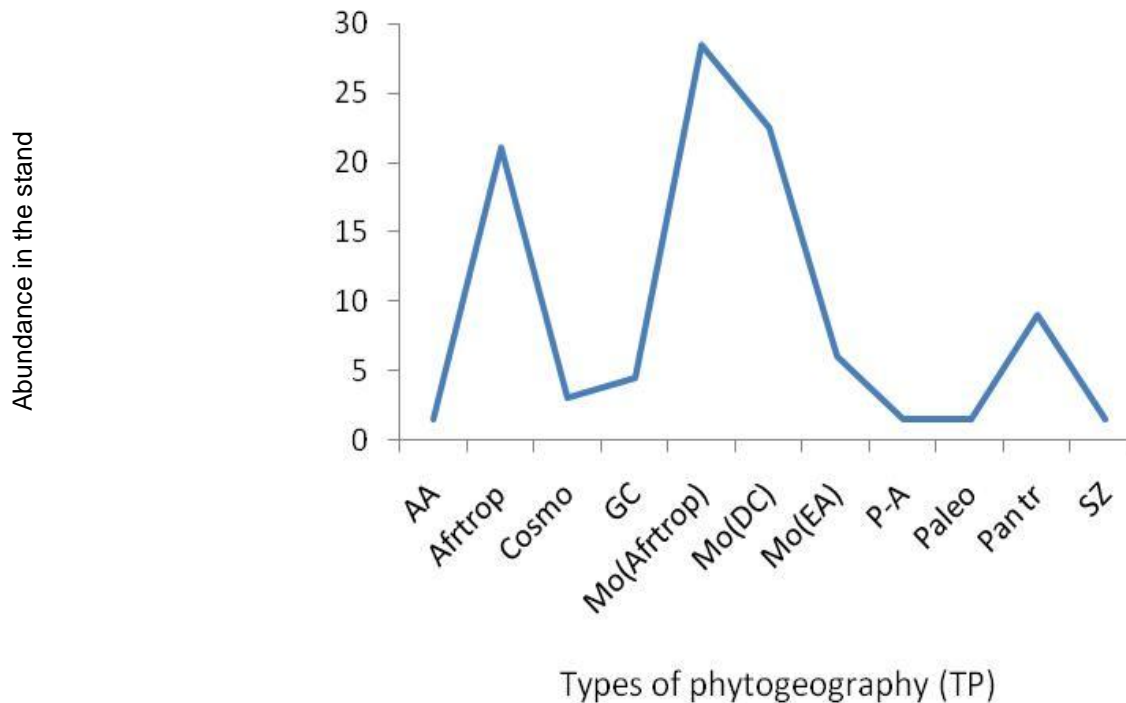


Figure 10. Types of phytogeography.

Table 2. Characterisation of the different surveys.

Surveys	1	2	3	4	5	MR
Surface of the survey (m ²)	400	400	400	400	400	
Altitude (m)	2,192	2,408	2,229	2,297	2,483	
Maximum high (m)	20	15	22	20	15	
Number of species	24	30	26	40	22	
Gradient	11.08	13.5	9.75	25.25	35.8	
Recovery (%)	55.8	62.7	56.4	41.4	38.9	68.4

Recoveries and density of seedlings of species recorded in the stand

The physiognomy of the survey area is similar to the ecosystems in reconstitution. Table 3 shows the presence of ruderal and weedy species representing a mean recovery (MR) of 13.01; that is, 177.97 m² of total area (2,000 m²), species of regrowth and secondary forests (MR = 5.24) and species of primary dense forests (MR = 10.2).

The group is dominated by grasslands. However, other layers are not negligible and more or less represented. We can find:

(a) A tree layer of 7 to 18 m represented by *Prunus africana*, *Allophyllus bullatus*, *Carapa grandifolia*, *Schefflera abyssinica*, *Syzygium staudtii*, *bersama abyssinica melanophloeos* *Rapana*, *Pittosporum viridiflorum*, *Psydrax dunlapii*.

