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Diversity of Basidiomycetous Macrofungi from Mpanga Forest in Mpigi District, Central Uganda

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted at Mpanga Research Forest located in Mpigi District, Uganda, during the months of March, April, May and Jun 2020 (for the first rainy season) then in September, October, November, and December 2020 (for the second rainy season) to determine the diversity and distribution of macrofungi as well as their influence by seasonality, and physicochemical properties of the soil. An inventory was carried out through plot sampling and survey which consists of installing three permanent plots of 30 m x 30 m in each of the four selected sites, the soil was also measured in the sample plots. To measure distribution and diversity, abundance, species richness, density, and Simpson's and Shannon's indices were calculated. SPSS version 20 software was used for the significance tests of the diversity parameters between the two rainy seasons and for those of the correlation between the soil factors and the abundance of macrofungi species. A total of 120 species of basidiomycetous macrofungi distributed in 53 genera and 22 families were recorded. The dominant genus was *Psathyrella* followed by *Marasmius* belonging to the most dominant families (Coprinaceae and Marasmiaceae), and the most dominant orders (Agaricales and Tricholomatales). During the two rainy seasons, the majority of the species

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that have been collected belong to the group of saprophytes. Macrofungi species collected during the second rainy season were more abundant and diverse than those collected during the first rainy season. Among the physicochemical properties of the soil, pH, calcium, potassium, nitrogen, organic carbon, phosphorus, clay, sand and organic matter were significantly correlated with the abundance of macrofungal species. The results of this study provided basic information on the diversity of macrofungi in Mpanga forest, it can be a point of reference for further research to study the evolution of macrofungal biodiversity in this forest.

Keywords: Macrofungi; diversity; rainy season; soil factors; Mpanga forest.

1. INTRODUCTION

Fungi are one of the four classifications of the living kingdom, alongside animals, plants, and bacteria. Formerly classified as plants, they now form a separate kingdom within the eukaryotic group, called Mycota or Fungi [1]. The reign of Mycota is not limited to large mushrooms whose appearance in the forest and sales in the markets are familiar to us; it also includes molds that attack our food, parasitize our skin or give the cheese a special taste. These molds are called microfungi because they are invisible to the naked eye. The term macrofungi (mushrooms) or macromycetes has been defined by several authors who all agree on the production of fruiting bodies visible to the naked eye [2-5]. Most macrofungi are members of Basidiomycota, but some belong to Ascomycota. These two divisions are distinguished by their sexual reproduction spores which are internal, contained in asci for Ascomycota and external, carried by sterigmata at the top of the basidia for Basidiomycota. Macrofungi, in particular basidiomycetous, which appear mainly during the rainy season in forests, are less known than higher plants because of their ephemeral appearance. Despite their short lifespan, basidiomycetous macrofungi play an important role for the local communities of tropical Africa as sources of food, medicines and substantial income [6,7,8]. Over two-thirds of these communities depend on forest products, either for subsistence or as cash income derived from a wide range of non-timber forest products (NTFPs), including basidiomycetous macrofungi [9].

Apart from the nutritional and medicinal aspects, basidiomycetous macrofungi play also an important role in ecosystem functioning [10] by allowing nutrient recycling, growth, and seedling establishment in forest soil [11]. Thus, they are very good indicators of the health or age of an ecosystem [12]. In Africa, the work of [13], [14], and [15] conducted in West Africa have shown this fundamental role played by basidiomycetous macrofungi in the functioning and regeneration of natural forest ecosystems in tropical Africa. In addition to their ecological importance, basidiomycetous macrofungi constitute an important heritage among the world's biological resources, on the one hand through their usefulness and on the other hand through their diversity [16- 20].

