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Diversity of agaricoid mushrooms in the Afromontane forests of Kedjom-Keku, North West Region, Cameroon

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Abstract

A study of the diversity of gill mushroom was carried out in the primary and secondary forests of Kedjom-keku montane forest, North West region, Cameroon. The purpose of this study was to conduct a comparative study of the specific diversity of fungi collected in these two forest types. Out of the two hundred and fifteen samples collected, there were strictly twenty-five species in the primary forests, twenty-one species in the secondary forests and fourteen species were common to both forests. In the primary forest, the most represented genera were *Mycena*, *Crepidotus*, *Pluteus*, *Crinipellis* and *Agaricus,* and the most abundant families were Mycenaceae, Agaricaceae, Marasmiaceae, Inocybaceae, Psathyrellaceae, while, the most represented genera in the secondary forest were *Mycena, Gymnopus*, *Agaricus*, *Pluteus*, *Crepidotus* and the most abundant families were Mycenaceae, Agaricaceae, Marasmiaceae, Psathyrelaceae and Omphalotaceae. In terms of ecology, 64% of the species was collected on wood, 40% from soil, 8% on wood and soil, 1% on litter and wood. All species collected were saprotrophs. The trend of this initial study showed that the primary forest had a higher biodiversity of agaric fungi though not significantly different from that of the secondary forest. This makes this forest ideal for the conservation of macrofungi.

Key Words – Altimontane – Central Africa – Mycoflora – Taxonomy – Vegetation

Introduction

The kingdom fungi are made up of heterotrophic eukaryotic organisms with vegetative structures called mycelia; they feed by absorption of nutrients from their environment. Due to their ecological and physiological diversities, they constitute a significant living component of all ecosystems (Seen-Irlet et al. 2007). Among these fungi, macrofungi are distinguished by having spore-bearing structures named sporocarps or fruiting bodies visible to the naked eyes. Among macrofungi are agaricoid fungi commonly called “Agaric” which are an important group with fruiting body characterized by the presence of a pileus or cap, a stipe or stalk and the hymenophore made of lamellae or gills underneath the pileus (Lodge et al. 2004, Hibbett & Binder 2002).

Cameroon as Africa in miniature hosts almost all types of vegetations found in tropical Africa including tropical rain forest, tropical savannah, steppes and prairies, lowland forests, sub-mountain

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forests and mountain forests. The latest type of forest in the Western highlands of Cameroon is part of the Afromontane forest which in Western Africa, are restricted to the Cameroon volcanic line and the Guinea highlands (Abiem et al. 2020). Afromontane forests are typically small and fragmented forest occurring above 1500 m of altitude within a grassland matrix. These forests grow in areas of dense population putting them under human pressures through agriculture, fire, and grazing, jeopardizing their rich biodiversity which needs to be conserved (Cordeiro et al. 2007).

Effective conservation of any forest ecosystem requires assimilation of knowledge concerning all its biological components including fungal community in terms of ecology and diversity which is usually looked down upon during forest ecosystem management despite the role they play in ecosystem processes (Lodge et al. 2004). Western highlands of Cameroon possess the largest remaining Afromontane forests in West Africa within which Bamenda highlands being one of its most diverse important part host several endemic plant and animal species (Ingram & Nsom 2007, Tropek & Konvicka 2010). Kedjom-Keku forests with high level of endemism in flora and fauna host many endemic birds, plants, amphibians, small mammals and reptiles (Cheek & Csiba 2000). These forests are potentially rich in other organisms such as fungi whose diversity and ecology have not yet been documented while the numerous endemic species could be the precursor of a potential rich fungal diversity with putative new species.

In Cameroon, Douanla-Meli (2007) estimated that there are 50000 species of fungi of which less than 3% were documented. So far, efforts are made to fill the gap on the lack of data cornering the diversity of these organisms. However, the majority of studies conducted in Cameroon have been done in the low-land forest zone (Onguene & Kuyper 2012, Njouonkou et al. 2013, Roberts 1999, 2000, 2001, Roberts et al. 2006, Douanla-Meli 2007, Egbe et al. 2013). Very few works concern the sub-montane and montane forests; these include that of Kinge et al. (2017) in the Awing forest reserve made of eucalyptus forest plantation and Teke et al. (2018) in the Kilum-Ijim mountain forest. Till now, no study addresses both the diversity and response of mushrooms to forest evolution in these particular forest types in the North West Region of Cameroon. More generally, only one study has been documented on the diversity of fungi in tropical Africa and especially in the dry Afromontane forests of Ethiopia (Dejene et al. 2017). The present study aims to document the diversity of gill fungi in the Afromontane forests of Cameroon, especially in the Kedjom-keku forest; and to estimate their variability between the primary and secondary mountain forests.