(b) Stratum of shrub up to 5 to 10 m composed of shrubs and bushes including *Ardisia kiwuensis*, *Xymalos monoconidial*, *Maesa lanceolata*, *Rubus pinnatus*, *Pavonia hookeriana*, *Rytigynia neglecta*.

(c) Herb layer where the height varies between 0.1 and 4 m, the following species predominate: *Cyperus rotundus*, *Achyra aspera*, *Hypoestes triflora*, *kamerunensis Impatiens*, *Lobelia columnaris*, *Drymaria cordata*, *Desmodium repandum*, *Laportea spp.* *Rhynchoscarpum Thalictum subsp. abyssinica*, *Rumex spp.*

(d) An important lianescent synusia composed on the one hand of: *Momordica cissoides*, *Tylophora cf. oblonga*, *Momordica foetida* *Raphidiocystis phyllocalyx*, *Stephania abyssinica var. abyssinica*, *Embelia schimperi*, *Gouania longispicata* and on the other hand an epiphytic synusia composed of *Peperomia spp.* and others.

In the settlement, many seedlings of species were identified over an area of 2000 m² r representing the total

Table 3. Data summarize of the phytosociology study.

Main species	BT	PT	R1	R2	R3	R4	R5	Pr	MR
<i>Piper capensis</i> L.f.	NanoPh	Afrtrop	3	3	3	3	3	V	36
1. Class of Ruderali - Manihotetea (Léonard in Taton 1949) ex Hoff 1991									1.81
Shrubs									
<i>Pavonia urens</i> Cav.	NanoPh	Afrtrop				0		I	0.01
<i>Rubus pinnatus</i> Willd.	NanPh	Mo(Afrtrop)	1	0		1	0	IV	0.75
Herbs									
<i>Sida acuta</i> Burm.f.subsp. <i>carpinifolia</i> (L.f.)Borss. Waalk	NanoPh	GC				0		I	0.07
<i>Sida rhombifolia</i> L.	Ch d	Pan tr			0			I	0.01
<i>Phyllanthus</i> sp.	NanoPh	Ind.				1		I	0.02
<i>Cyperus rotundus</i> L.	Gr	Cosmo	0	0		0		III	0.34
<i>Thalictrum rhyngocarpum</i> Quart.-Dill. & A.Rich.subsp. <i>abyssinica</i>	Ch d	Afrtrop	1	0		0	0	IV	0.61
2. Class of Soncho - Bidentetea Hoff and Brisse 1983									10.9
Shrublets									
<i>Achyrosperrum africanum</i> Hook.f. Baker	MégaPh	Mo(DC)				0		I	0.07
<i>Acanthopale decempedalis</i> C.B. Clarke	Ch	Mo(DC)	1					I	0.2
<i>Momordica cissoides</i> Benth.	Ph g	Pan tr	1	0	0	0	0	V	1
Lianes									
<i>Momordica foetida</i> Schum. & Thonn.	Ph g	Pan tr			0			I	0.01
<i>Raphidiocystis phyllocalyx</i> C. Jeffrey & Keraudren	Ph g	Afrtrop			1	0		II	0.29
<i>Stephania abyssinica</i> (Quart.-Dill. & A.Rich.) Walp. var. <i>abyssinica</i>	Ch g	Afrtrop		0				I	0.01
Herbs									
<i>Rumex abyssinicus</i> Jacq.	Gr	Mo(Afrtrop)		0	0			II	0.02
<i>Rumex nepalensis</i> Spreng.	Gr	Mo(DC)/EA		0				I	0.01
<i>Rumex</i> sp.	Gr	Ind.		0				II	0.08
<i>Pteridium aquilinum</i> (L.) Kuhn subsp. <i>aquilinum</i>	Gd	Afrtrop				2		I	2.31
<i>Drymaria cordata</i> (L.) Wild	Ch p	Pan tr		1	0			II	0.28
<i>Commelina cameroonensis</i> J.K. Morton	Ch p	Mo(DC)	2	1	1	0		IV	5.46
<i>Oxalis corniculata</i> L.	Ch d	Cosmo			0			I	0.01
<i>Achyranthes aspera</i> L.	Ch p	Pan tr				0	0	II	0.2
<i>Crassocephalum rubens</i> (Jacq.) S. Moore	Ch d	Afrtrop			0			I	0.01
<i>Desmodium repandum</i> (Vahl.)DC	Ch g	Paléo			0	0		II	0.14

Table 3. Contd.