The fungal kingdom is currently one of the most diverse systematic groups in the biosphere after insects [21], the number of species is estimated at 2.2 to 3.8 million worldwide [22], but macrofungi are less represented with an estimate of 140,00 species [23]. Within the group of macrofungi, the basidiomycetous are the most diversified and studied with 22,000 species described worldwide [24]. However, despite being an important heritage among the world's biological resources, the documentation on their diversity is still insufficient in sub-Saharan Africa. This insufficiency is more marked in West Africa because no flora has yet been available and the recent studies were carried out by [25,26], [10], [27], [28] and [29]. In South Africa, [30] recently published the first macrofungi checklist for South Africa. The most in-depth work has been carried out in Central and East Africa with the existence of three flora: “the iconographic flora of the mushrooms of Congo” [31], “the illustrated flora of the mushrooms of Central Africa” [32], and “a preliminary agaric flora of East Africa” [33] but the recent studies were carried out by [34, 35, 36]. In East Africa, diversity has been widely documented in older publications but recent ones have been done by [37], [38] and [39]. In Uganda, apart from the very old publications of [33], [40], [41], studies conducted by [42] and [43] summarize the literature on the diversity of basidiomycetous macrofungi. The studies conducted by [42] and [43] recorded respectively 10 species of basidiomycetous macrofungi belonging to 5 genera and 173 species of basidiomycetous macrofungi belonging to 62 genera. However, the study

conducted by [43] focused exclusively on one subclass of basidiomycetes called Aphyllophoromycetideae.

The equatorial natural forest of Mpanga with its 500 species of trees and shrubs, 300 species of birds, 97 butterflies, and 112 moths [44], has been the subject of many studies on animal and plant biodiversity [45-50]. It has also been the subject of a study on the Saprophytic Ascomycetous and Fungi Imperfecti on dead and decomposing branches, logs, and stumps [51], but no studies focusing exclusively on Basidiomycetous macrofungi have ever been carried out, hence the need to study them because of their risk of extinction due to anthropogenic activities to which the forest is exposed. Despite the Ugandan government's commitment to promoting the conservation, management, and sustainable use of its biological resources by 2025 [52], the lack of data on the diversity of such an important resource in Uganda, which is the wettest country in the sub-region with its 4.9 million hectares of natural forests [53] conducive for the development of macrofungi, constitutes a failure in the sustainable management of this forest resource. That's why this present study aims mainly to contribute to the knowledge of the diversity of Basidiomycetous macrofungi in Mpanga forest for good sustainable management, knowing that the protection of biodiversity has become a major issue of forest policy. Specifically, it consists in determining the diversity and distribution of macrofungi as well as their influence by seasonality and physicochemical properties of the soil.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at Mpanga Research Forest located in Mpigi District, Uganda (Fig. 1). Mpanga Forest Reserve (0° 127 'N, 32° 175' E) is an area of moist semi-deciduous tropical forest with *Celtis* that lies between 1140 and 1200 m altitude in Mawokota County, south of Mengo, 3 km southwest of Mpigi town, 36 km west of Kampala and 25 km north-west Entebbe, only about 20 km from the shores of Lake Victoria [48]. It is also located in the climatic zone of Lake Victoria [54], characterized by a bimodal distribution of precipitation, with the wettest periods from March to June and from September to December as shown by the ombrothermic diagram of Mpigi district (Fig. 2). The mean annual precipitation and the minimum and maximum temperatures are estimated at 1168 mm, 17.2°C, and 26.1°C, respectively with a relative humidity of 90% according to [49]. Soils in the region are generally red and yellow latosols on the peaks and crests, sandy-gray loams on the lower slopes of the hills, and gray-blue clays and silts on the lower slopes and valleys [55 and 56]. Mpanga is a small expanse of natural equatorial forest of 453 hectares [57] which supports an impressive plant biodiversity composed of 500 species of trees and shrubs [58], dominated by Cannabaceae followed by Moraceae and Euphorbiaceae [59]. Some of the floristic elements are *Beilschmiedia ugandensis, Euphorbia hirta, Euphorbia heterophylla, Lovoa trichillioides, Budongo Mahogany, Euntumia Africana, Morus nigra, Trichilla emetica, Celtis mildbraedii, Pseudospondias macrocarpa, Celtis durandii*, *Albizia coliria, Albizia glaberrima, Albizia zygia, Celtis zenkeri, Antiaris toxicaria, Entandrophragma* spp., *Funtumia* spp., *Antiaris toxicara, Ficus exasperata, Ficus mucoso*.

