African Journal of Environmental Science and Technology Vol. 4(5), pp. 263-273, May 2010
Available online at http://www.academicjournals.org/AJEST
ISSN 1991-637X © 2010 Academic Journals

Full Length Research Paper

A study of the distribution and diversity of the Family Orchidaceae on some selected lava flows of Mount Cameroon

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Accepted 18 March, 2010

A survey was conducted between December 2005 and November 2006 to determine the diversity and distribution of the family Orchidaceae on three lava flows on Mount Cameroon and to relate species diversity and abundance to altitude, age and soil types. Thirty plots, each of 10 × 10 m were surveyed at low, mid and high altitudes on each lava flow. Forty nine orchid species belonging to 14 genera were identified, with the genera *Bulbophyllum* and *Polystachya* being the most represented. One unidentified species was encountered. A rare species, *Vanilla* sp, was identified *in situ*. *Bulbophyllum porphyrostachys* was the most abundant species and grew on the 1959 and 1999 aa lava flows. The least represented species were *Ansellia africana* and *Diphananthe bueae*. Diversity and distribution of the orchids depended on altitude, age and climate types of the various lava flows. Diversity was in the order 1922> 1999> 1959. Soil analyses revealed that important chemical parameters change with age and altitude of lava flows. These changes result in changes in diversity. Principal component analyses carried out to determine the orchid safe sites showed that, for any orchid establishment, their ecology, altitude and their association with lower plants (ferns mosses and lichens) are of vital importance.

Key words: Mount Cameroon, diversity, lava flow, micosites, orchids.

INTRODUCTION

The family Orchidaceae is the most diverse and advanced of the angiosperms with over 800 genera and more than 25.000 species, about 75% of which are found in the tropics (Bell, 1994). The word Orchid is derived from a Greek word *Orchis* meaning testicle because of the appearance of subterranean tubers of the genus *Orchis* (Batygina et al., 2003). Orchids are perennial herbs. The stems in most species, for example the genus *Bulbophyllum*, are thickened to form pseudobulbs that function in the storage of nutrients and water for use during dry periods. Orchids are either terrestrial (growing on soils), epiphytes (growing on plants but not parasitizing on them) or lithophytes (growing on rocks and sand grains). They produce dust like seeds (often thousands to a million) in dehiscent capsules that have three to six longitudinal slits. The seeds lack endosperms and so depend entirely on the establishment of a mycorrhizal association for their germination and establishment (Allen, 1992; Judd et al., 1999; Lambers et al., 1998; Sylvia, 1994).

The mycorrhizae structure of orchids (orchidaceous mycorrhizae) is fairly similar to the vascular arbuscular mycorrhizae (VAM) in that there is extensive growth of the fungus. However, in the family Orchidaceae the intracellular fungal tissue appears as coils rather than arbuscules. The fungi forming the mycorrhizae are Basidiomycetes, many of which belong to the genus *Rhizoctonia*. As soon as they have germinated, orchid seedlings which have little or no reserve depend on organic matter from the surrounding substrate via the mycorrizal fungus (Lambers et al., 1998). Leake (1994) concluded that the orchids are not saprophytic, but mycoheterotrophic (that is parasitic on the fungus). Mount Cameroon is located in the Gulf of Guinea in the South West Region of Cameroon (Fonge et al., 2005). The Mount Cameroon region has a very complex ecosystem

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because of its numerous and frequent disturbances including bush fires, logging, farming and most especially its numerous volcanic activities. The volcanic activities are usually accompanied by lava flows during which craters cough out molten magma. In the past 100 years Mount Cameroon has erupted eight times (1909, 1922, 1925, 1954, 1959, 1982, 1999 and 2000) hence it is considered as one of the most active volcanoes in Africa (Suh et al., 2003; Tchouto, 1996). Successive eruptions and disturbances in this region have made it possible for biologists to study its recolonization and different stages of succession in the area. The family Orchidaceae plays an important role in this restoration process. Orchids are considered as being quite peculiar in complex and heterogeneous ecosystems like the lava flows, and contribute significantly to increase the biodiversity of Mount Cameroon. Cable and Cheek (1998) labelled this family as the second most important family in the region after the Rubiaceae, and the genus *Bulbophyllum* as the most important in terms of their abundance. Detailed studies of the orchids and characterisation of their safe sites have never been conducted in the Mount Cameroon region. The objectives of this study are to record the species diversity and distribution of the family Orchidaceae, and to chemically characterise their soils in order to determine micro sites suitable for germination and establishment (safe sites).

MATERIALS AND METHODS

This study was carried out from December 2005 to November 2006. Three lava flows were selected based on accessibility and size of flow. These lava flows were: The 1922 lava flow located at 9°1'W, 4°1' N, 2 km south of Idenau and 10 km N of Debundscha (West of Mount Cameroon). This lava is basaltic and typically a pahoe - hoe lava (Fonge et al., 2005). The mean annual rainfall around the area is 9086 mm. The 1959 lava flow at Ekona (East coast) located at 9° 18'W and 4° 14' N. The lava emerged from a crater at about 1500 m above sea level and flowed down covering a distance of about 4 km to 490 m and stopped. It is 300 m wide around the vent, narrowing to a rounded base about 100 m wide. It is an aa lava type. The mean annual rainfall of this region ranges between 2085 and 2887 mm. The 1999 lava flow is found in Bakingili, West of Mount Cameroon. This flow is located at 4° 7' 97'' N and 9° 5' 87" N covering a distance of about 12 km from the crater. It is about 1.4 km wide and 20 m high and is an aa lava type. It ends 200 m from the sea (Suh et al., 2001; 2003) (Figure 1).