	Link of <i>Lobelia giberroae</i> Lebrun and Gilbert 1954					
	Shrublets					
<i>Plectranthus insignis</i> Hook.f.	NanoPh	Mo(Afrtrop)	1	0	II	0.55
<i>Plectranthus sylvestris</i> Gürke	NanoPh	Mo(Afrtrop)	0	0	II	0.08
	herbs					
<i>Lobelia columnaris</i> Hook.f.	Ch d	Afrtrop	0		I	0.14
	3. Class of <i>Musango - Terminalietea</i> Lebrun and Gilbert 1994					
	herbe					
<i>Pilea rivularis</i> Wedd.	Th	Mo(Afrtrop)		0	I	0.02
	trees					
<i>Allophylus bullatus</i> Radlk.	MégaPh	Mo(DC)	0	0	0	III 0.15
	lianas					
<i>Gouania longispicata</i> Engl.	Ph g	Mo(Afrtrop)	1	1	II	0.65
	shrubs					
<i>Maesa lanceolata</i> Forssk.	MicroPh	Mo(DC)		0	1	II 0.27
<i>Xymalos monospora</i> (Harv.) Baill.ex Warb.	MicroPh	Mo(Afrtrop)	0	0	0	0
<i>Vernonia holstii</i> O.Hoffm.	Ch d	Afrtrop	0	1	0	III 0.35
	shrublets					
<i>Psychotria peduncularis</i> (Salisb.) Steyerm.	NanPh	GC	1	0	1	1
	herbs					
<i>Laportea alatipes</i> Hook.f.	Th	Mo(Afrtrop)		0		I 0.01
<i>Laportea ovalifolia</i> (Schum.) Chew	Th	Afrtrop	1	0	0	III 1.41
	Link of <i>Lobelia giberroae</i> Lebrun and Gilbert 1954					
	herbs					
<i>Helichrysum cameroonense</i> Hutch. & Dalziel	NanPh	Mo(DC)		0		I 0.07
	4. Class of <i>Mitragynetea</i> Schmitz 1963					
	trees					
<i>Syzygium staudtii</i> (Engl.) Mildbr.	MégaPh	Mo(DC)	0	0	0	III 0.02
	arbuste					

Table 3. Contd.

<i>Boehmeria macrophylla</i> Hornem.	NanPh	Afrtrop		0	I	0.14
<i>Rapanea melanophoeos</i> (L.) Mez	MicroPh	Mo(Afrtrop)	0		0 II	0.08
<i>Coniogramme africana</i> Hieron	Gr	Mo(Afrtrop)		0	I	0.07
<i>Impatiens kamerunensis</i> Warb.	Th	Mo(DC)	0	1 1 1	IV	0.7
5. Class of Strombosio- Parinarietea Lebrun and Gilbert 1954						10.2
trees						
<i>Cussonia djalonensis</i> A. Chev.	MégaPh	Mo(Afrtrop)	0		0 0 III	0.21
<i>Carapa grandiflora</i> Sprague	MégaPh	Mo(Afrtrop)	1	1 1	0 1 V	1.16
<i>Nuxia congesta</i> R.BR.ex Fresen	MégaPh	Afrtrop	1	0	0 0 IV	0.35
<i>Prunus africana</i> (Hook.f.) Kalkman	MégaPh	Mo(Afrtrop)	0		1 II	0.21
<i>Schefflera abyssinica</i> (Hochst.ex.A. Rich) Harms	MégaPh	Mo(Afrtrop)			0 I	0.14
shrubs						
<i>Mimulopsis solmsii</i> Schweinf.	MicroPh	Mo(DC)		0	1 0 III	1
<i>Ardisia kivuensis</i> Taton	MégaPh	GC	1	1 1 1	1 2 V	5.28
lianas						
<i>Embelia schimperi</i> Vatke	Ph g	Mo(Afrtrop)			1 0 II	0.35
Order of Ficalho-Podocarpetalia Lubrun and Gilbert 1954						
trees						
<i>Bersama abyssinica</i> Fresen.	MégaPh	Afrtrop	0	0	II	0.14
shrubs						
<i>Pavetta hookeriana</i> Hiern var <i>Hookeriana</i>	MicroPh	Mo(DC)	0		I	0.14
<i>Pavetta</i> sp.	MicroPh	Ind.		0	I	0.07
<i>Rytigynia neglecta</i> (Hiern) Robyns	MicroPh	SZ	1		0 II	0.34
<i>Dracaena fragrans</i> (L.)Ker-Gawl	NanPh	Mo(Afrtrop)	1	0 1	III	0.51
herbs						
<i>Hypoestes</i> sp.	Th	Ind.		0	I	0.07
<i>Hypoestes triflora</i> (Vahl) Roem. & Schult	Th	Mo(Afrtrop)	1		I	0.2
6. Class of Hyarrhernietea Schmitz 1963						0.7
sous arbuste						
<i>Solanum</i> sp.	MicroPh	Ind.		0 0 0	III	0.21
lianas						
<i>Tylophora</i> cf. <i>oblonga</i> N.E.Br	Ph g	Mo(DC)		0	I	0.07