2.2 Survey

Surveys were carried out in the forest of Mpanga, during the months of March, April, May and Jun 2020 (for the first rainy season) then of September, October, November and December 2020 (for the second rainy season) since macrofungi can't be observed all year round [60] for most of the time. Macrofungi are not distributed at random; several factors condition their growth. They exhibit pattern of diversity that are related to largely to substratum and host availability [61]. This host, which is related to vegetation, is obviously of capital importance for the success of the macrofungi harvesting campaign because many ectomycorrhizal species (for example in the genera *Cantharellus*, *Lactarius*, *Russula*, and most Boletales) are associated with certain forest species [62]. Apart from vegetation, ecological factors such as precipitation and physicochemical properties of the soil are also to be considered. Thus, a preliminary study was carried out at the beginning of February 2020 to confirm the choice of sites which should house the plots. This study was guided by an experienced forest agent who has a good knowledge of the different types of forest vegetation in Mpanga. At the end of this preliminary study, 4 sites were selected:

Sites 1 and **3:** are the clear part of the forest rich in Cannabaceae, dominated by the *Celtis* (**a** and **c**).

Sites 2 and **4:** characterized by a vegetation rich in Euphorbiaceae and Moraceae (**b** and **d**).

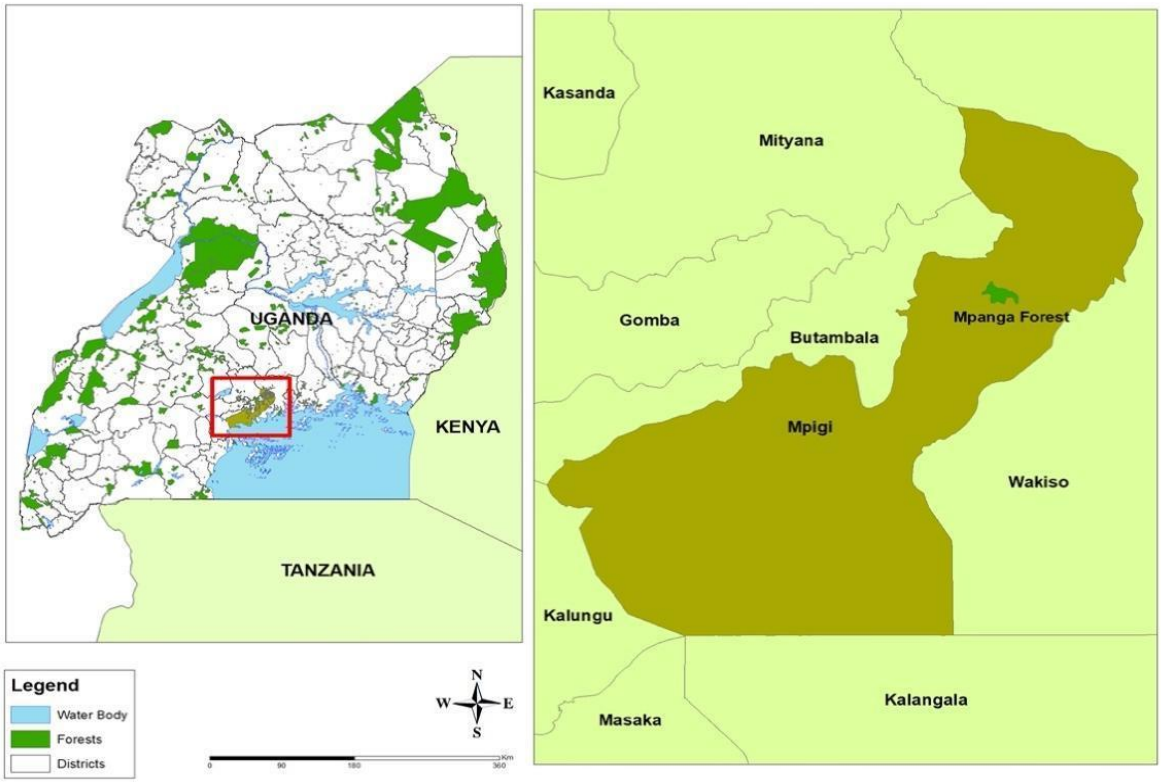

Fig. 1. Study area (Mpanga forest) in Mpigi district, Uganda

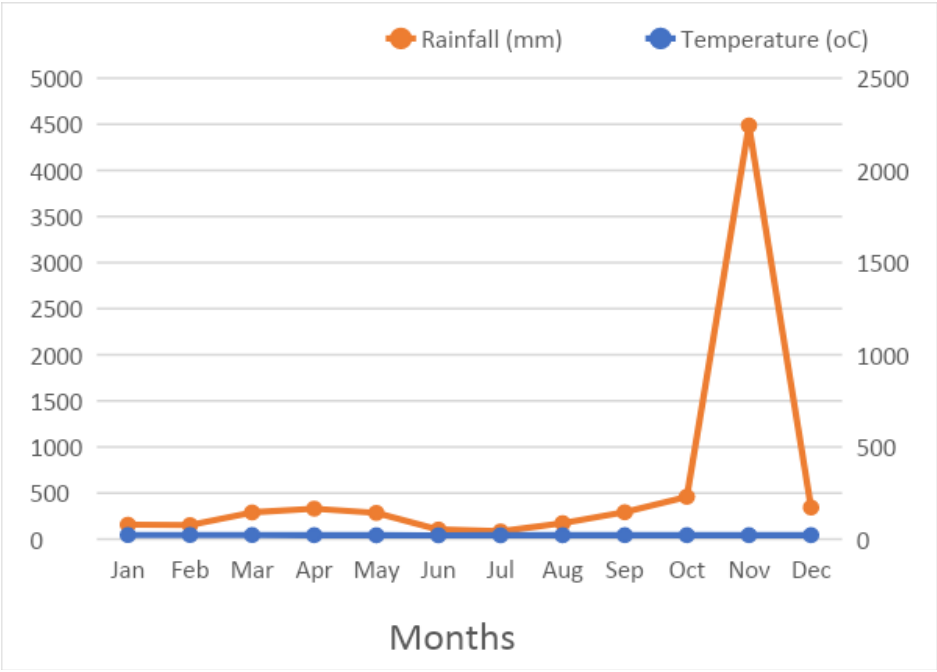

Fig. 2. Ombrothermic diagram of Mpigi district (2020)

Photo 1. The vegetation of the 4 prospected sites: (a and c)- Vegetation rich in Cannabaceae, dominated by *Celtis*; (b and d)- Vegetation rich in Euphorbiaceae and Moraceae

2.3 Sampling

The survey method that was used is plot and survey sampling recommended by [63]. Three permanent plots of 30m x 30m have been installed in each of the 4 sites (Fig. 3). The location of the plots was chosen at random within the sites. The distance between the plots (taken two by two) of the same site is at least 100 m. In order to facilitate the location of the plots, trees along the boundaries of the plots have been tied with a ribbon and the geographic coordinates of the plots and of each species of macrofungi harvested have been recorded using a GPS. The geographical coordinates of the plots are as follows:

Site 1 / Plot 1 (0º 12' 33'' N - 32º 18' 9'' E); Plot 2 (0º 12' 33'' N - 32º 18' 12'' E); Plot 3 (0º 12' 29'' N - 32 0 18' 6'' E).

