

Research Article

Altitudinal Distribution of Loranthaceae Parasites of Woody Plants on the Mandara Mountains in the Far North Region, Cameroon

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Abstract: Despite the importance of Loranthaceae parasites of woody plants in traditional Africa medicine, very few studies have been carried out on their diversity in the Sudano-Sahelian zone of Cameroon. The study aims to examine the diversity of Loranthaceae parasites of woody plants and determine their altitudinal distribution over the Mandara Mountains in the Far North region, Cameroon. It took place in nine (09) borough spread over four Departments of the Mandara Mountains. The experimental design is made up of 15 Hills (altitude ≥ 1000 m), representing the main treatment. The 15 Hills are chosen at the rate of one Mount every 10 km in the whole of the Mandara Mountains. The Mounts were grouped by three according to the level of altitude of the plain of each Mount to find five Mounts (Mount 1 (< 500 m = Mount 1 + Mount 2 + Mount 15) ; Mount 2 ([500 m - 600 m [= Mount 4 + Mount 5 + Mount 3) ; Mount 3 ([600 m - 700 m [= Mount 6 + Mount 7 + Mount 13); Mount 4 ([700 m - 800 m [= Mount 8 + Mount 9 + Mount 14) ; Mount 5 (> 800 m = Mount 10 + Mount 11 + Mount 12)). On each Hill, two flanks (East and West) were chosen and constituting the secondary treatment, and on each flank, 50 m x 20 m transects (repetitions) were installed by altitude level (tertiary treatment) starting with the plain, to the top of the Hill with a space of 50 m between two transects. All the parasitized trees or not, as well as the parasitic plants were inventoried. A total of 120 host species distributed in 34 families and 75 genera were inventoried. Combretaceae and Mimosaceae were the most represented with 13 species each, either 10.83% for each family. *Acacia* was the most diverse with 10 species, either 8.33% of the host species. 18 genera, either 24% of the flora, were reported to be monospecific in this zone. In all of the 120 listed host species, 68 species or 56.66% of the host species were parasitized by 1 or 2 parasitic species and represent the first class (I) which is the class of not very sensitive host species parasitism of Loranthaceae. The second class (II) of susceptible host species was made up of 8 species, either 6.66% of the host species which represent species susceptible to parasitism. The third class (III) of host plants consists of species highly susceptible to parasitism. It was represented by 4 species, either 3.33% of the host species. Seven (7) species of Loranthaceae have been identified (*Tapinanthus globiferus* (A. Rich.) Danser, *Tapinanthus ophiodes* (Sprague) Danser, *Tapinanthus belvisii* (DC) Danser), *Agelanthus dodoneifolius* (DC) Polh. & Wiens, *Tapinanthus bangwensis* (Engl. And Kr.) Danser, *Phragmanthera capitata* (Spreng) Ballé and *Globimetula braunii* (Engl.) Tiegh.) and divided into four genera which are *Tapinanthus*; *Phragmanthera*; *Agelanthus* and *Globimetula*. *Tapinanthus* was the most diverse with four species (*T. bangwensis*, *T. globiferus*, *T. ophiodes* and *T. dodoneifolius*). *Phragmanthera*, *Globimetula* and *Agelanthus* each have one species. *T. globiferus* was the most represented (125.66 ± 71.86 tufts / ha) and was more dense on the side West and at the top of the hills of the Mandara Mountains. Slopes and altitude influence the distribution of Loranthaceae over the Mounts.

Keywords: Loranthaceae, Parasite; Hemiparasite, Mandara Mountains, Far North, Cameroon.

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INTRODUCTION

Loranthaceae constitute a family of phanerogamous plants, chlorophyllian hemiparasites and epiphytes which, implanted on the aerial parts of

their host plants [1], are responsible for economic, ecological and morphogenetic damage which varies according to the crops or woody species parasitized [2-4]. These parasitic plants are subdivided into two large groups, holoparasites which are devoid of chlorophyll,

deriving from their hosts all their food and hemiparasites which take only water and mineral elements from the host while retaining their power of synthesis chlorophyllian. Loranthaceae are widely distributed around the world. They include around 77 genera and more than 950 species [5-8]. In Africa, Loranthaceae are very common and have caused extensive damage to natural formations and plantations in countries such as Burkina Faso, Cote d'Ivoire, Cameroon, Gabon, Ghana, Mali and many more Other African countries [4, 9, 10]. In Cameroon, the Loranthaceae are represented by nearly 26 species grouped into seven (07) genera. They lead to a huge drop in the yield of fruit species such as *Dacryodes edulis* and *Cola nitida* in the Littoral, East, South-West and West Regions [3, 11]. These woody parasitic plants are today a real scourge, given the damage they cause both in natural plant formations [3, 12] and in fruit plantations [11, 13]. Woody species of environmental and economic importance such as *Azadirachta indica* (Meliaceae), *Balanites aegyptiaca* (Balanitaceae), *Terminalia mantaly* (Combretaceae), *Dalbergia sisso'o* (Fabaceae), *Acacia albida* (Mimosaceae), *Ficus* sp. (Moraceae), *Dacryodes edulis* (Burseraceae) and fruit species of socio-economic importance such as *Psidium guajava* (Myrtaceae), *Vitellaria paradoxa* (Sapoteaceae), *Persea americana* (Lauraceae), are unfortunately attacked by Loranthaceae [14, 15, 3, 13]. Loranthaceae, although parasitic plants, are used internationally by traditional therapists and traditional healers in the treatment of various diseases such as cancer, hypertension, hypotension, diabetes, hepatitis, cerebral vascular accidents, infertility, microbial diseases and mental disturbances [16, 17, 18, 19]. They are also used for mystical purposes. In Cameroon, very few studies have been carried out on Loranthaceae parasites of woody plants except for the work of Dibong *et al.* [15, 20, 3] in the Littoral Region, de Azo'o *et al.* [13] in the Eastern Region, de Balle [21] in the Southern Region, and Ngotta *et al.* [14] in the South West Region, from Mapongmetsem *et al.* [22] and Ibrahima *et al.* [23] in

the Adamawa Region. The purpose of this study is to identify the species of Loranthaceae parasitic in woody plants and to highlight their distribution according to altitude on the Mandara Mountains in the Far North, Cameroon.