Materials & Methods

Study site

Kedjom-keku is located in Tubah Subdivision, Mezam division, North West Region of Cameroon. It is located at latitude 6° 07' 00" N and longitude 10° 15' 00" E and covers a land area of 108 Km^2 (Angong 2005). It is surrounded to the west by Finge, to the Southwest by Bambui, to the South by Bambili, East by Kedjom-Ketingo and South east by Sabga (Fig. 1). The climate is tropical with a dry and a rainy season, the average precipitation is 2500 mm/year (Ndenecho 2011). The temperature ranges between 13^{o}C and 22^{o}C with relative humidity above 86%. Its vegetation is composed of montane forest patches separated by grass land patches with some regrowth savanna and some woodland in certain areas (Sedláček et al. 2007). The forest woody flora includes 107 species of plants including 74 trees, 28 shrubs and 5 lianas, belonging to 83 genera and 58 families dominated by Rubiaceae and Asteraceae (Tsitoh & Bechem 2019). The soil is volcanic and sandy which makes it very rich and favorable to agriculture practiced by sedentary inhabitants while the nomadic cattle rearers are the Bororo.

Samples collection and identification

Two permanent plots of 50 m × 50 m each were established in secondary forests at Abongphen I (06° 55' 72" N and 10° 29' 27"E, 1950 m altitude) and primary forest at Abongphen II (06° 74' 12" N and 10° 29' 98" E, 2254 m altitude). Samples were collected in these permanent

plots at an interval of 15 days during a period of 3 months (from mid-March to mid-June in 2018). During each collection trip, all the surface of each plot was totally explored and all gill mushrooms found were collected. Each specimen found was photographed in its natural environment before being carefully and entirely collected. These samples were identified to the species or genus level using their macroscopic features such as stipe (position, shape, context, structure and color of the surface, dimensions and form of the base), pileus (shape, dimension, surface structure and color and form of the margin), gill (attachment, margin, spacing; color, width) as well as spore print color. Also, microscopic features such as spores, basidia and cystidia were observed using a light microscope according to Lodge et al. (2004) and Eyi-Ndong et al. (2011).

The samples were dried in a dehydrator at 45°C for 12-24 hours and packaged in separate envelopes and put in sealed polythene bags to make an herbarium conserved at the Biological Science laboratory of the Faculty of Science, of the University of Bamenda. Identification of the specimens was based on morphological characteristics using mainly literature on mushrooms especially those on Tropical African agaric mushrooms including Pegler (1977), Eyi-Ndong et al. (2011), Kamou et al. (2017) and the website Fungus Flora of Tropical Africa (FFTA-online). To update the nomenclatural taxa and authors names, the website Index Fungorum was consulted.