Sampling

Each lava flow was divided into three altitudinal ranges: low (100 - 400 m), mid (400-700 m) and high (> 700 m) altitudes. At each of these ranges, one 500 m long transect was laid and divided into 10 plots of 10 x 10 m placed at regular intervals of 45 m from each other. Within each plot, all individuals of the Orchidaceae were counted and recorded. Voucher specimens were prepared for later identification at the Limbe Botanic Garden Herbarium (SCA) and the Cameroon National Herbarium (YA). Rare species were identified *in situ*. The following parameters were examined to characterise safe sites: altitude, distance to species from nearest lava edge, topology of the plots (elevated, depressed, undulating or flat surface), orientation of exposure (N, S, W or E), substrate texture and position of epiphytes on trees, root ramification and association of orchid species with lower plants (moss, ferns or lichens).

At each altitudinal range, soil samples were collected at the flanks and centre and dried using standard procedures and the following soil components were determined: Soil pH was determined in a 2:5 (w/v) soil water suspension; organic carbon by chromic acid digestion and spectrophotometric analysis (Hanes, 1984). Total nitrogen was determined from wet acid digest (Buondonno et al., 1993), exchangeable cations (calcium, magnesium, and potassium) were extracted using the Mehlich-3 procedure (Mehlich, 1984) and determined by atomic absorption spectrophotometry. Available phosphorus was extracted by the Bray-1 procedure and analysed using the molybdate blue procedure described by Murphy and Riley (1962).

Data processing and analysis

Species diversities were determined using the Shannon-Weaver Diversity Index (H):

$$H = (Pi)(\log_n Pi)$$

Where Pi = ni/N; ni = number of individuals of species i; N = total number of individuals (Barbour et al., 1987). Safe sites data were analysed using the principal component analysis (PCA) in the Minitab (13.1) statistical package.

RESULTS

Species encountered

A total of 50 species distributed in 14 different genera were encountered in the study sites (Table 1). Forty-nine of these were identified at least to genera and consisted of 26 epiphytes, 14 lithophytes and 10 that were both epiphytes and lithophytes. One of the species growing both as epiphytes and lithophytes could not be identified. Thirty-six species in 12 genera were collected on the 1922 lava with 27 restricted only to the lava flow. Fifteen species in seven genera were found on the 1959 lava with eight restricted species. Twelve species in four genera were recorded for the 1999 lava with 5 restricted to it. All orchids in the 1922 lava flow were epiphytic while those of the 1959 and 1999 were lithophytic.

Distribution

In all, there were 17 species of *Bulbophyllum*, 14 *Polystachya*, 4 *Angraecum* species, and 2 species each of *Ancistrorhynchus, Chamaeangis* and *Habenaria*. *Ansellia, Calyptrochyllum, Liparis, Solenangis* and *Vanilla* were unispecific. The low range (0-400 m) had 28 species in 12 genera, with 10 restricted species. The mid range (400-700 m) had 33 species in 10 genera with 10 restricted species. The higher altitude (> 700 m) had 29 species in eight genera with five restricted to the range (Table 2).