MATERIAL AND METHODS

Study site

The study was carried out in the Sudano-Sahelian zone of the Far North, Cameroon, located between 10 ° 0 'and 12 ° 0' North latitude and between 14 ° 0 'and 15 ° 0' East longitude (Figure 1). Covering an area of 7660 km², this area covers the Departments of Mayo Sava, Mayo Tsanaga, the district, Meri, Pette, Diamare and district of Mayo-Oulo in Mayo-Louti in the North, either 16.2 % of the total area of the Far North Region. It forms a vast plain to the east and north and a set of mountain ranges called the Mandara Mountains in its western part along the Nigerian border, highly rugged with peaks reaching over 1200 m altitude. The climate is of the Sudano-Sahelian type, slightly milder and a single-mode rainfall, with two (2) seasons, a short rainy season, ranging from June to October and a long dry season, from November to May [16]. The annual average temperature is 28°C [24]. The soil is sandy-clayey and sandy. The plant formation is of the Sudano-Sahelian type characterized by the predominantly thorny shrub steppe and its extreme fragmentation due to natural conditions and human action. The main dominant species are *Acacia albida*, *Ziziphus mauritiana*, *Tamarindus indica*, *Azadirachta indica*, *Acacia seyal*, *Diospyros mespiliformis*, *Dalbergia sisso'o*. Some of these plants are used in traditional pharmacopoeia. The population of this Region was estimated at approximately 1,165,700 inhabitants in 2005 [25]. It is dominated by ethnic groups such as Mafa, Moufou, Hide, Foulbe (peuhl), Mabas and Woula. The main activities carried out are agriculture, commerce, animal husbandry and crafts.

species; $p(i)$ = Proportion of a species i compared to the total number of species (S) in the study environment (or specific diversity of the environment) which is calculated as follows: $p(i) = n_i / N$ where n_i is the number of individuals of the species and N is the total number of individuals of all species [27]. From this index, we can derive the equitability of Pielou (E) which is given by the formula $ISH / \log_2 N$. Statgraphic 5.0 software is used to do analysis of variance (ANOVA) and Xlstat 2007 software is used to do principal component variable analysis and Duncan's test is used to compare the different Means. The Loranthaceae species determination keys used by Boussim [4] and by Houénon [8] are used to identify Loranthaceae.

RESULTS

Floristic composition and sensitivity of host plants

In total, 120 host species distributed in 34 families and 75 genera are recorded on the Mandara Mountains (Table 1). Combretaceae and Mimosaceae are the most represented with 13 species each, either 10.83% for each family. They are followed by Caesalpiniaceae with 10 species or 8.33% and Moraceae with 9 species or 7.5%. *Acacia* is the most diverse genus with 10 species, or 8.33% of the host species. It is followed by *Combretum* and *Ficus* with 9 species each, either 7.5% of the host plants for each genus. 18 genera or 24% are reported monospecific.

Three classes of host species are defined depending on the level of susceptibility to parasitism. In all of the 120 host species listed 68 species or 56.66% of the host species are parasitized by 1 or 2 parasitic species and represent the first class (I) which is the class of host species not very sensitive to the parasitism of Loranthaceae. Among these species, mention may be made of: *Haematostaphis barteri*, *Lannea acida*, *Lannea fruticosa*, *Sclerocarya birrea*, *Annona senegalensis*, *Hexalobus monopetalus*, *Vernonia thomsoniana*, *Stereospermum kunthianum*, *Adansonia digitata*, *Boswellia dalzielii*, *Commiphora africana*, *Piliostigma thonningii*, *Piliostigma reticulatum*, *Capparis fascicularis*, *Boscia angustifolia*. The second class (II) of susceptible host species is made up of 8 species, either 6.66% of the host species which represent species susceptible to the parasitism of Loranthaceae. Among these species are: *Balanites aegyptiaca*, *Tamarindus indica*, *Boscia senegalensis*, *Anogeissus leiocarpus*, *Dalbergia sisso'o*, *Acacia seyal*, *Ziziphus abyssinica*, *Citrus limon*. The third class (III) of host plants consists of species highly susceptible to parasitism by Loranthaceae. It is represented by 4 species, either 3.33% of the host species. These include *Ziziphus mauritiana*, *Khaya senegalensis*, *Azadirachta indica* and *Diospyros mespiliformis*, among others.

Regarding the Loranthaceae species, *T. globiferus* is much more represented with 41.67%. It is followed by *A. dodoneifolius* with 38.47% and *T. ophiodes* with 12.50%. The least parasitic parasite is *G. braunii* with 7.50%.

Table 1: List of host species and their sensitivity to Loranthaceae parasitism

Host plants	Loranthaceae								
	AD	TG	TO	TE	TB	PC	GB	Nep	SPS
Anacardiaceae									
<i>Haematostaphis barteri</i> Hook f.	+	+						2	vshp
<i>Lannea acida</i> A. Rich.s.l.		+						1	vshp
<i>Lannea fruticosa</i> (Hochst. ex A. Rich.) Engl.		+						1	vshp
<i>Lannea schimperi</i> (Hochst. ex A. Rich.) Engl.									
<i>Lannea velunita</i> A. Rich.									
<i>Mangifera indica</i> L.									
<i>Sclerocarya birrea</i> (A. Rich.) Hochst.		+						1	vshp
Annonaceae									
<i>Annona senegalensis</i> Pers.			+			+		2	vshp
<i>Annona squamosa</i> L.									
<i>Hexalobus monopetalus</i> (A. Rich.) Engl. & Diels	+	+						2	vshp
Apiaceae									
<i>Steganotaenia araliacea</i> Hochst.									
Apocynaceae									
<i>Holarrhena floribunda</i> (G. Don) Dur. & Schinz									
Asclepiadaceae									
<i>Calotropis procera</i> (Ait.) Ait. f.									
Asteraceae									
<i>Vernonia thomsoniana</i> Oliv. & Hiern		+						1	vshp
Balanitaceae									
<i>Balanites aegyptiaca</i> (L.) Del.	+	+			+			3	shp
Bignoniaceae									
<i>Stereospermum kunthianum</i> Cham.		+						1	vshp
Bombacaceae									
<i>Adansonia digitata</i> L.		+						1	vshp