	herbs					
<i>Isodon ramosissimus</i> (Hook.f.) Codd	Ch d	Mo(Afrtrop)	0	I	0.07	
<i>Setaria megaphylla</i> (Steud.) T. Durand & Schinz	Th	AA	0	I	0.07	
<i>Adenostemma mauritianum</i> DC	Ch d	Afrtrop	0	I	0.14	
<i>Lactuca glandulifera</i> Hook.f.	G d	Mo(Afrtrop)	0	I	0.14	
	7. Class of <i>Lycopodieta cernuui</i> Schmitz 1971					0.07
<i>Solanecio mannii</i> (Hook.f.) C. Jeffrey	MicroPh	P-A	0	I	0.07	
	herbs					0.14
<i>Peperomia molleri</i> C.DC.	Epi	Mo(DC)	0	I	0.01	
<i>Asplenium mannii</i>	G d	Mo(EA)	0 0	II	0,12	
<i>Tapinanthus letouzeyi</i> (Balle) Polhill & Wiern	Epi	Mo(DC)	0	I	0.01	
	8. Others					2.24
	trees					
<i>Psydrax dunlapii</i> (Hutch. & Dalziel) Bridson	MicroPh	Mo(DC)	1	I	1.06	
	shrubs					
<i>Pittosporum viriflorum</i> Sims " <i>mannii</i> "	MicroPh	Mo(DC)	0 0	0 III	0.21	
<i>Arundinaria alpina</i> K. Schum.	Th	Mo(DC)/EA		1 I	0.27	
<i>Discopodium penninervium</i> Hochst.	MicroPh	Mo(DC)/EA	1	I	0.2	
	herbs					
<i>Oplismenus hirtellus</i> (L.) P. Beauv.	Th	Pan tr	1	1 II	0.5	

area of sampling. 210 seedlings of 8 species were recorded in all surveys for an average of 42 seedlings per stand and a density of 1050 seedlings per hectare.

Among the species whose seedlings have been recognized, there were: *Carapa grandifolia*, *Pittosporum viridiflorum*, *Rapana melanophloeos*, *Prunus africana*, *Schefflera abyssinica*, *Syzygium staudtii*, *bersama abyssinica* *Pavonia hookeriana*. In *Carapa grandifolia* for example, 32 seedlings were identified to be on average of 6.4 seedlings per stand and a density of 160/ha. Seedling size

is variable and ranges from 20 to 200 cm depending on the stage of development.