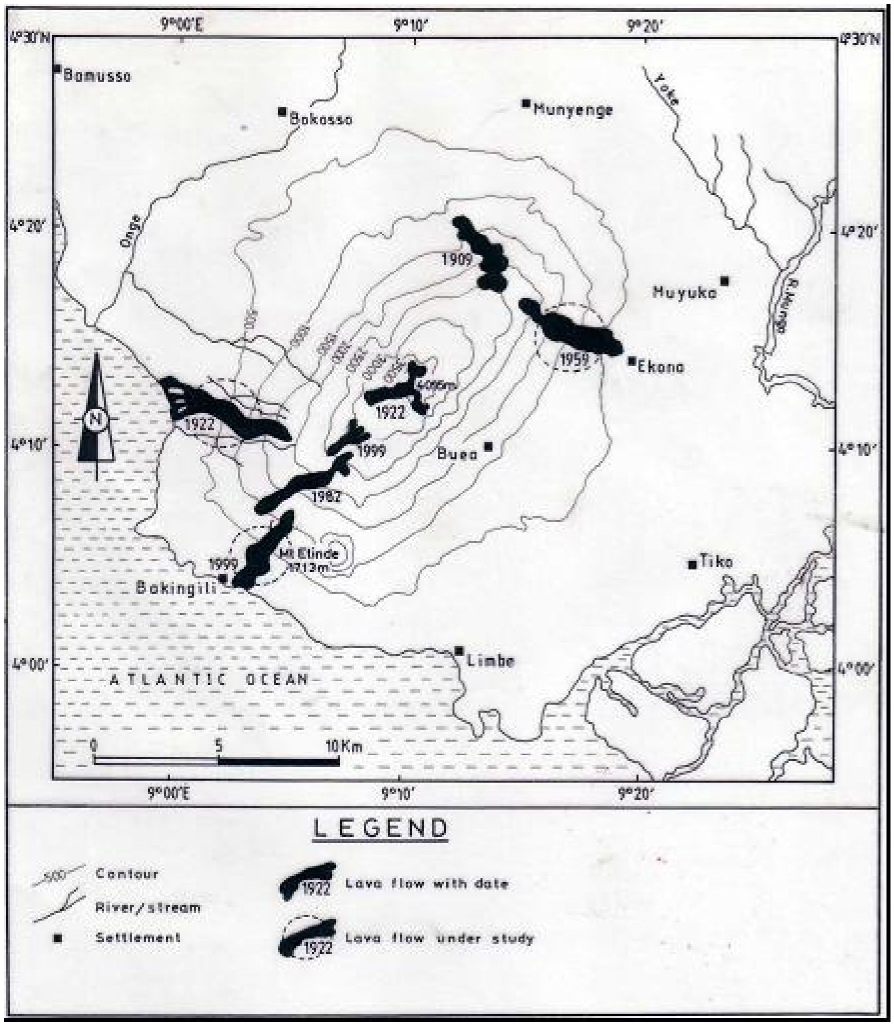

Figure 1. Map showing the different Lava flow sites on Mt Cameroon.
Source: Suh et al. (2003).

Overall, 11 species were common to all three altitudinal ranges with *Bulbophyllum porphyrostachys* (38.26%) and *Polystachya elegans* (13.9%) being the most abudant. The least abundant were *Ansellia africana* and *Diaphanathe bueae* with 0.02% relative abundance (Table 3). The highest density of orchid individuals was found in the mid altitude (with 2335 individuals counted), followed by the low altitude (1343 individuals) and then the high altitude (with 622 individuals). Species distribution along altitudinal ranges on each lava flow was continuous, except for *B. pumilum* that was fragmented, implying presence on the low and high altitude and absence on the mid altitude.

Diversity

The Shannon-Weaver diversity indices (H) for the different altitudes for the three lava flows are shown in Table 4. They show that the 1922 lava is the most diverse, with the mid altitude having the highest diversity value (2.46) while the least diverse is the 1959 lava flow at mid altitude (1.04). There is no low altitude in the 1959 lava flow since the lava ended at 490 m asl, while in the 1999 lava there are no orchids found at high altitude. The highest diversity at low altitude (1.96) was recorded on the 1999 lava flow.

Similarity levels

The most similar altitudinal ranges are the mid and high altitudes of the 1959 lava flow (54.6%) and the mid and high altitudes of the 1922 lava flows (40.82%) (Table 5). These higher similarity values occurred within the same lava flows. Taking the different lava flows, it could be seen that the highest similarity values were obtained at mid altitude of the 1922 lava and low altitude of 1999 (13.16%) and at low altitude of 1999 and high altitude of

Table 1. List of orchid species collected on the three lava flows of Mt. Cameroon.

No	Species name	1922 lava	1959 lava	1999 lava	Life form *
1	*Ancistrorhynchus capitatus* (Lindl.) Kuntze	+	-	-	Epi.
2	*Ancistrorhynchus serratus* Summerh	+	-	-	Epi.
3	*Angraecum augustipetallum* Rendle	+	-	-	Epi.
4	*Angraecum birrimense* Rolfe	+	-	-	Epi.
5	*Angraecum distichum* Lindl.	+	-	-	Epi.
6	*Angraecum eiclerianum* Kraenzl.	+	-	-	Epi.
7	*Ansellia africana* Lindl.	-	+	-	Litho.
8	*Bulbophyllum barbigerum* Lindl.	-	+	+	Litho.
9	*Bulbophyllum buntingii* Rendle	+	-	-	Epi.
10	*Bulbophyllum calvum* Summerh	+	-	-	Epi.
11	*Bulbophyllum calyptratum* Kraenzl.	+	+	+	Epi and Litho.
12	*Bulbophyllum.falcatum*(Lindl.) Rcbh.f.	+	+	+	Epi.
13	*Bulbophyllum flavidium* Schltr.	+	-	+	Epi.and Litho.
14	*Bulbophyllum. fuscum* Lindl.	+	-	-	Epi.
15	*Bulbophyllum. intertextum* Lindl.	+	-	-	Epi.
16	*Bulbophyllum josephii* (Kuntze) Summerh.	+	-	-	Epi.
17	*Bulbophyllum. lupulinum* Lindl.	+	-	-	Epi.
18	*Bulbophyllum.melinostachyum* Schlechter	-	-	+	Litho.
19	*Bulbophyllum. oreonastes* Rchb.f.	+	+	+	Epi and Litho
20	*Bulbophyllum.porphyrostachys* Summerh.	-	+	+	Litho.
21	*Bulbophyllum pumilum*(Swartz.) Lindl.	+	-	-	Epi.
22	*Bulbophyllum.schimperianum* Kraenzl.	-	-	+	Litho.
23	*Bulbophyllum simonii* Summerh.	+	-	+	Epiand Litho
24	*Bulbophyllum* sp	+	-	-	Epi.
25	*Calyptrochylum emarginatum* Schltr	-	+	-	Litho.
26	*Chamaeangis odoratissima* (Rchb.f.) Schltr.	-	+	-	Litho.
27	*Chamaengis sp*	+	-	-	Epi.
28	*Cyrtorchis chailluana* Hook.f.	+	+	-	Epi and Litho.
29	*Diaphananthe bueae* (Schltr) Schltr.	+	-	-	Epi.
30	*Graphorkis lurida* (Sw.) O.Ktze.	+	+	+	Epi and Litho.
31	*Habenaria procera* (Sw.) Lindl.	+	-	+	Epi and Litho.
32	*Habenaria sp*	-	-	+	Litho.
33	*Liparis epiphytica*	+	-	-	Epi.
34	*Polystachya adansoniae* Rchb.f.	+	-	-	Epi.
35	*Polystachya affinis* Lindl.	+	-	-	Epi.
36	*Polystachya bifida* Lindl.	+	-	-	Epi.
37	*Polystachya caloglossa* Rchb.f.	+	-	+	Epi and Litho.
38	*Polystachya. concreta* (Jacq.) Garay and Sweet	+	-	+	Epi and Litho.
39	*Polystachya. cultriformis* (Thouars) Lindl ex Spreng.	-	+	-	Litho.
40	*Polystachya elegans* Rchb.f.	-	+	-	Litho.
41	*Polystachya fulvilabia* Schltr.	+	-	-	Epi.
42	*Polystachya letouzeyana* Szlach.	+	-	-	Epi.
43	*Polystachya obanensis* Rendle	-	+	-	Litho.
44	*Polystachya odorata* Lindl.	-	+	-	Litho.
45	*Polystachya paniculata* (Sw.) Rolfe	-	+	-	Litho.
46	*Polystachya polychaete* Kraenzl.	+	-	-	Epi.
47	*Polystachya tessalata* Lindl.	-	-	+	Litho.
48	*Solenangis scandens* (Rolfe) Schltr.	+	-	-	Epi.
49	*Vanilla* sp	+	-	-	Epi.
50	Unidentified sp	+	-	-	Epi and Litho.