<i>Ceiba pentandra</i> (L.) Gaertn.									
Burseraceae									
<i>Boswellia dalzielii</i> Hutch.		+		+				2	vshp
<i>Boswellia papyrifera</i> (Del.) A. Rich.									
<i>Commiphora africana</i> (A. Rich.) Engl.							+	1	vshp
<i>Commiphora kerstingii</i> Engl.									
Caesalpiniaceae									
<i>Bauhinia rufescens</i> Lam.	+	+						2	vshp
<i>Azelia africana</i> Smith ex Pers.									
<i>Daniellia oliveri</i> (Rolfe) Hutch. & Dalz.				+				1	vshp
<i>Isobertinia doka</i> Craib & Stapf									
<i>Piliostigma reticulatum</i> (DC.) Hochst.	+	+						2	vshp
<i>Piliostigma thonningii</i> (Schum.) Milne-Redh.		+						1	vshp
<i>Pterocarpus erinaceus</i> Poir.									
<i>Senna siamea</i> Lam.									
<i>Senna singueana</i> (Del.) Lock									
<i>Tamarindus indica</i> L.	+	+	+	+				4	shp
Capparaceae									
<i>Capparis fascicularis</i> DC.		+			+			2	vshp
<i>Boscia angustifolia</i> A. Rich.		+						1	vshp
<i>Boscia senegalensis</i> (Pers.) Lam. ex Poir.	+	+	+					3	shp
<i>Cadaba farinosa</i> Forssk.							+	1	vshp
<i>Capparis sepiaria</i> L.							+	1	vshp
<i>Maerua angolensis</i> DC.									
Celastraceae									
<i>Maytenus senegalensis</i> (Lam.) Exell.		+						1	vshp
Combretaceae									
<i>Anogeissus leiocarpus</i> (DC.) Guill. & Perr.	+	+					+	3	shp
<i>Combretum aculeatum</i> Vent.									
<i>Combretum adenogonium</i> Steud. ex. A. Rich.							+	1	vshp
<i>Combretum collinum</i> Fresen.									
<i>Combretum glutinosum</i> Perr. ex DC.	+						+	2	vshp
<i>Combretum lecardii</i> Engl. & Diels					+	+		2	vshp
<i>Combretum micranthum</i> G. Don			+					1	vshp
<i>Combretum molle</i> R. Br. ex G. Don									
<i>Combretum nigricans</i> Lepr. ex Guill. et Perr.			+		+			2	vshp
<i>Combretum nioroense</i> Aubrév. ex Keay									
<i>Guiera senegalensis</i> J.F. Gmel.	+	+						2	vshp
<i>Terminalia glauscescens</i> Hochst.		+	+					2	vshp
<i>Terminalia macroptera</i> Guill. & Perr.		+						1	vshp
<i>Terminalia mantaly</i> H. Perr.									
Ebenaceae									
<i>Diospyros mespiliformis</i> Hochst. ex A. Rich.	+	+	+	+	+			5	hshp
Euphorbiaceae									
<i>Croton macrostachyus</i> Hochst. ex Del.		+						1	vshp
<i>Croton psedopulchellus</i> Pax		+						1	vshp
<i>Euphorbia kamerunica</i> Pax	+	+						2	vshp
<i>Flueggea virosa</i> (Roxb. ex Willd.) Voigt									
<i>Jatropha gossypifolia</i> L.		+	+					2	vshp
<i>Phyllanthus muellerianus</i> (O. Ktze) Exell	+							1	vshp
<i>Uapaca togoensis</i> Pax							+	1	vshp
Fabaceae									
<i>Andira inermis</i> (Wright) DC.									
<i>Dalbergia boehmii</i> Taub.	+	+						2	vshp
<i>Dalbergia melanoxyton</i> Guill. & Perr.	+							1	vshp
<i>Dalbergia sissoo</i> Roxb.	+	+			+			3	shp
<i>Dicrostachys cinera</i> (L.) Wight & Arn.						+	+	2	vshp
<i>Entada africana</i> Guill. & Perr.							+	1	vshp
<i>Pterocarpus erinaceus</i> Poir.	+							1	vshp
<i>Pterocarpus lucens</i> Guill. & Perr.	+							1	vshp
Flacourtiaceae									
<i>Flacourtia indica</i> Willd.		+						1	vshp
Loganiaceae									

<i>Strychnos spinosa</i> Lam.		+						1	vshp
Meliaceae									
<i>Azadirachta indica</i> A. Juss.	+	+	+		+	+		5	hshp
<i>Khaya senegalensis</i> (Desr.) A. Juss.	+	+	+	+		+		5	hshp
Mimosaceae									
<i>Acacia albida</i> Del.	+	+						2	vshp
<i>Acacia amythethophylla</i> Steud. ex A. Rich.		+						1	vshp
<i>Acacia ataxacantha</i> DC.					+		+	2	vshp
<i>Acacia ehrenbergiana</i> Hayne	+							1	vshp
<i>Acacia erythrocalyx</i> Brenan									
<i>Acacia gerardii</i> Benth.									
<i>Acacia hocki</i> De Wild.	+				+			2	vshp
<i>Acacia nilotica</i> (L.) Willd. ex Del	+							1	vshp
<i>Acacia seyal</i> Del.	+		+	+				3	shp
<i>Acacia tortilis</i> sub sp. raddiana (Savi) Brenan	+	+						2	vshp
<i>Albizia chevalieri</i> Harms									
<i>Albizia zygia</i> (DC.) J.F. Macbr.		+		+				2	vshp
<i>Prosopis juliflora</i> (Sw.) DC.									
Moraceae									
<i>Ficus sycomor</i> (Miq.) C.C. Berg		+	+					2	vshp
<i>Ficus abutilifolia</i> (Miq.) Miq.									
<i>Ficus asperifolia</i> Miq.	+							1	vshp
<i>Ficus cordata</i> ssp. lecardii (Warb.) C.C. Berg	+	+						2	vshp
<i>Ficus dicranostyla</i> Mildbr.									
<i>Ficus glumosa</i> Del.					+	+		2	vshp
<i>Ficus platyphylla</i> Del.	+							1	vshp
<i>Ficus thonningii</i> Blume									
<i>Ficus umbellata</i> Vahl		+						1	vshp
Myrtaceae									
<i>Psidium guajava</i> L.	+	+						2	vshp
Ochnaceae									
<i>Ochna schweinfurthiana</i> F. Hoffm.									
Olacaceae									
<i>Jasminum obtusifolium</i> Bak.									
<i>Ximena americana</i> L.	+	+						2	vshp
Polygalaceae									
<i>Securidaca longipedunculata</i> Fres.									
Rhamnaceae									
<i>Ziziphus abyssinica</i> Hochst. ex A. Rich.	+	+	+	+				4	shp
<i>Ziziphus mauritiana</i> Lam.	+	+	+	+	+	+		6	hshp
Rubiaceae									
<i>Crossopteryx febrifuga</i> (Afzel. ex G. Don) Benth.									
<i>Feretia apodanthera</i> Del.	+	+						2	vshp
<i>Gardenia aqualla</i> Stapf. & Hutch.	+							1	vshp
<i>Pavetta corymbosa</i> (DC.) F. N. Williams									
<i>Sarcocephalus latifolius</i> (Smith) Bruce		+						1	vshp
<i>Tricalysia okelensis</i> Hiern									
Rutaceae									
<i>Citrus limon</i> (L.) Burm. F.		+	+	+				3	shp
<i>Citrus sinensis</i> (L.) Osbeck	+	+						2	vshp
Sapotaceae									
<i>Malacantha alnifolia</i> (Bak.) Pierre									
<i>Vitellaria paradoxa</i> Gaertn. f.		+						1	vshp
Sterculiaceae									
<i>Sterculia setigera</i> Del.					+		+	2	vshp
Tilliaceae									
<i>Grewia barteri</i> Burret						+		1	vshp
<i>Grewia bicolor</i> Juss.									
<i>Grewia flavescens</i> Juss.	+							1	vshp
<i>Guibourtia copallifera</i> Benn.									
Ulmaceae									
<i>Celtis integrifolia</i> Lam.									
Verbenaceae									