DISCUSSION

Adaptation and biotic interactions

In *P. capensis*, with the exception of individuals from gaps which sometimes have the appearance of a single-stemmed trunk with records up to 2 to 3 m in height, individuals from understory are

dwarves and rarely reach 1 m in height. Such individuals have plagiotropic branches extended laterally. This architectural model has been simulated for that of Petit (Jaramillo and Callejas, 2004). Dwarfism and the architectural model in *P. capensis* are forms of adaptation of individuals in their environment, in fact in the understory; the lateral plagiotropic branches can capture the small amount of light that appears on spots. This adaptation also occurs in many species of understory of tropical forests and is very common in *Rubiaceae* species which are abundant in

understory of the equatorial forests like *Oxyanthus* spp. and *Bertiera* spp. (Sonké, 1999; Nguembou, 2008). This mode of adaptation to the function of architectural model of *P. capensis* is not the only character to adapt to the photosynthetic activity of individuals in response to insufficiency of light in understory.

In addition, individuals react to their environment through morphology of the leaves varies depending on whether the individual emerges in the presence or absence of light. In understory, the leaf acumen is highly developed. Indeed, the development of the leaf acumen allows rapid evacuation of water from the leaf surface, which will prevent installation of epiphyllous and fungi. Morphology of leaf is also a character to adapt to the chlorophyll activity in this species; in fact, the installation of epiphyllous prevents light absorption and causes a brake on the photosynthetic activity. Chlorophyll by emission of plagiotropic branches is very common in the shrublets of understory. For some herbs, like *Costus* spp., the spiral disposition of leaves allows them to produce more nutrients. The plagiotropy is not very noticeable in *P. capensis* at the level of gaps. The Biotic interactions are mainly with ants. This association is common among individuals of such an open environment in *P. capensis*. The presence of light accelerates photosynthetic activity and thus promotes the "cost" of predators, if the case may be. This interaction, unlike that seen in the genus *Peperomia* (Noumi et al., 2011), which has an advantage one way (a sort of commensalism), is rather a mutualism; in fact, plants that host ants produce extra floral sugar glands that are a source of nutrition for the ants and these, in turn, eat the eggs from predators of leaves on the leaf surface (Longino, 1986; Davidson et al., 1990; Kaufmann et al., 1999; Koptur, 1992; Davidson and McKey, 1993; Gullan, 1997; Davidson, 1997; McKey et al., 1999), which limits the "cost" of predators of leaves. In most cases, such plants develop "true symbiosis" with ants by establishing structures for the accommodation of their protector (McKey et al., 1999). The genus *Piper* has no such structure, this is just a protective mutualism called "opportunistic mutualism" as described by McKey et al. (1999) with a remarkable advantage for individuals that develops it. This biotic interaction is very common in *P. capensis* in opening canopy. In understory where individuals are covered by emerging trees, the struggle against predators of leaves is due to the development of the phenomenon of "late turning green" of leaves, but this ensures leaf longevity and hence that of the species. The "late turning green" of the leaves is a consequence of the inadequate presence of light, photosynthetic activity is slow and progressive, which also slows the growth of individuals, hence the observed dwarfism. Predators often attack the mature leaves that have already pushed enough nutrients. At the level of gaps, where individuals are exposed to light, some leaves are fragmented by leaf predator; the presence of ants in this case ensures the

longevity of leaves.

Flowering and fruiting

Fluctuations in the curves correspond to the different seasons of the year (Gwanfogbe et al., 1992). In a young forest of Cameroon, the period of flowering of mass was observed in the dry season (Bindzi et al., 2005). These results are not concordant, the individuals of the studied species bloom mostly during the rainy season and fruiting during the dry season.

The two peaks of flowering observed in both species correspond to early and long rainy season respectively. Most works have demonstrated the indirect effect of rainfall (Opler et al., 1976) or temperature (Ashton, 1989) on flower induction and anthesis (Augspurger, 1982; Borchert, 1983; Rathcke and Lacey, 1985). Other studies in tropical flowering bind to the existence of a dry and wet spell (Endress, 1998; Sabatier, 1985). The fruiting season in the genus *Piper* coincides with periods of drought in Africa. In Cameroon, the fruits of *P. guineense* for example, abound in the market from November to February and the results obtained corroborate these observations. The fact that the flowering periods are superimposed in both species, it is plausible to think of a similarity between the pollinator of both species.