Site 2 / Plot 4 (0º 12' 42'' N - 32º 17' 27'' E); Plot 5 (0º 12' 36'' N - 2º 17' 27'' E); Plot 6 (0º 12' 39'' N - 32º 17' 31'' E).

Site 3 / Plot 7 (0º 12' 14'' N - 32º 17' 7'' E); Plot 8 (0º 12' 9'' N - 32º 17' 11'' E); Plot 9 (0º 12' 15'' N - 32º 17' 13'' E).

Site4 / Plot 10 (0º 12' 11'' N - 32º 17' 42'' E); Plot 11 (0º 12' 9'' N - 32º 17' 4'' E); Plot 12 (0º 12' 6'' N - 32º 17' 46'' E).

To measure the soil, 1-kilogram soil samples were taken at a depth of 0 to 15 cm + the humus layer in each of the four sites in duplicate. The samples were air-dried at about 25 ^{0}C for 5 days to eliminate the moisture. They were then ground using a porcelain pestle and mortar and then sieved through a 2-millimeter sieve to remove debris and other non-soil materials including stones and roots. The sieved soil samples were repackaged, clearly labeled to be analyzed from the Soil, Plant, and Water analytical Laboratory at the Department of Agricultural and Environmental Sciences of Makerere University. On the sieved soils samples, a broad spectrum of agronomy related soil properties was analyzed and these included; soil pH, soil organic matter and carbon, total nitrogen, available phosphorus; exchangeable Calcium ($Ca2^{+}$), Magnesium ($Mg2^{+}$), Sodium (Na^{+}), Potassium (K^{+}), and soil texture (the percentage proportions of sand, clay, and silt).

2.4 Data Collection

Each week, a site was visited, and always on the same day of the week. Since we have 4 sites in which 3 plots were placed, every month, all the plots were visited during the first rainy season and second rainy season of the year 2020. Thus, in one month, 4 surveys (periods) were carried out in all the sites, which corresponds to 16 surveys for the first rainy season and 16 surveys

for the second rainy season. A total of 32 surveys were taken throughout the harvesting season. The survey technique consists of sweeping the entire plot in 2m parallel strips to avoid omissions [64]. During the survey, all visible macrofungi were systematically collected and sorted by species, the number of individuals of each species was also counted.

This technique was supplemented by opportunistic sampling to consider the random distribution of fruiting bodies and species observed outside the plots [64].

For in situ photography of collected samples, a digital camera was used to photograph each taxon encountered in order to materialize the morphological characters. The following parameters were taken into account and noted for each sample collected: the type of substrate on which the macrofungi grows (on bare soil, on litter, on a living or senescent tree trunk or other); the degree of cover (a wooded area or not) and the humidity of the environment (very humid, humid, dry or very dry soil). The characteristics of each species of macrofungi harvested are noted, including the size and color of each part, the presence or absence of a ring, the shape of the ring, and the presence of pores or blades [28]. The collected samples are put in a basket and transported to the Laboratory of the Faculty of Agriculture of Uganda Martyrs University.

2.5 Identification

The identification of the samples collected was based on the description of the morphological, organoleptic and ecological characteristics of the specimens. The description of the macromorphological characteristics require a rigorous and detailed visual examination of the macrofungus in all its contours. The description of our samples was carried out based on the recommendations of [65] concerning the agricoid (lamellate) and boletoid species and of [66] for the description of the porous and rough structure species (polypores). These recommendations consist in describing the different parts of the sporophore (cap, hymenophore, and foot or stipe) as well as the flesh of each sample.

The description of the cap focused on the main identification characteristics such as the shape, the coating, margin, color, and diameter. That of the hymenophore focused on its color, shape, and insertion as well as the organization of its lamellae. Concerning the foot or stipe, the description also covered the color, shape, length, insertion, and ornamentation. The general veil and the partial veil or ring are also described if they exist. Consistency, color, smell and flavor are the characteristics that have been described for the flesh.