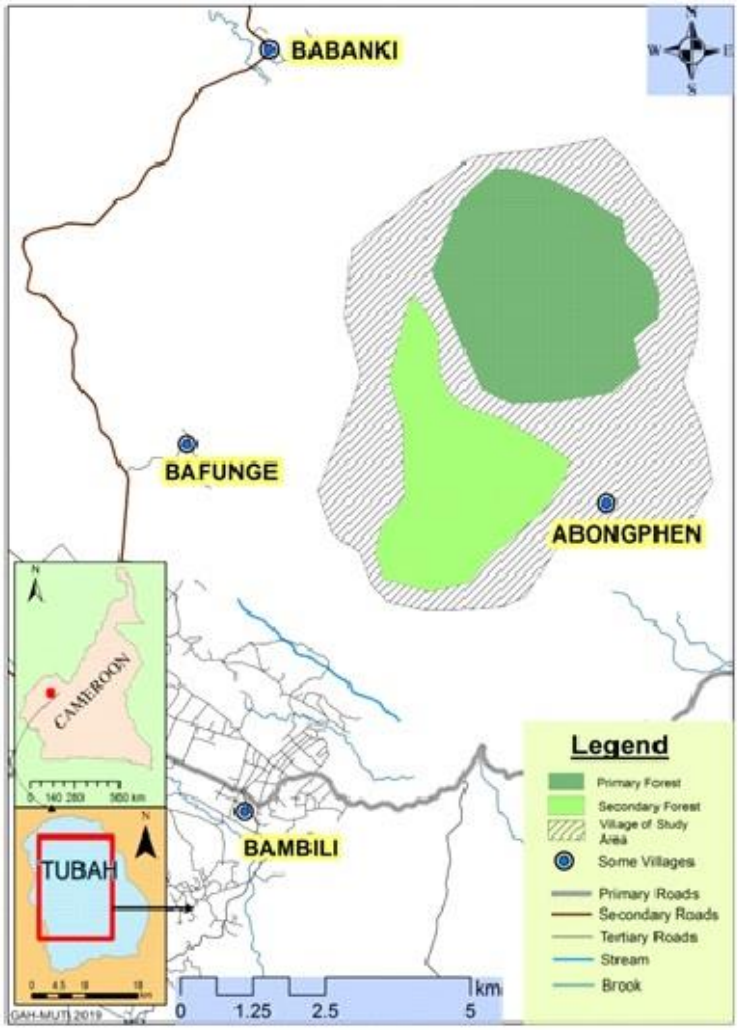

Fig. 1 – Map of study area.

Comparison of fungi diversity in the Primary and Secondary forests

To compare the fungi diversity in the two forests, species richness, genera richness and family richness as well as Jaccard similarity Index (Ji) (Jaccard 1912) were calculated. The species richness is the number of species in a given plot; while the genera and family richness are

respectively the number of genera and family in a plot. The genera diversity index (GDI) which is the ratio between the number of species and the number of genera of a community (Evrad 1968) was calculated. Normally the value of this index is superior or equal to 1. When the ratio is high then the collection area is relatively poor in genera with many species, if it is low (closer but not inferior to 1), the area is relatively rich in genera with fewer species. The GDI was used here to compare the ratio of species to genera in both forest types.

The Jaccard similarity index (Ji) was calculated to compare the similarity of species between the two forests. It was estimated according to the formula below; Ji is the Jaccard similarity index; a number of species in plot a, b number of species in plot b and c the number of common species in plots a and b). If Ij >50%, the two plots are similar and if Ij <50%, there is no similarity among the two plots (Jaccard 1912).

$Ji = (c/(a+b+c)) \times 100$

Ecological Studies and frequency of occurrence

During sample collection, the information on the substrate (soil, wood and litter) of each specimen found was noted. After identification and using documentations, (Ye et al. 2019, Lodge et al. 2004) the mode of life (parasitic, saprophytic and mycorrhizal) of each species was determined. To have an idea on the phenology of different species, the frequency of occurrence of each taxon collected during the six collection trips in the different communities was calculated. This was done by determining the percentage of the number of collection where the species was found during the 6 collection trips. Then the species were regrouped per relative frequency classes of occurrence adopted from Raunkiear (1934) (Table 1).

Table 1 Classes of occurrence of species

Class	Frequency	Signification (qualification of species)
I	0-20%	Very rare
II	21-40%	Seldom present
III	41-60%	Often present
IV	61-80%	Mostly present
V	81-100%	Commonly or regularly present

Results

Agaricoid fungal diversity in permanent plots

Out of the 215 samples collected, 60 species distributed in 33 genera, 15 families and 2 orders were identified in both primary and secondary afromontane forests of Kedjom keku (Table 2). Among these taxa, 76% (46 species) were identified to the species level while 23% (14 species) were identified to the genera level. Fig. 2 presents some of the collected species. The most represented genera were *Mycena* (7), *Crepidotus* (4), *Psathyrella* (4), *Agaricus* (3), *and Pluteus* (3). The dominant families were Mycenaceae (12), Agaricaceae (8), Psathyrellaceae (7), Marasmiaceae (5) and Inocybaceae (5).