*Epi. = Epiphytes; Litho. = Lithophytes; + = Presence; - = Absence.

Table 2. Altitudinal distribution of genera and species of Orchidaceae on three lava flows of Mount Cameroon.

Lava flows									
Sites		**1922**			**1959**			**1999**	
Altitudes	**Genera**	**Species**	**Restricted**	**Genera**	**Species**	**Restricted**	**Genera**	**Species**	**Restricted**
Low range	10	22	6	-	-	-	04	13	04
Mid range	10	25	9	04	11	01	04	10	02
High range	07	16	3	06	14	04	-	-	-

Table 3. Number of individuals per species of Orchidaceae and their relative densities encountered at various altitudinal ranges of lava flows on Mount Cameroon.

	Lava flows														
Sites			**1922**					**1959**					**1999**		
Species	**Low**	**Mid**	**High**	**Total**	**Rd**	**Low**	**Mid**	**High**	**Total**	**Rd**	**Low**	**Mid**	**High**	**Total**	**Rd**
Ancistrorhynchus capitatus (Lindl.) Kuntze	6	-	-	6	0.14	-	-	-	-	-	-	-	-	-	-
Ancistrorhychus serratus Summerh	23	-	-	23	0.54	-	-	-	-	-	-	-	-	-	-
Angraecum augustipetallum Rendle	8	-	-	8	0.19	-	-	-	-	-	-	-	-	-	-
Angraecum birrimense Rolfe	10	12	2	24	0.56	-	-	-	-	-	-	-	-	-	-
Angraecum distichum Lindl.	-	-	3	3	0.07	-	-	-	-	-	-	-	-	-	-
Angraecum eiclerianum Kraenzl.	3	10	-	13	0.30	-	-	-	-	-	-	-	-	-	-
Ansellia africana Lindl.	-	-	-	-	-	-	1	-	1	0.02	-	-	-	-	-
Bulbophyllum barbigerum Lindl.	-	-	-	-	-	-	9	24	33	0.76	2	4	-	6	0.14
Bulbophyllum buntingii Rendle	16	-	-	16	0.37	-	-	-	-	-	-	-	-	-	-
Bulbophyllum calvum Summerh	-	5	-	5	0.12	-	-	-	-	-	-	-	-	-	-
Bulbophyllum calyptratum Kraenzl.	38	9	7	54	1.25	-	17	6	23	0.53	53	2	-	55	1.2
B. falcatum (Lindl.) Rcbh.f.	1	-	1	2	0.05	-	4	3	7	0.16	4	2	-	6	0.14
B. flavidium Schltr.	4	2	5	11	0.25	-	-	-	-	-	3	1	-	4	0.09
B. fuscum Lindl.	-	8	-	8	0.19	-	-	-	-	-	-	-	-	-	-
B. intertextum Lindl.	112	-	-	112	2.62	-	-	-	-	-	-	-	-	-	-
B. josephii (Kuntze) Summerh.	-	29	-	29	0.68	-	-	-	-	-	-	-	-	-	-
B. lupulinum Lindl.	29	9	-	36	0.84	-	-	-	-	-	-	-	-	-	-
B. melinostachyum Schlechter	-	-	-	-	-	-	-	-	-	-	7	-	-	7	0.16
B. oreonastes Rchb.f.	10	9	29	48	1.11	-	6	3	9	0.20	4	4	-	8	0.19
B. porphyrostachys Summerh.	-	-	-	-	-	-	1162	475	1637	38.26	2	7	-	9	0.20
B. pumilum (Swartz.) Lindl.	3	-	22	25	0.58	-	-	-	-	-	-	-	-	-	-
B. schimperianum Kraenzl.	-	-	-	-	-	-	-	-	-	-	3	-	-	3	0.07
B. simonii Summerh.	20	2	5	27	0.63	-	-	-	-	-	2	-	-	2	0.05
Bulbophyllum sp	-	2	-	2	0.05	-	-	-	-	-	-	-	-	-	-
Calyptrochylum emarginatum Schltr.	-	-	-	-	-	-	-	3	3	0.07	-	-	-	-	-
Chamaeangis odoratissima (Rchb.f.) Schltr.	-	-	-	-	-	-	-	16	16	0.37	-	-	-	-	-
Chamaengis sp	1	5	-	6	0.14	-	-	-	-	-	-	-	-	-	-
Cyrtorchis chailluana Hook.f.	-	-	116	116	2.69	-	-	60	60	1.39	-	-	-	-	-
Diaphananthe bueae (Schltr) Schltr.	1	-	-	1	o.o2	-	-	-	-	-	-	-	-	-	-