The organoleptic characteristics that have been described are smell and taste. These are important characters but very difficult to categorize. Nevertheless, certain smells like bleach, radish, corpse, lighting gas, old camembert, etc. [67] can be distinguished. The smell can sometimes be surprising: garlic, citrus, almond, anise, cinnamon, chlorine, maple, flour, fetid, etc. [68, 69, 62].

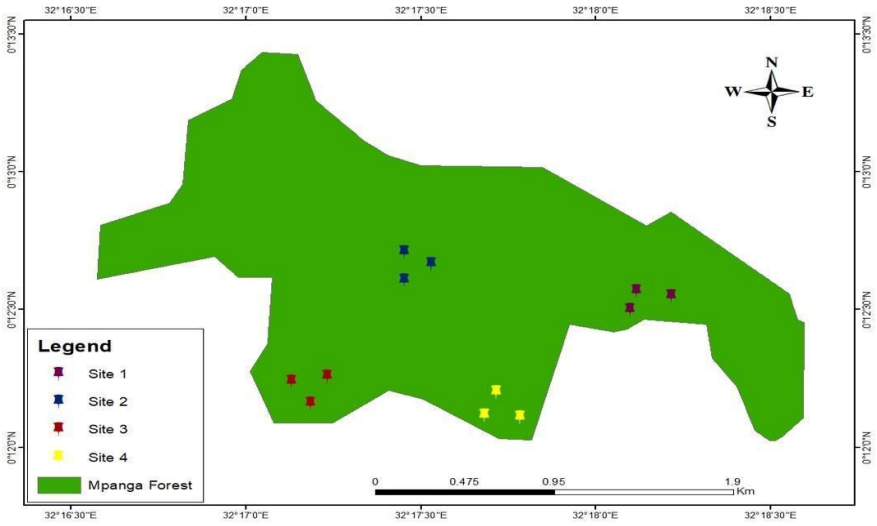

Fig. 3. Location of sites in Mpanga Forest

The parameters which have been taken into account to describe the ecological characteristics are the texture of the soil, the type of substrate on which the macrofungus grows (on bare soil, on litter, on the trunk of a living or senescent tree or other); the degree of cover (a wooded area or not) and the humidity of the environment (very wet, wet, dry or very dry soil).

Other characteristics like latex and spore color are also described. Some basidiomycetous macrofungi such as species belonging to the genus *Lactarius*, present milk after their cutting or crumpling. The color, the taste the viscosity and abundance of this milk are important characteristics for determining a species [68, 62]. To reveal the color of the spores, the classic technique (Fig.4) inspired by [62] was performed. It consists in cutting the foot of the fresh specimen and placing the cap, hymenium downwards, on a white paper. Then cover the hat with glass to prevent it from drying out and maintain a humid confined atmosphere. A few hours are needed to that the hymenium releases enough spores and that their color can be judged by mass. Spore color is one of the most important characters for species identification [68, 62].

The identification of a macrofungus based on the description of the morphological characteristics is a tedious task that systematically appeals to all the senses and requires a very observant mind, but essential to obtain a reference specimen of scientific value [62,28]. The study of these characteristics, part of which was carried out in the field, was completed in the laboratory of the Faculty of Agriculture of Uganda Martyrs University.

By comparing the morphological and ecological characteristics previously described with those described in the identification manuals, the confirmation of the identification of our samples was carried out. The manuals which were used to confirm the identification are: "Iconographic flora of the mushrooms of the Congo" [70], "Illustrated flora of the mushrooms of Central Africa [71], Taxonomic and identification of edible mushrooms dense forests from central Africa [62], and " A preliminary Agaric Flora of East Africa" [33]. The last one is a review of the macrofungi of tropical Africa with a focus on East Africa. For the update and the nomenclature of macrofungi, the exhaustive synonym update list available at: http://www.indexfungorum.org/names/Names.asp was consulted.