Comparing the diversity between the primary and secondary forests of Kedjom-Keku

Taxonomic Diversity

Species richness

The primary forest had higher number of species (39) while in the secondary forest, 35 species were recorded (Fig. 3a). Out of the 60 species collected, 25 were collected only (strictly) in the primary forest and 21 only in the secondary forest (Fig. 3b). Fourteen species (common species) were collected in both primary and secondary forests among which: *Mycena myxocaulis*,

Crepidotus applanatus, *Trogia* aff. *venenata*, *Mycena leaiana* var. *australis*, *Mycena cyanocephala*, *Mycena holoporphyra*, *Cyptotrama asprata*, *Pluteus cervinus*, *Lepista nuda*, *Gymnopus iocephalus* and *Favolaschia thwaithesii*. The Jaccard similarity index between the two forests was 23.33% indicating that their mycoflora communities are not that similar since the similarity less than 50%.

Table 2 List of collected species of Agaricoid fungi in forests of Kedjom-keku

Species	Frequency class	Substrate			Forest type
		Soil	Wood	Liter	
Agaricaceae (Agaricales)					
Agaricus aff. *impudicus* (Rea) Pilát	II	×			SF/PF
Agaricus sp. 1	I	×			SF
Agaricus sp. 2	I	×			PF
Chlorophyllum abruptibulbum (R. Heim) Vellinga	I	×			PF
Leucoagaricus bulbillosus Heinem.	I	×			PF
Leucoagaricus rubrotinctus (Peck) Singer	I		×		PF
Ripartitella alba Halling & Franco-Mol	I	×			SF
Ripartitella cf. *brasiliensis* (Speg.) Singer	III		×		PF
Bolbitiaceae (Agaricales)					
Conocybe apala (Fr.) Arnolds	I		×		SF
Conocybe tenera (Schaeff.) Fayod	I	×			PF
Crepidotaceae (Agaricales)					
Crepidotus applanatus (Pers.) P. Kumm.	V		×		SF/PF
Crepidotus cf. *variabilis* (Pers.) P. Kumm.	I		×		PF
Crepidotus ehrendorferi Hauskn. & Krisai	I		×		SF
Crepidotus nephrodes (Berk & M.A Curtis) Sacc	I		×		PF
Inocybaceae (Agaricales)					
Inocybe sp.	I	×			PF
Marasmiaceae (Agaricales)					
Crinipellis pseudostipitaria Singer	II		×		PF
Crinipellis scabella (Alb. & Schwein.) Murrill	I		×		PF
Marasmius epiphyllus (Pers.) Fr	I		×		SF
Marasmius rotalis Berk. & Broome	III		×		SF\PF
Tetrapyrgos nigripes (Fr.) E. Horak	V		×		SF\PF
Trogia aff.*venenata* Zhu L. Yang, Y.C. Li & L.P. Tang	IV		×		SF/PF
Trogia cf. *cantharelloides* (Mont.) Pat.	I		×		PF
Trogia infundibuliformis Berk. & Broome	I		×		SF
Mycenaceae (Agaricales)					
Favolaschia thwaitesii (Berk. & Broome) Kuntze	V		×		SF/PF
Hydropus sp.	I		×		SF
Mycena cf. *cyanocephala* Singer	V	×	×		SF/PF
Mycena holoporphyra (Berk. & M.A. Curtis) Singer	V	×			SF/PF
Mycena leaiana var. *australis* Dennis	V	×	×		SF/PF
Mycena myxocaulis Pegler	IV	×	×		SF/PF
Mycena sp. 1	II		×		SF
Mycena sp. 2	II		×		SF
Mycena sp. 3	I		×		PF
Omphalotaceae (Agaricales)					
Gymnopus cf. *dryophilus* (Bull.) Murill	III	×			SF
Gymnopus iocephalus (Berk. & M.A.Curtis) Halling	III	×			SF/PF
Gymnopus sp.	III		×		SF
Paxillaceae (Agaricales)					
Paxillus sp.	I	×			SF
Physalacriaceae (Agaricales)					
Flammulina aff. *fennae* Bas	I				SF
Cyptotrama asprata (Berk.) Redhead & Ginns	IV		×		SF/PF
Oudemansiella canarii (Jungh.) Höhn.	I		×		SF
Ponticulomyces sp.	I		×		PF

Table 2 Continued.