<i>Lippia chevalieri</i> Moldenke									
<i>Vitex doniana</i> Sweet.	+	+						2	vshp
<i>Vitex madiensis</i> Oliv.		+			+			2	vshp
SeP (%)	31.67	41.67	12.5	8.33	10.83	8.33	7.5		

AD: *Agelanthus dodoneifolius*, TG: *Tapinanthus globiferus*, TO: *Tapinanthus ophiodes*, TB.: *Tapinanthus bangwensis*, TE: *Tapinanthus belvisii*, PC: *Phragmanthera capitata*, GB: *Globimetula braunii*; SPS: Specificity of parasitic species; Npshp: number of parasitic species per host plant; pshp: parasitic sensitivity of the host plant (1 to 2 parasites = not very sensitive host plant (vshp), 3 to 4 parasites = sensitive host plant (shp), 5 to 6 parasites = highly sensitive host plant (hshp); +: presence.

Taxonomic composition of Loranthaceae

In total, seven (7) species of Loranthaceae have been recorded on the Mandara Mountains (Table 2). *Tapinanthus globiferus* (A. Rich.) Danser is the most represented with an average density of 125.66 ± 71.86 tufts / ha. It is followed by *Agelanthus dodoneifolius* (DC) Polh. & Wiens with an average density of 116.39 ± 53.74 tufts / ha. Then it is *Tapinanthus ophiodes* (Sprague) Danser which comes with an average density of 92.65 ± 51.06 tufts / ha; *Tapinanthus belvisii* (DC) Danser has an average

density of 70.24 ± 53.63 tufts / ha; *Phragmanthera capitata* (Spreng) Ballé has an average density of 57.74 ± 27.2 tufts / ha. *Tapinanthus bangwensis* (Engl. And Kr.) Danser has an average density of 51.4 ± 33.24 tufts / ha. *Globimetula braunii* (Engl.) Tiegh. is the least represented parasitic species on the Hills with an average density of 45.57 ± 19.01 tufts / ha. The specific richness of Loranthaceae species varies between 1 and 3 parasitic species per host plant. Variance analysis shows that there is a highly significant difference between Loranthaceae species (P <0.001).

Table 2: Taxonomic diversity of Loranthaceae

Kind	Species	Density
<i>Agelanthus</i>	<i>Agelanthus dodoneifolius</i>	59.69±34.91 ^e
<i>Tapinanthus</i>	<i>Tapinanthus globiferus</i>	73.38±37.48 ^f
	<i>Tapinanthus ophiodes</i>	44.35±42.8 ^d
	<i>Tapinanthus bangwensis</i>	25.22±36.87 ^b
	<i>Tapinanthus belvisii</i>	35.01±17.77 ^c
<i>Phragmanthera</i>	<i>Phragmanthera capitata</i>	26.96±21.89 ^b
<i>Globimetula</i>	<i>Globimetula braunii</i>	17.26±29.36 ^a
Average/ Standard deviation		40.27±31.58

Values assigned the same letters in superscript do not show significant statistical differences

Loranthaceae species are unevenly dispersed over the Hills. *T. globiferus*, *A. dodoneifolius* and *T. ophiodes* are respectively the most represented in the study area (Figure 2). These dispersed species are the densest, that is to say the species for which we are more

likely to encounter them on all the mountains in the study area. The other species which are less represented form clouds around the two (axes f1 and f2: 99.91%). These species represented in the form of a cloud are less dense and are less common in the study area.

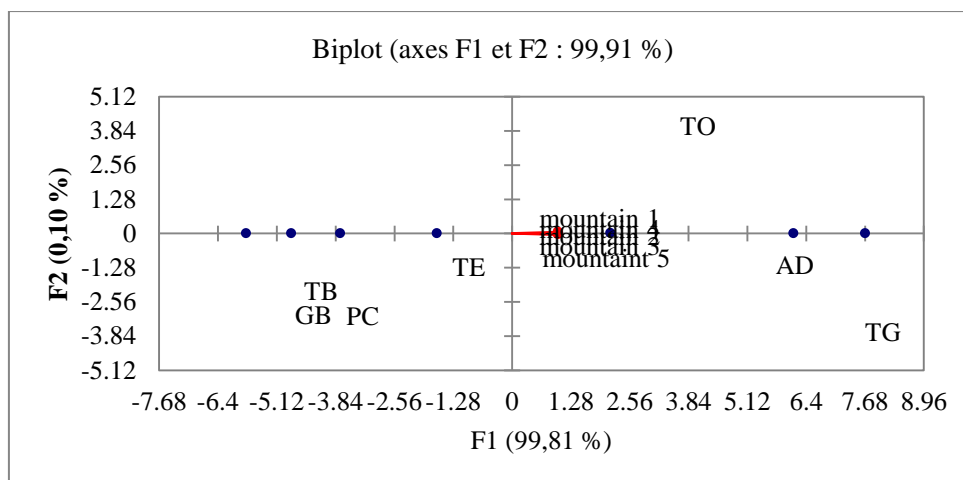


Figure 2: Dispersion of species on the Mountains

AD: *Agelanthus dodoneifolius*, TG: *Tapinanthus globiferus*, TO: *Tapinanthus ophiodes*, TB: *Tapinanthus bangwensis*, TE: *Tapinanthus belvisii*, PC: *Phragmanthera capitata*, GB: *Globimetula braunii*

Density of Loranthaceae on the Mountains

Table 3 shows the density on the two sides of the Mandara Mountains. Between the two sides, the density of parasitic species is higher on the East side (82.07 ± 61.68 tufts / ha) than on the West side (77.83 ± 49.62 tufts / ha). Between the Loranthaceae, on the East flank, *T. globiferus* is more abundant (150.11 ± 125.69 tufts / ha). It is followed by *A. dodoneifolius* so the average density is 120.24 ± 136.19 tufts / ha and *T. ophiodes* with an average density of 92.58 ± 104.9 tufts / ha; *T. belvisii* (71.78 ± 71.8 tufts / ha); *P. capitata* (56.19 ± 50.87 tufts / ha); *T. bangwensis* (48.44 ± 27.92 tufts / ha). On this slope, the least represented species is *G. braunii* with an average density of 35.14 ± 126.43 tufts / ha.