Table 3. Contd.

Graphorkis lurida (Sw.) O.Ktze.	33	8	1	42	0.97	-	15	3	18	0.42	93	3	-	96	2.23
Habenaria procera (Sw.) Lindl.	22	10	3	35	0,8	-	-	-	-	-	3	2	-	-	0.12
Habenaria sp	-	-	-	-	-	-	-	-	-	-	5	-	-	5	0.12
Liparis epiphytica	-	2	-	2	0.05	-	-	-	-	-	-	-	-	-	-
Polystachya adansoniae Rchb.f.	-	4	-	4	0.09	-	-	-	-	-	-	-	-	-	-
Polystachya affinis Lindl.	-	2	-	2	0.05	-	-	-	-	-	-	-	-	-	-
Polystachya bifida Lindl.	-	2	-	2	0.05	-	-	-	-	-	-	-	-	-	-
Polystachya caloglossa Rchb.f.	-	29	1	30	0.69	-	-	-	-	-	-	7	-	7	0.16
P. concreta (Jacq.) Garay and Sweet	6	81	2	89	2.06	-	-	-	-	-	-	16	-	16	0.37
P. cultriformis (Thouars) Lindl ex Spreng.	-	-	-	-	-	-	8	12	20	0.47	-	-	-	-	-
Polystachya elegans Rchb.f.	-	-	-	-	-	-	509	86	595	13.90	-	-	-	-	-
Polystachya fulvilabia Schltr.	-	-	94	94	2.19	-	-	-	-	-	-	-	-	-	-
Polystachya letouzeyana Szlach.	-	64	113	177	4.14	-	-	-	-	-	-	-	-	-	-
Polystachya obanensis Rendle	-	-	-	-	-	-	-	2	2	0.05	-	-	-	-	-
Polystachya odorata Lindl.	-	-	-	-	-	-	135	150	285	6.66	-	-	-	-	-
Polystachya paniculata (Sw.) Rolfe	-	-	-	-	-	-	34	82	116	2.71	-	-	-	-	-
Polystachya polychaete Kraenzl.	-	5	-	5	0.12	-	-	-	-	-	-	-	-	-	-
Polystachya tessalata Lindl.	-	-	-	-	-	-	-	-	-	-	4	-	-	4	0.09
Solenangis scandens (Rolfe) Schltr.	9	27	-	36	0.84	-	-	-	-	-	-	-	-	-	-
Vanilla sp	-	2	-	2	0.05	-	-	-	-	-	-	-	-	-	-
Unidentified sp	2	59	57	118	2.74	-	-	-	-	-	-	-	-	-	-

*¬¬- = Absent, RD = Relative density.

Table 4. Shannon-Weaver diversity indices of species encountered on three altitudinal ranges of the lava flows on Mount Cameroon.

Lava	Low altitude	Mid altitude	High altitude
1922	1.81	2.46	1.82
1959	-	1.04	1.57
1999	1.96	1.25	-

the 1922 lava flows (7.68%). The high altitude of the 1922 and mid altitude of 1959 lava flow had no similarity at all (0.00%), implying that they were no species common to both sites.

Characterization of safe sites of the Orchidaceae

Table 6 gives the results of the principal component analysis carried out to determine which parameters contribute to the establishment of orchids on a particular micro site. A multivariate correlation analysis to determine the influence of each parameter on the presence of orchid species on particular sites shows principal component (PC) 1 explaining 92.3% of the overall variance and PC 2 and 3 contribute 2.7 and 2.4%, respectively. The first three principal components put together explain 97.5% of the overall variation. PC 1 is most strongly affected by the epiphyte position on the tree, followed by root establishment and altitude. PC 2 was also strongly associated to their association with other plant species, followed by lava edge distance. The PC 3 is most strongly associated with ecology and root ramification. Thus for any orchid establishment, their ecology, altitude, root system and their association with other plants (lower plants) are of vital importance.