Species	Frequency class	Substrate			Forest type
		Soil	Wood	Liter	
Plurotaceae (Agaricales)					
Hohenbuehelia angustata (Berk.) Singer	III		×		PF
Pluteaceae (Agaricales)					
Pluteus albostipitatus (Dennis) Singer	II	×			SF
Pluteus cervinus (Schaeff.) P. Kumm.	IV	×	×		SF/PF
Pluteus aff. *tomentosulus* Peck	I	×			PF
Polyporaceae (Polyporales)					
Lentinus retinervis Pegler	IV		×		PF
Psathyrellaceae (Agaricales)					
Coprinellus micaceus (Bull.) Vilgalys, Hopple & Jacq. Johnson	I	×			PF
Coprinellus disseminatus (Pers.) J.E. Lange.	I		×		SF
Parasola plicatilis (Curtis) Redhead, Vilgalys & Hopple	II		×	×	PF
Psathyrella atroumbonata Pegler	I		×		SF
Psathyrella candolleana (Fr.) Maire	I	×			PF
Psathyrella cf. *pusilla* Pegler	I		×		SF
Psathyrella sp.	III	×			PF
Strophariaceae					
Hypholoma acutum (Sacc.) E. Horak	I		×		PF
Hypholoma fasciculare (Huds.) P. Kumm	I	×			SF
Protostropharia semiglobata (Batsch) Redhead, Moncalvo & Vilgalys	I				PF
Pholiota spumosa (Fr.) Singer	I		×		SF
Tricholomataceae					
Lepista nuda (Bull.) Cooke	IV	×	×		SF/PF
Leucopaxillus sp.	I	×			SF
Collybia sp.	I		×		PF
Tricholoma sp.	I	×			PF

Abbreviations: SF = Secondary forest, PF = Primary forest

Genera richness

According to Table 3, the number of genera is relatively higher in the primary forest than in the secondary forest. In contrast, the GDI is higher in the secondary compared to the primary forest showing that in percentage, the secondary forest had many genera with more than one species while the primary forest had many genera with a single species. *Mycena* is the dominant genera in both forests followed by *Crepidotus, Psathyrella, Agaricus* and *Pluteus* in the primary forest and *Gymnopus*, *Crepidotus*, *Psathyrella*, *Agaricus* and *Pluteus* in the secondary forest (Fig. 4).

Family Richness

The number of family in both forests is quite the same with 14 and 13 in the primary and secondary forests respectively. The number of species per families varies from 1 in Polyporaceae, Paxillaceae, Plurotaceae to 9 in Mycenaceae. In the Primary forest, Mycenaceae, Agaricaceae, Psathyrelaceae, Inocybaceae, and Marasmiaceae were dominant while Mycenaceae, Psathyrellaceae, Physsalacriaceae, Marasmiaceae and Omphalotaceae were dominant in the secondary forest (Fig. 5).

Frequency of occurrence of species

The bar chart of classes of occurrence (Fig. 6) showed a double reverse J shape for primary and secondary forests typical of the normal Raunkiaer frequency diagram. Classes III, IV and V were equal in the primary forest. The various class of occurrence of the different species is presented in Table 2, giving an idea on their phenology despite the short collection period. Class I had 17 and 16, class II 3 and 4, class III had 6 and 4, class IV had 6 and 5 and class V 6 and 6 species in the primary and secondary forests respectively. Hence, the very rare species collected

only once (class I) were the most numerous in the forest while the common or regular species (class V) were fewer in number but highest than those seldom present. *Leucoagaricus ribrontinctus, Crinipeliis scabella, Crepidotus nephrodes, marasmius epiphyllus, Pholiota spumosa, Coprinellus disseminatus, Psathyrella athrombonata,* were among species of class I, and *Mycena holoporphyra, Mycena cyanocephala, Mycena laena, Favolaschia thwaitesii, Marasmiellus nigripes, Crepidotus aplanatus* were among those of class V.