On the West side, *T. globiferus* has a higher density (143.42 ± 82.3 tufts / ha) but below the density on the East side. *A. dodoneifolius* comes next with an average density of 114.5 ± 87.3 tufts / ha; followed by *T. ophiodes* (82.03 ± 29.45 tufts / ha); *T. belvisii* (68.28 ± 70.94 tufts / ha); *P. capitata* (51.64 ± 40.54 tufts / ha); *T. bangwensis* (51.03 ± 56.87 tufts / ha) and *G. braunii* is less represented on this slope with an average density of 33.92 ± 99.23 tufts / ha. The analysis of variance (ANOVA) indicates that there is no difference between the two sides ($P > 0.05$) while between the parasitic species the difference is highly significant ($P < 0.001$).

Table 3: Density of Loranthaceae on the Mounts

Species	M 1	M 2	M 3	M 4	M 5	average/SD
TD	347.71	343.96	347.71	347.71	358.75	349.17±5.6
TG	378.33	365.00	376.46	385.42	379.69	376.98±7.49
TO	278.33	286.88	276.04	273.13	275.42	277.96±5.32
TB	152.92	153.33	155.00	150.21	159.58	154.21±3.46
TE	201.04	211.98	215.31	213.44	211.77	210.71±5.59
PC	173.75	172.50	171.35	177.81	170.63	173.21±2.83
GB	135.21	136.98	134.38	137.60	139.38	136.71±1.98
average/SD	238.18±97.17	238.66±93.17	239.46±95.94	240.76±97.43	242.17±97.5	239.85±96.15

M 1 = Mount 1 (< 500 m = M 1 + M 2 + M 15) ; M 2 = Mount 2 (500 m - 600 m [= M 4 + M 5 + M 3]) ; M 3 = Mount 3 (600 m - 700 m [= M 6 + M 7 + M 13]) ; M 4 = Mount 4 (700 m - 800 m [= M 8 + M 9 + M 14]) ; M 5 = Mount 5 (> 800 m = M 10 + M 11 + M 12) ; SD: Standard deviation ; AD: *Agelanthus dodoneifolius*, TG: *Tapinanthus globiferus*, TO: *Tapinanthus ophiodes*, TB: *Tapinanthus bangwensis*, TE: *Tapinanthus belvisii*, PC: *Phragmanthera capitata*, GB: *Globimetula braunii*

On the same lines on the one hand and the same columns on the other hand, the values assigned the same superscript letters do not show statistically significant differences.

The analysis of the principal component variables (PCA) shows that the five (05). Mounts are

positively correlated with each other. Figure 3 shows the correlation between the different Mounts. The correlation is very strong (Pearson, $r = 0.987$) between Mount 3 and Mount 4, between Mount 3 and Mount 5 (0.986) and between Mount 1 and Mount 2 (Pearson, $r=0.942$).

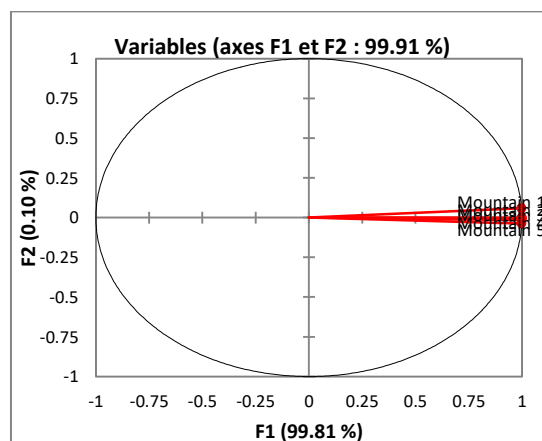


Figure 3: Correlation between the Mounts

Loranthaceae density on the slopes

Table 4 shows the density on the two sides of the Mandara Mountains. Between the two sides, the density of parasitic species is higher on the East side (82.07 ± 61.68 tufts / ha) than on the West side (77.83 ± 49.62 tufts / ha). Between the Loranthaceae, on the East flank, *T. globiferus* is more abundant (150.11 ± 125.69 tufts / ha). It is followed by *A. dodoneifolius* so the average density is 120.24 ± 136.19 tufts / ha and *T. ophiodes* with an average density of 92.58 ± 104.9 tufts / ha ; *T. belvisii* (71.78 ± 71.8 tufts / ha) ; *P. capitata* (56.19 ± 50.87 tufts / ha) ; *T. bangwensis* (48.44 ± 27.92 tufts / ha). On this slope, the least represented species is *G. braunii* with an average density of 35.14 ± 126.43 tufts / ha.

On the West side, *T. globiferus* has a higher density (143.42 ± 82.3 tufts / ha) but below the density on the East side. *A. dodoneifolius* comes next with an average density of 114.5 ± 87.3 tufts / ha; followed by *T. ophiodes* (82.03 ± 29.45 tufts / ha) ; *T. belvisii* (68.28 ± 70.94 tufts / ha) ; *P. capitata* (51.64 ± 40.54 tufts / ha) ; *T. bangwensis* (51.03 ± 56.87 tufts / ha) and *G. braunii* is less represented on this slope with an average density of 33.92 ± 99.23 tufts / ha. The analysis of variance (ANOVA) indicates that there is no difference between the two sides ($P = 0.395 > 0.05$) while between the parasitic species the difference is highly significant ($P < 0.001$).

Table 4: density of Loranthaceae species on the slopes

Kinds	Species	East side	West side
		Density	Density
<i>Agelanthus</i>	<i>Agelanthus dodoneifolius</i>	120.24 ± 136.19^e	114.5 ± 87.3^e
<i>Tapinanthus</i>	<i>Tapinanthus globiferus</i>	150.11 ± 125.69^f	143.42 ± 82.3^f
	<i>Tapinanthus ophiodes</i>	92.58 ± 104.9^d	82.03 ± 29.45^d
	<i>Tapinanthus bangwensis</i>	48.44 ± 27.92^b	51.03 ± 56.87^b
	<i>Tapinanthus belvisii</i>	71.78 ± 71.8^c	68.28 ± 70.94^c
<i>Phragmanthera</i>	<i>Phragmanthera capitata</i>	56.19 ± 50.87^b	51.64 ± 40.54^b
<i>Globimetula</i>	<i>Globimetula braunii</i>	35.14 ± 126.43^a	33.92 ± 99.23^a
Average/ Standard deviation		82.07 ± 61.68^a	77.83 ± 49.62^a

On the same column, the values assigned the same letters in superscript do not show significant statistical differences