Phytogeographic data

The genus *Piper* L. is pantropically distributed (Jaramillo and Manos, 2001). Species of tropical America, Asia and South Pacific were commonly the subject of many studies (Jaramillo and Manos, 2001; Jaramillo and Callejas, 2004; Jaramillo, 2004; Quijano-Abril et al., 2006). Only the distribution of the genus *Piper* has been made particularly in tropical America and the Pacific Islands (Jaramillo and Manos, 2001). This study proposes a model of distribution of endemic species in Central Africa. The most important studies of African phytogeography date back from White (1979, 1983). The African continent has been subdivided into units (phytochoria), subdivision based on chorological criteria. The studied species abound in Guineo-Congolean Region of White (1979) and particularly in the equatorial forests of Africa. Guineo-Congolean Region includes three areas: the area of Lower Guinea, the area of Upper Guinea and the Congo Basin. Fifteen species of the genus *Piper* is estimated in Africa.

The species distribution map shows that the two taxa are extended from Senegal to Tanzania. These results are consistent with previous studies undertaken in the African tropical forests (Sonké, 1999; Nguembou, 2008). There is an abundance of individuals in the Congo Basin and Lower Guinea, and these two sub-regions represent areas of endemism of White, on a sampling of a thousand species in Guineo-Congolean Region, White

identified 288 endemic species in the two sub-regions. The sub-region of Lake Victoria is also well represented. Superimposing the map of species distribution with the African phytogeographic map the studied genus emerges mostly in forests.

Phytosociology

Conditions of the stand existence and its importance

The dominance of herbaceous (42.2%) confirms the state of disturbance in the area surveyed. Species frequency of *Ruderalis Manihotetea* and *Soncho-Bidentetea* classes, on the one hand and *Musango Terminalietera* (species of recruits and secondary forests) and *Strombosio-Parinarieta* classes (dense primary forest species) on the other hand, shows that the flora is ecologically diverse. The presence of species of the class of *Ruderalis Manihotetea* and *Soncho Bidentetea* shows that *P. capensis* is highly abundant in opening canopy, *P. capensis* is a species highly heliophilic whose dwarfism observed in the understory is a form of adaptation of species to the chlorophyll function. To this dwarfism, Jaramillo and Callejas (2004) combined the architecture of the species similar to the model of Petit; plagiotropic branches allow individuals to capture the small amount of light reaching in some places in the understory. This aspect shows a state of vegetation recovery. The population of *P. capensis* in certain circumstances may contribute to the regeneration of existing plant communities, there is a nesting species characteristic of the studied forest (*Cussonia djalensis*, *Carapa grandiflora*, *Nuxia congesta*, *Prunus africana*, *Schefflera abyssinica*, *Mimulopsis solmsii*, *Ardisia kivuensis*, *Embelia schimperi*, *bersama abyssinica* *Pavetta hookeriana*, *Rytigynia neglecta*) with many plantlets from seeds of the studied species of flora including *Carapa grandifolia*, *Pittosporum viridiflorum*, *Rapana melanophloeos*, *Prunus africana*, *Schefflera abyssinica*, *Syzygium staudtii*, *bersama abyssinica*, *Pavonia hookeriana*. The density of seedlings of species recorded in the group is very important (1050 plants / ha).

Phytochoria

The results show a dominance of mountain species (56.7%) where those from tropical Africa are the most represented (26.38%). This emergence of the mountain species concerns in most endemic species of the Afro-mountain domain. These results corroborate those of Momo (2010). In some previous data, samplings carried out in the mountains of Cameroon have shown a dominance of Guineo-Congolese species (Tchiengué, 2004; Fomete and Tchanou, 1998). According to Thomas (2010), 56% of Mount Oku species are common to East

African Mountains, 32% in the mountains of West Africa and 18% endemic in the highlands of Cameroon. These results corroborate those of Momo (2010) and show that Mount Oku is situated in the centre of endemism Afro-mountain in the West African system, as classified by White (1979). Among the species investigated, the majority are classified as sub-mountain species, *Carapa grandiflora*, *Pilea tetraphylla*, *Gouania longispicata*, *Embelia schimperi*. Momo (2010) identified these species also on the mountain stage of Mount Oku.