Fig. 2 – Pictures of some species collected. a *Agaricus* aff. *impudicus*. b *Ripartitella* cf. *brasiliensis*. c *Crinipellis pseudostipitaria*. d *Favolaschia thwaitesii*. e *Mycena* cf. *cyanocephala.* f *Mycena leaiana* var. *australis*. g *Mycena myxocaulis*. h *Trogia infundibuliformis*. i *Gymnopus iocephalus*. j *Cyptotrama asprata*. k *Ponticulomyces* sp. l *Lentinus retinevis.*

Table 3 Genera diversity index of the primary and secondary forests

Forest type	PF	SF
Number of species	39	35
Number of genera	25	20
GDI	1.56	1.75

Abbreviations: PF = Primary forest, SF = Secondary forest

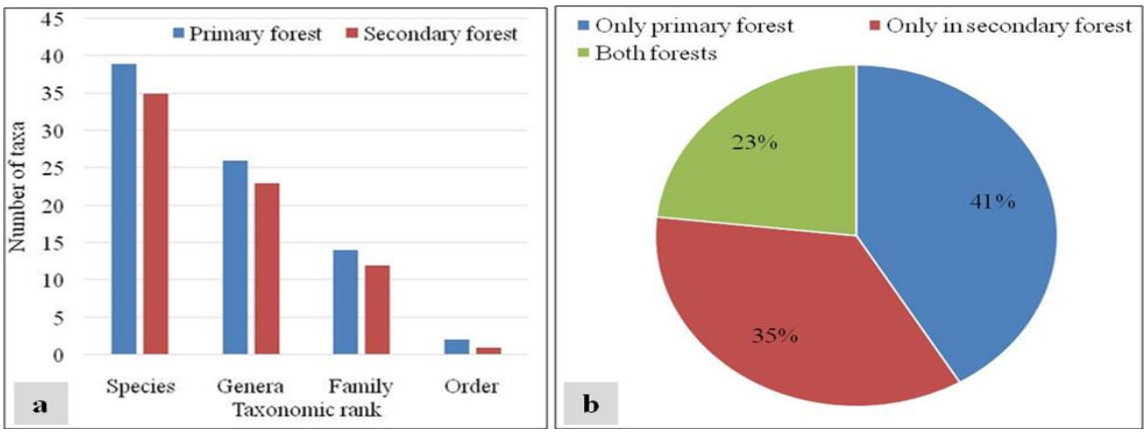

Fig. 3 – Variation of the number of taxa in both forests. a Number of taxa in some taxonomic rank. b Percentage of species per forest type.

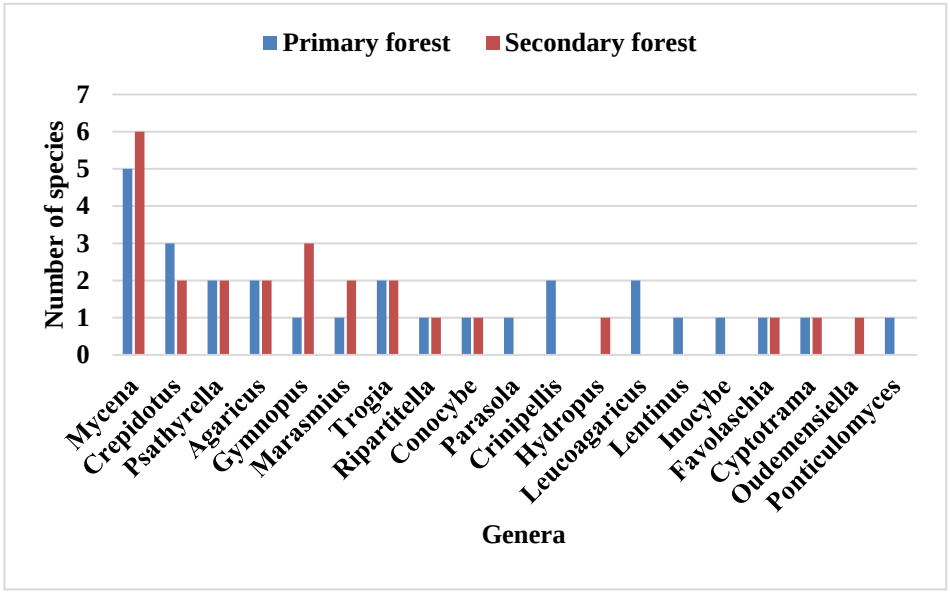

Fig. 4 – Number of species per genus of each plot in the primary and secondary forest.