Loranthaceae density according to the altitudinal gradient

The density of Loranthaceae species varies between the plain and the Mount but also between the different altitude levels of the Mount ranging from the bottom (A 1) to the top (A 3). Between the different height differences, the summit of the Mount (A 3) has a higher density (25.02 ± 12.65 tufts / ha) compared to the other altitude levels. It precedes the middle of the Mounts (A 2) which has an average density of 21.83 ± 10.69 tufts / ha ; the bottom (A1) therefore the average density is 18.19 ± 9.83 tufts / ha and the plain (A 0) is the least dense zone in individuals (14.9 ± 8.87 tufts /

ha). The average density of Loranthaceae species increases as one moves from the plain (A 0) to the top of the Hills (A 3). At the species level, the density of six species increases from bottom to top. These are *A. dodoneifolius*, *T. globiferus*, *T. ophiodes*, *T. belvisii*, *P. capitata* and *G. braunii*. On the other hand, the average density of *T. bangwensis* decreases as one goes from the plain (A 0) to the top of the Hills. This species rather prefers the plain than the summit of the Mounts compared to the other species which, they rather prefer the summit. The analysis of variance (ANOVA) states that there is a highly significant difference between the altitude levels ($P < 0.001$).

Table 5: Density of Loranthaceae species on altitudinal gradients

Species	A 0	A 1	A 2	A 3	Average/SD
TD	21.15	26.65	33.19	38.38	29.84 ± 7.52
TG	28.75	33.22	38.73	44.75	36.36 ± 6.92
TO	17.07	21.57	23.14	26.22	22 ± 3.81
TB	15.72	14.44	10.81	8.76	12.43 ± 3.21
TE	11.36	16.13	20.00	22.54	17.51 ± 4.87
PC	9.15	11.64	14.96	16.78	13.13 ± 3.4
GB	1.11	3.71	11.99	17.72	8.63 ± 7.63
Average/SD	14.9 ± 8.87	18.19 ± 9.83	21.83 ± 10.69	25.02 ± 12.65	19.99 ± 10.07

A 0 = plain (< 500 m) ; A 1 = Altitude 1 ([500 m - 700 m]) ; A 2 = Altitude 2 ([700 m - 900 m]) ; A 3 = Altitude 3 (> 900 m) ; SD: Standard deviation ; AD: *Agelanthus dodoneifolius*, TG: *Tapinanthus globiferus*, TO: *Tapinanthus ophiodes*, TB: *Tapinanthus bangwensis*, TE: *Tapinanthus belvisii*, PC: *Phragmanthera capitata*, GB: *Globimetula braunii*.

On the same lines on the one hand and the same columns on the other hand, the values assigned the same superscript letters do not show statistically significant differences.

Density of Loranthaceae interaction between Mounts and Slopes

The density of the two sides of each Mount varies from one Mount to another (table 6). Mount 5 is denser with an average density of 142.03 ± 3.87 tufts / ha for both sides. It is followed by Mount 4 which has

an average density of 131.24 ± 4.36 tufts / ha for the two slopes; Mount 3 (120.67 ± 5.53 tufts / ha) for the two slopes; Mount 2 (114.16 ± 5.62 tufts / ha) combining the two sides and Mount 1 has the lowest density for the two sides (95.92 ± 5.09 tufts / ha). The analysis of variance shows that the difference is very significant between the different Mounts ($P = 0.004$). Between the two sides of each Mount, ANOVA does not report any significant difference ($P > 0.05$).

Table 6: density of Loranthaceae species of the interaction between the Mounts and the Slopes

Species	M 1		M 2		M 3		M 4		M 5	
	East side	West side	East side	West side	East side	West side	East side	West side	East side	West side
TD	154.38	146.46	175.42	159.17	183.75	179.58	191.04	183.75	216.88	200.21
TG	192.08	185.21	222.29	209.79	216.88	206.46	239.79	227.71	254.79	246.46
TO	116.67	109.58	107.71	100.00	140.42	122.08	156.46	135.42	183.54	158.54
TB	38.96	36.46	78.54	75.00	79.58	75.63	100.63	97.50	76.04	98.13
TE	107.71	96.46	96.04	87.29	99.79	97.29	116.04	114.58	118.75	116.46
PC	61.25	52.08	89.38	78.96	94.79	84.79	90.83	83.75	85.21	87.71
GB	25.63	20.00	57.50	61.04	56.88	51.46	45.42	54.38	78.13	67.50
Average/SD	99.52 $\pm 56.73^a$	92.32 $\pm 55.86^a$	118.13 $\pm 58.88^b$	110.18 $\pm 54.12^b$	124.58 $\pm 58.28^c$	116.76 $\pm 56.83^c$	134.32 $\pm 65.95^d$	128.15 $\pm 59.99^d$	144.76 $\pm 73.25^e$	139.29 $\pm 65.32^e$
	95.92 ± 5.09^a		114.16 ± 5.62^{ab}		120.67 ± 5.53^{abc}		131.24 ± 4.36^{bc}		142.03 ± 3.87^c	

Mount 1 (< 500 m = M 1 + M 2 + M 15) ; Mount 2 ([500 m - 600 m [= M 4 + M 5 + M 3) ; Mount 3 ([600 m -700 m [= M 6 + M 7 + M 13) ; Mount 4 ([700 m - 800 m [= M 8 + M 9 + M 14) ; Mount 5 (> 800 m = M 10 + M 11 + M 12) ; SD: Standard deviation ; TD: *Agelanthus dodoneifolius* ; TG: *Tapinanthus globiferus* ; TO: *Tapinanthus ophiodes* ; TB: *Tapinanthus bangwensis* ; TE: *Tapinanthus belvisii* ; PC: *Phragmanthera capitata* ; GB: *Globimetula braunii*

On the same lines, values assigned the same superscript letters do not show statistically significant differences.

Density of Loranthaceae of interaction between slopes and altitudes

For the four altitude levels combined, the mean density of Loranthaceae species varies from species to species (Table 7). *T. globiferus* shows a higher density of 899.38 ± 19.01 tufts / ha. It is followed by *A. dodoneifolius* (842.77 ± 19.23 tufts / ha). *T. ophiodes* occupies the third position with a density of $784.44 \pm$

19.64 tufts / ha. A density of 575 ± 15.12 tufts / ha is then recorded by *T. bangwensis*. The latter is followed by *T. belvisii* which obtains a density of 556.12 ± 5.26 tufts / ha. A relatively low density of 440.56 ± 7.5 tufts / ha is observed by *P. capitata* and the lowest density (378.89 ± 6.99 tufts / ha) is obtained by *G. braunii*. For the difference between species, the analysis of variance (ANOVA) specifies a highly significant difference ($P < 0.001$).