2.6 Classification

The systematic classification of macrofungi is based and established on morphological characteristics. To classify a macrofungus, it must first be identified. This identification was based on the observation of morphological, organoleptic, and ecological characteristics. The systematic classification method that was used is largely inspired by that of [72], [65], and [67]. The use of keys determination of [73] concerning the characteristics observed, allowed, by a succession of choices and proposals, to move forward in the determination. However, all characteristics allowing the identification of macrofungi are not taken into consideration to classify them [74].

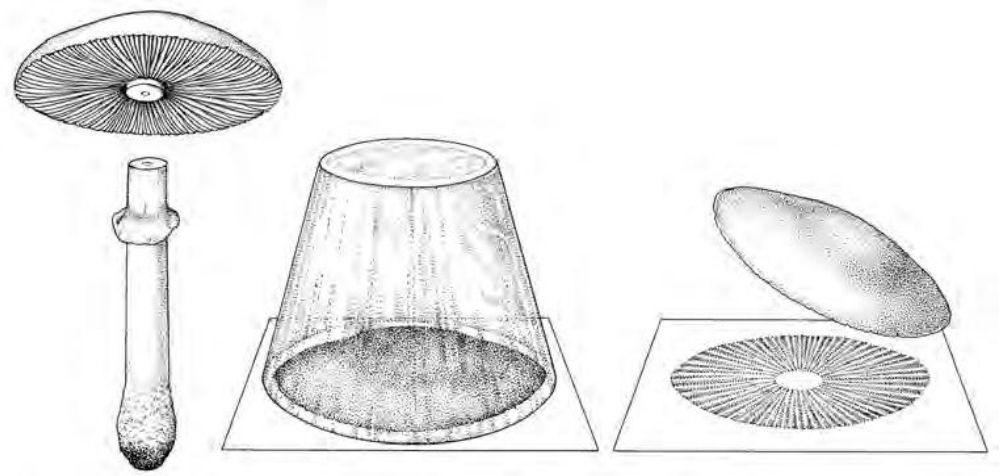

Fig. 4. Classic method of obtaining a spore [62]

2.7 Preservation

The most practical and common method of preservation in mycology consists of simply drying the specimens [62]. Thus, samples were dried using a drying oven at a temperature of 50 to 65 ° C in order to preserve the DNA and allow its subsequent analysis. The drying time was 2 hours for non-fleshy specimens and 4 hours for fleshy or waterlogged specimens. After drying and in order to avoid any rehydration, the still hot specimens were packaged with their number in hermetic plastic bags of the "Minigrip" type which were immediately sealed. Before final conservation in the herbarium, labelling was carried out. On the label, the name of the collector and the unique number associated with the specimen, the date, and place of harvest, the geographical coordinates, the altitude as well as any vegetation and ecological data [62] have been included.

2.8 Data Analysis

2.8.1 Diversity analysis

The different orders and families of macrofungi were plotted against the total number of individual isolates (species) per given order and family. Species richness was calculated as the total number of species per 30 X 30 m plot. The density of species was determined by the following formula [11].

$$Density\ of\ macrofungi\ sp.\ (\%) = \frac{Total\ no.\ of\ individuals\ of\ a\ particular\ species}{Total\ no.\ of\ species} X\ 100$$

Diversity indices, widely used to measure biological diversity [75] such as Shannon, and

Simpson diversity indices noted below were used.

$$Shannon\ Index\ (H) = -\sum_{i=1}^{s} pi \ln ln\ pi$$

$$Simpson\ Index\ (1 - D) = 1 - 1/\sum_{i=1}^{s} pi^2$$

p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), **ln** is the natural log, **Σ** is the sum of the calculations, and **s** is the number of species.

Pair T-test ANOVA at a 95% confidence level between means using SPSS version 20 software was performed for species richness, density, Simpson and Shannon diversity indices to find out if there is a significant effect of seasonality on macrofungi species.