Table 5. Similarity matrix for the some altitudinal ranges of the three lava flows on Mount Cameroon.

%	Low 1922	Mid 1922	High 1922	Mid 1959	High 1959	Low 1999	Mid 1999
Low 1922	0	17.90	4.30	0.37	0.16	1.23	2.00
Mid 1922		0	40.82	0.44	0.29	13.16	3.67
High 1922			0	0.00	0.45	7.68	3.95
Mid 1959				0	54.61	0.78	030
High 1959					0	1.13	1.71
Low 1999						0	25.45
Mid 1999							0

Table 6. Eigen analysis of the covariance matrix for the distribution of Orchidaceae on some lava flows of Mount Cameroon.

Eigenvalue	250.530	7.380	6.620
Proportion	0.923	0.027	0.024
Cumulative	0.923	0.950	0.975
Variables	PC1	PC2	PC3
Altitude	0.061	-0.316	-0.576
Lava edge distance	0.029	-0.092	-0.107
Topology	0.010	-0.034	-0.023
Orientation	0.001	-0.010	-0.087
Association	-0.025	0.942	-0.241
Site establishment	-0.995	-0.002	-0.095
Root ramification	0.068	-0.047	-0.759
Rock type	-0.026	0.028	-0.067

All the *Bulbophyllum* species were mostly associated with mosses and ferns and found on disintegrating rocks, except *Bulbophyllum barbigerum* that preferred the lichens and were found on hard rocks. *Bulbophyllum* species were always found on inclined surfaces. *Graphorkis* and *Habenaria* preferred mosses and sand. *Solenangis, Angraecum,* and *Chamaeangis* preferred ferns and humidity and were mostly found under shades. *Calyptrochyllum emarginatum* and *Chamaeangis odoratissima* were often associated with mosses and always grew synergistically. *Polystachya* grew in association with ferns and lichens and if found on rock, preferred the hard ones. *P. letouzeyana* and *P. fulvilabia* preferred growing between branches. *Ancistrorhynchus* grew in association with ferns, which were abundant at the low altitude of the 1922 lava flow. Trees with smooth surfaces and bare rocks harboured no orchid species.

Soil properties of the lava flows

Table 7 gives results of analyses of soils collected at the three altitudes on the lava flows.

Organic carbon

This showed an increase with age and reduction with increasing altitude. Highest values were obtained at the left flank at 100 m asl and the centre at 1000 m asl of the 1922 lava. On this same lava, the lowest value for organic carbon was recorded at the centre at 100 m asl. On the 1959 lava, the centre at 1000 m asl had the highest reading while the right flank at 700 m asl had the lowest. On the 1999 lava, the highest reading was obtained at the left flank at 400 m asl while the lowest was at the right flank 700 m asl.

Total nitrogen

Nitrogen was highest on the 1922 lava and lowest on the 1999. Comparing the different sites on the 1922 lava, the left flank at 400 m asl had the highest total N while the centre at 100 m asl had the lowest. On the 1959 flow,

Table 7. Chemical characteristics of the 1922, 1959, 1999 lava flows on Mount Cameroon.

		1922			1959			1999		
Altitude	**Chemical properties**	**Left flank**	**Centre**	**Right flank**	**Left flank**	**Centre**	**Right flank**	**Left flank**	**Centre**	**Right flank**
100 m asl	pH	4.40	4.67	-	-	-	-	5.53	5.21	5.55
	Ca Meq/100 g	9.28	0.49	-	-	-	-	0.42	0.43	0.58
	Mg Meq/100 g	2.21	0.51	-	-	-	-	0.13	0.10	0.13
	K Meq/100 g	0.93	0.13	-	-	-	-	0.36	0.84	0.36
	P ppm	4.59	2.77	-	-	-	-	7.08	6.92	2.81
	Org C %	14.88	4.59	-	-	-	-	0.47	0.31	0.36
	Tot. N %	0.90	0.32	-	-	-	-	0.01	0.14	0.02
	C/N	16.54	14.33	-	-	-	-	11.78	21.53	20.12
400 m asl	pH	4.53	4.80	-	6.23	6.25	6.39	5.51	6.1	5.68
	Ca	12.71	3.81	-	0.94	1.74	1.03	0.50	0.53	0.72
	Mg	2.64	0.66	-	0.19	0.31	0.16	0.10	0.13	0.18
	K	0.42	0.18	-	0.43	0.43	0.24	0.27	0.49	0.39
	P	8.78	11.29	-	6.58	7.13	6.58	4.07	3.99	3.78
	Org C	17.17	9.95	-	0.79	1.22	1.5	0.49	0.22	0.15
	Tot. N	1.07	0.80	-	0.06	0.09	0.138	0.03	0.01	0.01
	C/N	15.96	12.43	-	12.40	13.03	10.56	18.70	23.60	21.90
700 m asl	pH	4.44	4.91	-	6.23	6.19	6.19	-	5.86	6.12
	Ca	3.07	1.66	-	0.43	1.24	0.84	-	0.75	1.14
	Mg	0.98	0.52	-	0.17	0.32	0.18	-	0.11	0.21
	K	0.32	0.17	-	0.32	0.24	0.42	-	0.30	0.40
	P	4.96	6.14	-	3.52	4.59	3.15	-	4.16	3.20
	Org C	13.29	9.69	-	0.62	2.43	0.50	-	0.13	0.07
	Tot. N	0.81	0.64	-	0.05	0.12	0.04	-	0.01	0.01
	C/N	15.74	18.08	-	13.98	20.70	13.82	-	23.96	13.25
1000 m asl	pH	5.17	4.67	-	6.18	6.12	5.92	5.73	5.36	-
	Ca	2.13	3.06	-	0.43	1.14	0.81	0.74	0.73	-
	Mg	0.75	0.57	-	0.14	0.21	0.13	0.12	0.09	-
	K	0.18	0.35	-	0.21	0.24	0.13	0.26	0.35	-
	P	3.20	4.49	-	4.32	3.92	2.56	10.26	3.73	-
	Org C	9.57	14.93	-	0.86	3.61	0.64	0.11	0.11	-
	Tot. N	0.61	0.65	-	0.03	0.14	0.03	0.01	0.01	-
	C/N	15.59	22.85	-	25.77	25.33	19.53	19.55	12.86	-