Table 7: density of Loranthaceae species on the slopes with the four levels of altitude

Species	East				West				Average/SD
	A 0	A 1	A 2	A 3	A 0	A 1	A 2	A 3	
AD	118.00	121.00	123.00	129.28	86.50	82.72	87.44	94.83	842.77 ± 19.23^e
TG	124.67	126.78	127.72	138.44	94.83	88.44	95.33	103.17	899.38 ± 19.01^f
TO	105.78	115.44	115.22	124.83	75.39	75.50	83.00	89.28	784.44 ± 19.64^d
TB	86.89	82.11	77.44	92.61	50.39	57.72	60.78	67.06	575 ± 15.12^c
TE	64.11	65.44	71.89	77.06	67.06	63.28	71.89	75.39	556.12 ± 5.26^c
PC	55.22	54.33	55.22	65.39	42.06	49.39	54.67	64.28	440.56 ± 7.5^b
GB	41.89	48.78	49.67	55.94	33.72	45.50	50.22	53.17	378.89 ± 6.99^a

A0 = plain (< 500 m) ; A 1= Altitude 1 ([500 m -700 m]) ; A 2 = Altitude 2 ([700 m - 900 m]) ; A 3 = Altitude 3 (> 900 m) ; SD: Standard deviation AD: *Agelanthus dodoneifolius* ; TG: *Tapinanthus globiferus* ; TO: *Tapinanthus ophiodes* ; TB: *Tapinanthus bangwensis* ; TE: *Tapinanthus belvisii* ; PC: *Phragmanthera capitata* ; GB: *Globimetula braunii*

Values assigned the same letters in superscript do not show statistically significant differences.

Relative frequency of distribution of Loranthaceae species

The number of species of Loranthaceae parasitic on ligneous plants does not vary from one slope to another ($P = 0.597$). All 7 species of parasitic plants are present on the two slopes (Table 8). The parasitic flora common to both sides is made up of all seven species (*A. dodoneifolius*, *T. globiferus*, *T. ophiodes*, *P. capitata*, *T. bangwensis*, *T. belvisii* and *G. braunii*). In sides, *A. dodoneifolius* and *T. globiferus* are the most frequent species with a frequency of 100% in both sides. *T. ophiodes* is more frequent on the East side (93.33%) than on the West side (86.66%). As for *T.*

bangwensis, it has the same frequency of occurrence on both flanks (80%). *T. belvisii* is much more present on the West side (93.33%) than on the East side (86.66%). *P. capitata* and *G. braunii* are more frequent on the East side with respectively 66.66% and 40% than on the West side (40% and 26.66% respectively). In terms of species presence, there is no significant difference between the two sides. Depending on the frequency of presence, the analysis of variance (ANOVA) shows no very significant difference between the two sides ($P > 0.05$). In terms of the frequency of species on the slopes, the analysis of variance (ANOVA) states a highly significant difference ($P < 0.001$).

Table 8: Frequencies of presence of Loranthaceae species on the east and west slopes

Species	Relative frequency of presence of species (%)	
	East side	West side
AD	100 ^e	100a
TG	100 ^e	100a
TO	93.33 ^d	86.66c
TB	80 ^c	80c
TE	86.66 ^c	93.33b
PC	66.66 ^b	40d
GB	40 ^a	26.66e

AD: *Agelanthus dodoneifolius* ; TG: *Tapinanthus globiferus* ; TO: *Tapinanthus ophiodes* ; TB: *Tapinanthus bangwensis* ; TE: *Tapinanthus belvisii* ; PC: *Phragmanthera capitata* ; GB: *Globimetula braunii*.

On the same columns, the values assigned the same letters in superscript do not present statistically significant differences.

Diversity indices of Loranthaceae of the Mandara Mountains

The Shannon diversity index and the fairness of Pielou are higher on Mount 5 (0.328 and 0.120 respectively) which is made up of the Mount whose

plain has an altitude greater than 800 m (table 9) while these indices are more weak on Mount 1 where the plain is less than 500 m, 0.317 for the Shannon index and 0.113 for the equitability of Piélou. This means that the diversity of Loranthaceae is less dense in Mount 1 where the plain has a low altitude (ISH = 0.317 ; EQ = 0.113) compared to the Mount where the altitude of the plain is greater than 800 m (ISH = 0.328 ; EQ = 0.120).

Table 9: Loranthaceae diversity indices

Parameters	M1	M2	M3	M4	M5
D	536.32	544.13	559.34	573.99	584.44
ISH	0.317	0.318	0.322	0.325	0.328
EQ	0.113	0.113	0.115	0.117	0.120

Mount 1 (< 500 m = M 1 + M 2 + M 15) ; Mount 2 ([500 m - 600 m [= M 4 + M 5 + M 3) ; Mount 3 ([600 m - 700 m [= M 6 + M 7+M 13) ; Mount 4 ([700 m - 800 m [= M 8 + M 9 + M 14) ; Mount 5 (> 800 m = M 10 + M 11 + M 12) ; D = Density ; ISH = Shannon's Index, EQ = Piélou's Equitability.

DISCUSSION

The taxonomic diversity of the host plants in our study is made up of 120 species belonging to 75 genera and grouped into 34 botanical families. These results are different from those of Houénon *et al.* [8] who obtained a diversity of 105 species distributed in 85 genera and 33 families. Our results reveal that Combretaceae and Mimosaceae are the most represented with 13 species each, either 10.83% for each family. *Acacia* is the most diverse genus with 10

species, or 8.33% of the host species. It is followed by *Combretum* and *Ficus* with 9 species each, either 7.5% of the host plants for each genus. 18 genera or 24% are reported monospecific. These results are different from those of Souare *et al.*, [28] who obtained 34 species in the Diamare plain located in the same Sudano-Sahelian zone and from those of Houénon *et al.*, [8] who showed in their study that *Ficus* is the most diverse genus with 5 species, or 5.9% of host plants. It is followed by *Albizia* with 4 species; either 4.7% or Leguminosaceae represent the highest family with 25 species, either