Conclusion

In spite of the varying habitats of species, *P. capensis* and *P. guineense* are two species of mountain forests. Beyond 1500 m, *P. guineense* begins to be absent. In contrast, *P. capensis* emerges up to 2500 m. Between altitudes of 1000 to 2500 m, *P. capensis* often forms a population physiognomically homogeneous. The presence of species of the class of *Ruderalis - Manihotetea* which constitute the ruderal vegetation and species of the class of *Soncho - Bidentetea* vegetation weed of crops shows that the population settles in environments with sparse and sometimes sunny sustained anthropogenic activities. The overlapping of the two species with those of previous classes *Musango - Terminalietera* of recruits and fragmented mediums also justifies the disturbance of the forest at the level of the sampling. The class of *Strombosio - Parinarieta* represents dense rain forest species. The presence of this class shows that the areas surveyed are in constant dynamism, the identification of seedlings of dominant species and characteristics of the flora of Mount Oku where phytosociological surveys were carried out; let's predict the subsequent restoration of the existing plant communities.

ACKNOWLEDGEMENTS

We sincerely thank the National Herbarium of Cameroon (YA) for the library and herbarium specimens which have allowed the realization of the present work.

REFERENCES

- Ashton PS (1989). Dipterocarp reproductive biology. In : Ecosystems of the world, 14, tropical rain forest ecosystem, pp. 1-14
- Augspurger CK (1982). Reproductive synchrony of tropical shrub: experimental studies on effects of pollinators and seed predators on *Hybanthus parviflorus* (Violaceae). Ecol., 62: 775-788.
- Balle S (1942). Piperaceae. flora of RDC and Ruanda-Urundi. Spermatophytes, I: 15-27.