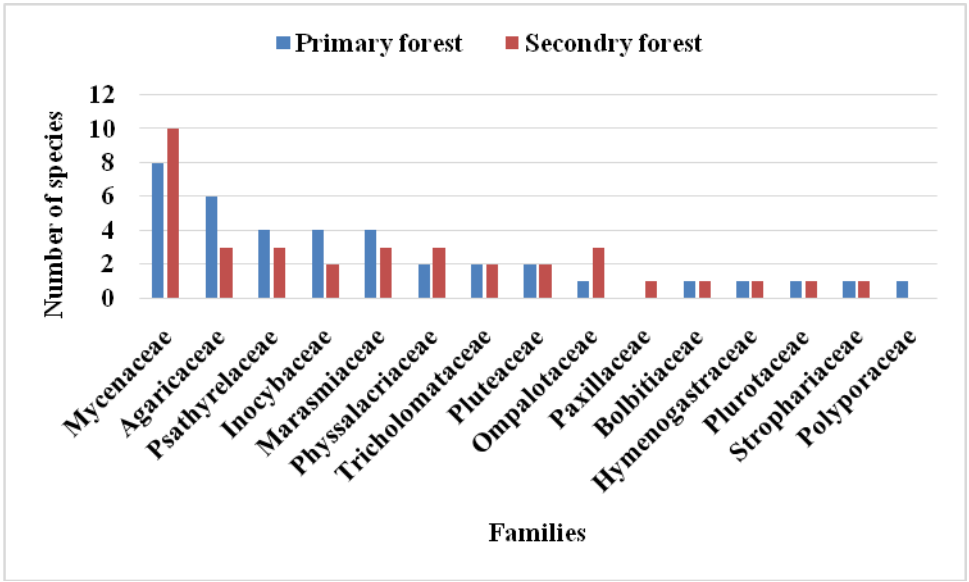

Fig. 5 – Number of species per family of the primary and secondary forests.

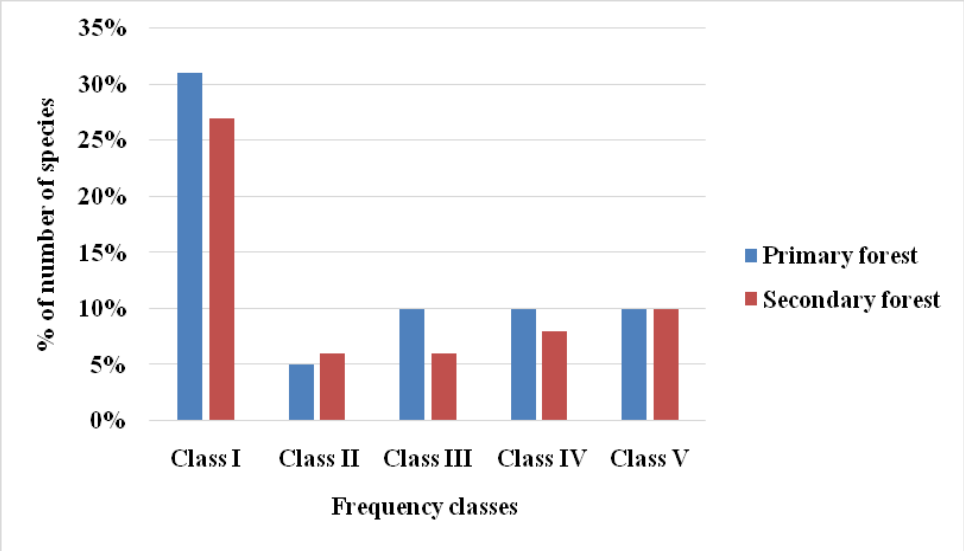

Fig. 6 – Percentage of species per classes of frequency occurrences.

Discussion

Despite the short period of collection, the Agaricoid mushroom diversity in Kedjom-keku forest seemed to be higher compared to the that obtained in other areas of the western highlands of Cameroon including the *Eucalyptus* Awing Forest Reserve and the Kilum Ijim montane forest where Kinge et al. (2017) and Teke et al. (2017) obtained respectively 53 and 6 agaricoid species respectively. The number of species is also superior to that of the dry Afromontane forests of Ethiopia where Dejene et al. (2017) obtained 61 taxa including Polyporales and Boletales. However, this number is inferior to that obtained by Njouonkou et al. (2020) in the Melap forest reserve made of *Eucalyptus* and *Pinus*. In the above studies Agaricaceae, Marasmiaceae, and Psathyrellaceae were also among the dominant families.