23.8%. The differences observed would be due to the Hills which are rich in biodiversity. In all of the 120 listed host species, 68 species or 56.66% of the host species are parasitized by 1 or 2 parasitic species and represent the first class (I) which is the class of host species not very sensitive to parasitism of Loranthaceae. These species include: *Haematostaphis barteri*, *Lannea acida*, *Lannea fruticosa*, *Sclerocarya birrea*, *Annona senegalensis*, *Hexalobus monopetalus*, *Vernonia thomsoniana*, *Stereospermum kunthianum*, *Adansonia digitata*, *Boswellia dalzielii*, *Commiphora africana*, *Piliostigma reticulatum*, *Capparis fascicularis*, *Boscia angustifolia* etc. The second class (II) of sensitive host species consists of 8 species or 6.66% of the host species that represent the species susceptible to Loranthaceae parasitism. Among these species are: *Balanites aegyptiaca*, *Tamarindus indica*, *Boscia senegalensis*, *Anogeissus leiocarpus*, *Dalbergia sisso'o*, *Acacia seyal*, *Ziziphus abyssinica*, *Citrus limon*. The third class (III) of host plants consists of species highly sensitive to Loranthaceae parasitism. It is represented by 4 species or 3.33% of the host species. These include *Ziziphus mauritiana*, *Khaya senegalensis*, *Azadirachta indica* and *Diospyros mespiliformis*. These parasitic sensitivity classes are different from those of Houénon *et al.*, [8] who indicated that in a sample of 105 identified host species, 79 species or 75.2% are infested with 1 or 2 species and represent class I (insensitive). They cited species such as *Calotropis procera*, *Jatropha multifida*, *Khaya senegalensis*, *Persea americana*, *Triplochiton scleroxylon* and *Vitex doniana*. Class II of sensitive hosts includes 20 species or 19.1% including *Adansonia digitata*, *Ceiba pentandra*, *Irvingia gabonensis*, *Morinda lucida*, *Newbouldia laevis*, *Parkia biglobosa*. Class III (highly sensitive) is rich in 4 species, or 3.8%, namely: *Acacia auriculiformis*, *Citrus reticulata*, *Senna siamea* and *Tectona grandis* and the last class which is class IV contains only *Citrus sinensis* which is the only plant-host with a very high parasitic sensitivity.

The Mandara Mountains of Cameroon are home to the Loranthaceae flora. Of the 7 genera (*Agelanthus*, *Englerina*, *Globimetula*, *Helixanthera*, *Phragmanthera*, *Tapinanthus* and *Viscum*) and 25 species reported in Cameroon [29, 1, and 30], the Loranthaceae of this area group 4 genera (*Agelanthus*, *Tapinanthus*, *Phragmanthera* and *Globimetula*) or 57.14% and 7 species (*T. globiferus*, *A. dodoneifolius*, *T. ophiodes*, *T. belvisii*, *T. bangwensis*, *P. capitata* and *G. braunii*) or 26.92%. These results do not corroborate those of Souare *et al.* [28], which identified 3 genera (*Agelanthus*, *Tapinanthus* and *Phragmanthera*) and 9 species. This taxonomic diversity of 4 genera and 7 is higher than that obtained by Ahamide *et al.* [31], who identified 3 genera (*Globimetula*, *Phragmanthera* and *Tapinanthus*) and 6 species in southern Benin, those of Boussim [32, 4] which inventoried 3 genera and 6 species in Burkina Fasso. Similarly, these results are superior to those of 2 genera and 3 species observed in

Lokomo in eastern Cameroon [13] and to those of 2 species of the same genus reported by Mony *et al.* [30] on the Logbessou Plateau in Douala, Cameroon but less than 6 genera and 19 species recorded in Côte d'Ivoire [33], 6 genera and 25 species examined in Cameroon [21] and those by Aka *et al.* [33] who identified eleven (11) species of parasitic plants in Côte d'Ivoire. In contrast, these results are close to those of Houénon *et al.* [8] who inventoried 4 genera and 10 species in the Guinean and Sudan-Guinean areas in Benin. The differences observed between these different results would be due to the altitudinal gradients of the study areas but also to climatic factors.

Our study reveals that the abundance of parasitic species is variable with a dominance of *T. globiferus* (73.38 ± 37.48 tufts / ha). Our results are in contradiction with those of Amon *et al.* [35] who instead showed that *T. bangwensis* dominates in Côte-d'Ivoire and de Mony *et al.* [30] showing *T. ogowensis* dominates on the Logbessou plateau in Douala in Cameroon. This difference would be due to the fact that our study is focused on the hills while the previous studies were conducted in orchards. In the Sudano-Guinean Savannas of the Adamawa Cameroon, Mapongmetsem *et al.* [22] found five species of parasitic plants on woody plants. Likewise, Boussim [32] observed five species and three genera of parasitic plants on Shea butter in the savannas of Burkina Faso. For Soro *et al.* [7], *P. capitata* is abundant at 74.82% in the forest zone of the sub-prefectures of Gagnoa and Ourahadio, in Côte d'Ivoire. Our study shows that the frequency of Loranthaceae species varies according to height difference, with hilltops as the preferred altitude. These results corroborate those obtained by Jiofack *et al.* [1] who found that Loranthaceae species evolve with altitude in the Bafou group in Cameroon. These authors also reported that Loranthaceae species are characterized by their variable expansion from one level to another depending on the temperature fluctuation in altitude.

CONCLUSION

The Mandara Mountains present a very rich specific diversity, likely to be parasitized by Loranthaceae. In total, we inventoried 120 host species belonging to 34 families and 75 genera. Combretaceae and Mimosaceae are the most represented each with 13 species, either 10.83% for each family. *Acacia* is the most diverse genus with 10 species, or 8.33% of the host species. 18 genera or 24% of the flora are reported to be monospecific. These Mountains abound over their area a taxonomic diversity of Loranthaceae of four (4) genera (*Tapinanthus*, *Phragmanthera*, *Agelanthus* and *Globimetula*) and 7 species (*T. bangwensis*, *T. belvisii*, *T. globiferus*, *A. dodoneifolius*, *T. ophiodes*, *P. capitata* and *Globimetula braunii*). From the point of view of the ecological distribution of Loranthaceae species, *T. globiferus* is the most represented (125.66 ± 71.86 tufts / ha). It is followed by *A. dodoneifolius* (116.39 ± 53.74

tufts / ha). Then it is *T. ophiodes* which comes with an average density of 92.65 ± 51.06 tufts / ha; *T. belvisii* has an average density of 70.24 ± 53.63 tufts / ha. *P. capitata* has an average density of 57.74 ± 27.2 tufts / ha. *T. bangwensis* has an average density of 51.4 ± 33.24 tufts / ha. *G. braunii* is the least represented parasitic species with an average density of 45.57 ± 19.01 tufts / ha on the Mandara Mountains. The diversity and frequency vary according to the altitude and the slope of the hills. *T. globiferus* is most common in the Mandara Mountains, followed by *T. dodoneifolius*. These hemiparasites parasitize plants throughout their range in the Mandara Mountains. Knowledge of the diversity and altitudinal distribution of parasitic plants will contribute to their sustainable management on the Mandara Mountains in particular and on the Mountains of the World in general.

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