*- = lower range absent due to lava flow ending at 450m asl in 1959.

total N ranged from 0.03 - 0.14% with highest values obtained at the centre at 1000 m asl and lowest at the right flank also at 1000 m asl. Finally, on the 1999 flow the lowest values were recorded at high altitudes and the highest at the centre at 100 m asl.

Carbon/nitrogen ratio

The highest value for this ratio was recorded at high altitudes for all the lava flows. The lowest values were recorded at 100 and 400 m asl.

Phosphorus

Phosphorus did not show any clear pattern, that is, there were fluctuations of this element with respect to age and altitude. Highest values were obtained on the centre (400 m asl) on the 1922 and left flank (1000 m asl) of the 1999 flow. The lowest values were recorded at 1000 m asl at the right flank of the 1959 lava flow.

Potassium

Potassium decreased with age especially in the centres of the lava flows. It also decreased with increasing altitude. Differences between the sides were proportional to age difference.

Calcium

Values obtained for calcium showed an overall increase with age of lava, with the highest values at 400 m asl on the 1922 lava.

Magnesium

Values for magnesium were highest at low altitudes at 400 m asl and 100 m asl in the 1922 lava flow. The lowest value was recorded at 1000 m asl on the 1999 lava flow.

pH

There was little variation of pH with increasing altitude however the most basic soils were recorded in the 1959 lava flow while the most acidic were recorded in the 1922 lava flow.

DISCUSSION

Species distribution

The family Orchidaceae is the most dominant angiosperm family on both the 1959 and 1922 lava flows. Ndam et al. (2001) reported that the 1922 lava is in the third stage and moving toward the fourth stage of recolonization. During this period, about 90% of the Orchidaceae are supposed to have disappeared. Our results are therefore contrary to this rule. A possible reason for the pattern observed could be human disturbances (fuel wood harvesting) leading to the creation of favourable micro sites for the growth of orchids.

The distribution of orchids along the altitudinal gradient was continuous for all species except *Bulbophyllum pumilum* that was fragmented. This fragmented distribution may be attributed to illumination in accordance with Namwene (2005) who concluded that forest openings contribute to the maintenance of high biodiversity. *B. pumilum* was also found in abundance on the high altitude of the 1922 lava flow because of the savanna nature of the range.

Diversity of the Orchidaceae

The diversity of the Orchidaceae on the lava flows was in the order 1922> 1999> 1959. In terms of number of individuals, 1959 records the highest density. The low diversity of the 1959 lava (near Mpundu), though an aa lava type like the 1999 lava, could be attributed to frequent natural diebacks as a result of the climatic conditions. The 1959 lava is situated on the leeward side of the mountain and experiences lower amounts of precipitation compared to the 1999 and 1922 lava flows, which are found on the windward side of the mountain. Here the influx of the wet monsoon winds leads to high precipitation (Fraser et al., 1998).

The low annual rainfall on the 1959 lava flow causes frequent natural diebacks and fire incidents that consume large orchid communities. The genus *Diaphananthe* is represented by only one species *(D. bueae).*This species and *Polystachya letouzeyana* are endemic to Mount Cameroon (Szlachetko and Olszewski, 2001). *Bulbophyllum porphyrostachys* recorded the highest number of individuals in the entire study especially on the 1959 lava flow. This species has very large pseudobulbs that store large amounts of water giving it some resistance to fire and excessive heat. Hence it is competitively more successful on the 1959 lava. Although the 1959 lava flow had the highest number of individuals of the species, it was the least diverse. Richness and diversity are quite different although they are positively correlated with each other (Barbour et al., 1987). The lava flows are abundant with species of orchids, which were classified by Ndam (1998) as early and later colonizers, with the early colonizers dominated by

Bulbophyllum species and the later colonizers dominated by *Polystachya* and *Crytorchis* species. On the 1999 lava, seven species of *Bulbophyllum* species were recorded while just two of *Polystachya* species were found. On the 1959 lava, five *Bulbophyllum* species and five *Polystachya* species were found. Fonge (2004) reported in a survey conducted in 2002 that there were no orchid species found on the 1999 lava flow. Four years later, the diversity of the orchid species on this lava was higher than that of the 1959 lava flow. Species found on the 1999 lava could be regarded as early colonizers. These were mostly species of the genus *Bulbophyllum*. Although genus *Bulbophyllum* is represented by the highest number of species, the most abundant species was *Graphorkis lurida*. Only two and four individuals of this species were recorded in the 1999 and 1959 lava flows respectively.