Concerning the species richness, the difference between the diversity of the two forests was not significant although there was a difference of four species between the two forests. The relative dominance of the diversity in the primary forest could be due to environmantal conditions such as organic matter availability, moisture, light intensity and temperature that have strong effects on macrofungi diversity (Ye et al. 2019). In fact, according to Gilbert et al. (2002), primary forests generally experience less anthropogenic disturbance which create favorable conditions for fungi development and fructification. However, according to Lodge et al. (2004), it needs several years of collection or monitoring to identify almost all species of a study area. Therefore it would need many years of collection to have suitable data for an efficient comparison of Agaric fungi diversity in both types of this montane forest.

According to this result, in Kedjom-keku montane forest, each identified genus has averagely 1.65 species; thus, majority of the genera are represented by less than 2 species; this was also observed in *Eucalyptus* and *Pinus* plantation forest of Melap (Njouonkou et al. 2020). The dominant genera of this study were found to be among the dominant genera in other studies in tropical areas (Pegler 1977, 1983). Same was the result in Kinge et al. (2017) and Egbe et al. (2013). The genus *Mycena* which was the richest genus in this study is one of the most species-rich genera worldwide being the sixth species rich genera recorded in many countries of the world (Kirk et al. 2008, O'Hanlon & Harrington 2011); this is also in line with the findings of Swapna et al. (2008) in India where they obtained this genus among the richest genera in terms of species number. Here, *Mycena leaiana* and *M.* cf. *cyanacephala* are collected for the first time in Cameroon and even in tropical Africa. Members of the dominant families in this study are able to grow anywhere provided conditions are favorable (Uzun 2010); they have been reported to be among the richest families in various studies in the tropical region (Swapna et al. 2008, Gogoi & Parkash 2015, Apollos et al. 2017, Kinge et al. 2017, Teke et al. 2017, Njouonkou et al. 2020). *Lentinus retinervis* was the only

species of agaricoid Polyporaceae collected exclusively in the primary forest. According to Njouonkou et al. (2013) this species seems to prefer areas of dense canopy and high moisture.

This study revealed that gill mushrooms in Kedjom-keku forest seemed to be made up of saprotrophs. The absence of ectomycorrhizal fungi can be explained by the absence of ectotrophic trees species in and around both forests. Wood inhabiting agaricoid fungi was higher in both primary and secondary forest than those on soil and litter. Wood based substrate has been the major determinants of mushroom diversity in forest in both temperate and tropical regions (Jonsson et al. 2008, Chen et al. 2018). In fact, wood inhabiting species are dominant in the forests as dead wood are randomly distributed forming an important structural and functional component of this ecosystem (Fridman & Walheim 2000, Harmon 2001, Rolstad et al. 2004, Martikainen et al. 2000). Some mushroom species exhibit environmental plasticity that allows them to grow on various substrate types. Hence, they grow on more than one substrate type as observed in this study. This is in concomitance with the findings of Karun et al. (2018) in Yenepoya Campus, Southwest India. The result of the study concerning the frequency of species revealed that species in class I are in contrast to that of Ashwani et al. (2013) where *Coprinellus disseminatus* was among those of class V with the highest frequencies.

Conclusion

Afromontane forests are a haven of biodiversity in which macrofungi are important component due to the role they play in forest dynamics; but data on their diversity here is limited. This preliminary study contributes to the documentation of gill mushrooms in montane forests of the Cameroon volcano line especially those of Kedjom-Keku montane forests. It reveals that even though not significant, here, the agaric mushrooms seem to be more diverse in primary forest than secondary forest which are facing anthropogenic activities. According to the result in both forest types, *Mycena* is the dominant genus while Agaricaceae, Marasmiaceae, and Mycenaceae are dominant families. In addition, it reports the occurrence of some taxa for the first time in Cameroon. This study gives an overview of the trend in the diversity and distribution of agaricoid mushroom in both forests of this particular montane ecosystem. However, as the collection period was relatively short, it is important to extend the study for a longer period of at least 5 years and in various ecosystems of the Cameroon volcanic line with many replicates in each forest type to get ample statistical data to best explain the diversity of these species. This will bring more information on the fungal diversity and pattern of distribution of these gill mushrooms and macrofungi species in general in the Afromontane forest including ecology and biotechnological potential applications of various species.

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