- Berrie A (1989). The ecology distribution of pteridophytes of Zambia Mt. Malawi. *Fern. Gaz.*, 13(5): 316.
- Blaun B (1932). *The life forms of plants and statistical plant geography*. Oxford Clarendon Press, p. 632.
- Borchert R (1983). Phenology and control of flowering in tropical trees. *Biotropica*, 15(2): 81-89.
- Davidson DW (1997). The role of resource balance in the evolutionary ecology of tropical arboreal ants. *Biol. J. Linn. Soc.*, 61: 153-181.
- Davidson DW, McKey D (1993). The evolutionary ecology of symbiotic ant-plant relationships. *J. Hymenoptera Res.*, 2: 13-83.
- Davidson DW, Sedeil JL, Epstein WW (1990). Neotropical ant gardens. II. Bioassays of seed compounds. *J. Chem. Ecol.*, 16: 2993-3013.
- Endress PK (1998). *Diversity and evolutionary biology of tropical flowers*. Cambridge Univ. Press, Cambridge, p. 511.
- Fischer E (1993). *The vegetation of the national park of Kahuzi-Biega (South Kivu, Zaire)*. Gehurt Stag, p. 93.
- Fomete NT, Tchanou Z (1998). *Management of forest ecosystems of Cameroon, Gabon and Equatorial Guinea*. Report of International Union for Conservation of Nature (IUCN), Yaounde, Cameroon, p. 50.
- Gentry A (1990). Floristic similarities and differences between southern Central America and upper Central Amazonia. Four Neotropical forest rain forests (ed. by A.H. Gentry), pp. 141-157.
- Gullan PJ (1997). Relationships with ants, in: Ben-Dov Y., Hodgson C.J.(eds.), *soft scale insects: their biology, natural enemies and control*, Elsevier Science B.V., pp. 351-373.
- Gwanfogbe M, Melingui A, Moungam J, Nguoghia J, Nofiele D (1992). *New geography for form 2*. Edicef, p. 192.
- Jaramillo MA (2004). Using *Piper* species diversity conservation priorities in the Choco Region of Colombia. *Biodivers. Conserv.* 15: 1695-1712.
- Jaramillo MA, Callejas R (2004). Current perspectives on the classification and phylogenetics of the genus *Piper* L. In: Dyer, L.A. & Palmer, A.N. (eds.) (2004). *Piper. A model genus for studies of evolution, chemical ecology, and trophic interactions*. Kluwer Academic Publishers, Boston, p. 500.
- Jaramillo MA, Manos PS (2001). Phylogeny and patterns of floral diversity of the genus *Piper* (Piperaceae). *Am. J. Bot.*, 88(4): 706-716.
- Kaufmann S, McKey DB, Hossaert-McKey M, Horvitz CC (1999). Adaptations for a two-phase seed dispersal system involving vertebrates and ants in a hemi epiphytic fig (*Ficus microcarpa*: Moraceae). *Am. J. Bot.*, 78: 971-977.
- Koptur S (1992). Extrafloral nectary-mediated interactions between insects and plants, in: Bernays E. (ed.), *insect-plant interactions*, CRC Press, Boca Raton, pp. 81-129.
- Longino JT (1986). Ants provide substrate for epiphytes. *Selbiana*, 9: 100-103.
- Mangambu MJD, Noiha NV, Zapfack L, Sonké B (2010). Phytosociological study of a population of *Piper capensis* in mountain forest (RD Congo). *Int. J. Environ. Stud.*, 67(3): 417-430.
- Martin C, Onana JM, Pollard BJ (2000). *The plants of Mount Oku and the Ijim Ridge, Cameroon, A conservation checklist*. Royal Botanic Gardens, Kew, p 211.
- Mbarga BMA, Lacoste A, Amougou A, Biye EH (2005). Floral phenology in a young secondary forest of Cameroon *Acta Bot. Gallica*, 152(1): 25-43.
- McKey DL, Gaume F, Dalecky A (1999). Symbiosis between plants and ants. *Année Biol.*, 38: 169-194.
- Momo SMC (2010). *Influence of human activities upon the vegetation of mount Oku (Cameroon)*. PhD thesis. Université de Picardie, France, p. 161.
- Nguembou KC (2008). *Phylogeny, distribution, ecology and taxonomical revision of the genus Bertiera (Rubiaceae) in Africa*. PhD thesis, Université Libre de Bruxelles, Lab. Bot. Syst. Phytosiol., p. 187.
- Noumi NV, Zapfack L, Kengne OC, Mangambu MJD, Ngueguim JR, Tchadji JC, Sonké B (2011). Eco-biogeography of the genus *Peperomia* in Africa : case of the Guineo-Congolean Region. *Int. J. Environ. Stud.*, 68(1): 43-60.
- Opler PA, Frankie GW, Baker HG (1976). Rain-fall as a factor in the release timing and synchronization of anthesis by tropical trees and shrubs. *J. Biogeogr.*, 3: 231-236.
- Quijano-Abril MA, Callejas-Posada R, Miranda-Esquivel DR (2006). Areas of endemism and distribution patterns for Neotropical *Piper* species (Piperaceae). *J. Biogeogr.*, 33: 1266-1278.
- Rathcke B, Lacey EB (1985). Phenological patterns of terrestrial plants. *Ann. Rev. Ecol. Syst.*, 16: 179-214.
- Sabatier D (1985). Seasonality and determinism of the peak fruiting in the forest of Guyana. *Revue d'Ecologie (Terre et Vie)*.
- Sonké B (1999). *Oxyanthus (Rubiaceae-Gardenieae-Gardeniinae) in central Africa: Systematic study*. National Botanical Garden of Belgium, p. 106.
- Tchiengué B (2004). *Ecological and floristic study of the vegetation of mount Koupe*. Doctorate thesis. University of Yaounde. p 1, 238.
- White F (1979). The Guineo-Congolean region and its relationship to other phytochoria. *Bulletin du Jardin Botanique National de Belgique*, 49: 11-55.
- White F (1983). *The vegetation of Africa. A descriptive memory to accompany unesco/aetfat/unso vegetation map of Africa*. Paris, pp. 1-356.