Substrate parameters

Based on studies of soil properties, phosphorus is present only in rocks and lacks a significant gas phase. During ecosystem development on a new substrates like volcanic eruptions, all the phosphorus needed by plants come from primary minerals released slowly through weathering of rocks. On the contrary nitrogen is brought in with time through biological fixation and atmospheric deposition. Other rock-derived nutrients follow a similar pattern as phosphorus (Vitousek, 2004). As expected, the general nutrient status of the study sites increased with increasing substrate age and decreased with altitude.

This is not surprising since older sites have been undergoing weathering, biological fixation and atmospheric deposition much more than younger sites (Cochran and Berner, 1996). Lava fronts and flanks generally had more nutrients than the centre locations. Orchid populations were seen to concentrate more on the centre of the lava, which had low values of soil nutrients than at the edges. This shows that the species strive very well with a minimum amount of nutrients.

The influence of climate on weathering, decomposition, mineralization, leaching, colonization and succession also has a rule to play on the status of soil nutrients. Excessive rainfall on the 1922 lava has enhanced leaching while rainfall deficiency on the 1959 lava flow retards the weathering process. Some nutrients, (phosphorus) were higher on the 1999 than on the 1959 lava flow similar results have been reported by Chadwick et al. (1999). There are generally high levels of P, Ca and Mg in the leaves of epiphytes (Trezeder et al., 1995). The vascular epiphytes such as the orchids have a rooting system that takes advantage of what is known as epiphyte mat formed by non-vascular epiphytes such as ferns, mosses, liverworts and lichens, which capture wind borne soils, blowing dust, aerial fallouts, rain and mist (Zotz and Hietz, 2001). Epiphytic orchids could also derive nutrients from ground-rooted plants through leaching or decomposition, dinitrogen fixation, and to a lesser extent, remains of animals as well as mineral organic matter imported by them (Benzing, 1990). Animals that associate with epiphytes are mostly ants. In many cases these live in cavities formed by plant organs, or nests of colonies and provide the rooting substrate for the plants (Stuntz et al., 2002). *Dischidia major* (Rubiaceae) derives almost 30% of its nitrogen from debris deposited by ants inhabiting its cavities (Trezeder et al., 1995). Similarly, lithophytes growing naturally on rocks derive their nutrients from the atmosphere, rain water, litter, humus and even their own dead tissue (Brickell, 1999). Both epiphytic and lithophytic species of orchids have aerial roots that are covered with velamen, which trap atmospheric gases and convert them to nutrients required for growth (Baker, 2005). The high diversity of the 1922 and 1999 lava flows is mainly influenced by climatic conditions. Water is the most relevant abiotic constraint for growth and vegetative function of epiphytes while other factors such as nutrient availability or irradiation, are generally of less importance (Zotz and Hietz, 2001). Since these lava flows are situated close to the second wettest place in the world (Debundscha), amount of rainfall may account for their high diversity (Fraser et al., 1998). It should be noted that orchids do not exist independently. They always depend on some lower plants such as lichens, ferns and mosses. No orchid species was recorded at high altitude on the 1999 lava flow. The rocks of this range were practically bear, crispy and highly porous. The presence of lower plants plays important roles in the establishment of an orchid plant. The lower plants act as "keystone" species of the Orchidaceae. Keystone species are those on which other species depend for their survival, the absence of which would therefore lead to the absence of a range of other species (Given, 1994). It was thus observed that trees, such as the *Ficus* sp., and rocks with smooth surfaces, did not carry any orchids.

Conclusion

In the Mount Cameroon lava flows, the diversity and distribution of the family Orchidaceae change with age and altitudinal gradients. The species strive well with a minimum amount of nutrients. This is why they prefer the middle of flows with fewer nutrients than the edges which have more nutrients. Orchid establishment is mostly dependent on altitude, root establishment and lower plants that aid to trap their seeds and aerial fallouts, providing favourable micro sites for growth. Also, the growth of an orchid on a given micro site depends on the quality of the site and the probability of a viable seed reaching it. Species diversity of the Orchidaceae on lava flows of Mount Cameroon is dependent on climatic type. More rainfall leads to higher orchid diversity.

Just as the relative importance of species varies with space, so their pattern of abundance may change with time. In either case, a species will only occur where and when (i) it is capable of reaching a location, (ii) appropriate conditions and resources exist there and (iii) competitors and predators do not preclude it. The Mount Cameroon region is rich in orchid species having about 147 species with the genus *Bulbophyllum* being the most important in terms of number of species. *Bulbophyllum porphyrostachys* is the most represented orchid species in the entire study.

ACKNOWLEDGEMENTS

Special thanks go to the University of Buea and the University of Dschang for their facilities, the Limbe Botanic Garden Herbarium (SCA) and the Cameroon National Herbarium (YA) where plant identities were validated, and IITA Yaounde where soil analyses were conducted.

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