2.9 Soil Analysis

Each soil property was specifically analyzed by particular analytical methods and procedures. Calcium and Magnesium were analyzed using the atomic absorption spectrophotometer (AAS) on a mehlich 1 extracts. Potassium and Sodium were analyzed using the Flame photometer on the same mehlich 1 extract, Available phosphorus content was determined using a spectrophotometer at 882 nm wavelength after the mehlich 1 extracts reaction with ammonium molybdate in the presence of ascorbic acid [76]. Soil pH was measured in a soil-water solution at a ratio of 1:2.5 by the help of a pH meter; Total Nitrogen (N) was determined calorimetrically at a wave length of 655 nm on the complexed digestions mixtures using N^1 and N^2 reagents. (Reagents in N^1 include; sodium salicylate, sodium citrate, sodium tartrate and sodium nitroprusside, N^2 reagents include; sodium hydroxide and sodium hypochlorite (JIK) mixed in the stipulated proportions by [77]. Organic matter (O.M) was determined using the Walkley and Black method following wet oxidation using concentrated Sulphuric acid and Potassium Dichromate. Soil texture was analysed using the hydrometer method (Bouyoucous method). All analyzes were performed using routine procedures described by [77] and other internationally recommended standard operating procedures (SOPs). To assess the correlation between the physicochemical properties of the soil and the abundance of macrofungi species, correlation analysis by using SPSS software was done. The abundance of species was determined by the following formulas [78].

$$Abund.\ of\ macrofungi\ sp.\ (\%) = \frac{Number\ of\ individuals\ of\ the\ species\ in\ the\ site}{Total\ number\ of\ individuals\ of\ all\ species\ in\ the\ site} X\ 100$$

3. RESULTS

3.1 Diversity of the Macrofungal Community within Mpanga Forest

A total of 120 species of basidiomycetous macrofungi distributed in 53 genera were recorded. Among these genera, the most dominant are *Psathyrella* and *Marasmius* respectively represented by 11 and 9 species while those like *Tremalla, Neofavolus, Daedaleopsis, Trametes, Hexagonia, Oligoporus, Ganoderma, Cantharellus, Hymenagaricus, Micropsalliota, Amanita, Parasola, Cystolepiota, Volvariella, Cortinarius, Claudopus, Rhodocybe, Panus, Pleurotus, Neonothopanus, Cuphophyllus, Cystoderma, Lentinula, Lactocollybia, Oudemansiella* are all represented by 1 species (Appendix.1).

The 53 genera of macrofungi belong to 22 families and 9 orders. The majority of identified species belong to Marasmiaceae (20 species) followed by Coprinaceae (17 species) while Dermolomataceae, Pluteaceae, Amanitaceae, Cantharellaceae, Fomitopsidaceae and Auriculariaceae are represented by a single species (Fig.5). Among the 9 orders, the most abundant was that of Tricholomatales (55 species) followed by Agaricales and Polyporales represented by 34 and 16 species respectively (Fig.6).

3.2 Ecological Distribution of Macrofungi

The results of this preliminary study on the diversity of basidiomycetous macrofungi showed that the Mpanga forest abounds in considerable macrofungal biodiversity with 120 species harvested in just two rainy seasons. During these two rainy seasons, the majority of macrofungi collected belonged to the group of saprophytes. Macrofungal species collected during the second rainy season were more abundant and diverse than those collected during the first rainy season.

From the collected macrofungi species, the saprophyte group largely dominates with 79% followed by the ectomycorrhizal symbiont group, while the symbiont group with termites and the parasitic group are poorly represented with 3% and 1% respectively (Fig.7). Depending on the substrate they decompose, the group of saprophytes is dominated by humicolous species which decompose soil organic matter (60%), followed respectively by saprophytic species of litter which decompose dead leaves, twigs, and other plant debris (25%) and lignicolous species which decompose dead wood's organic matter (15%) (Fig.8).

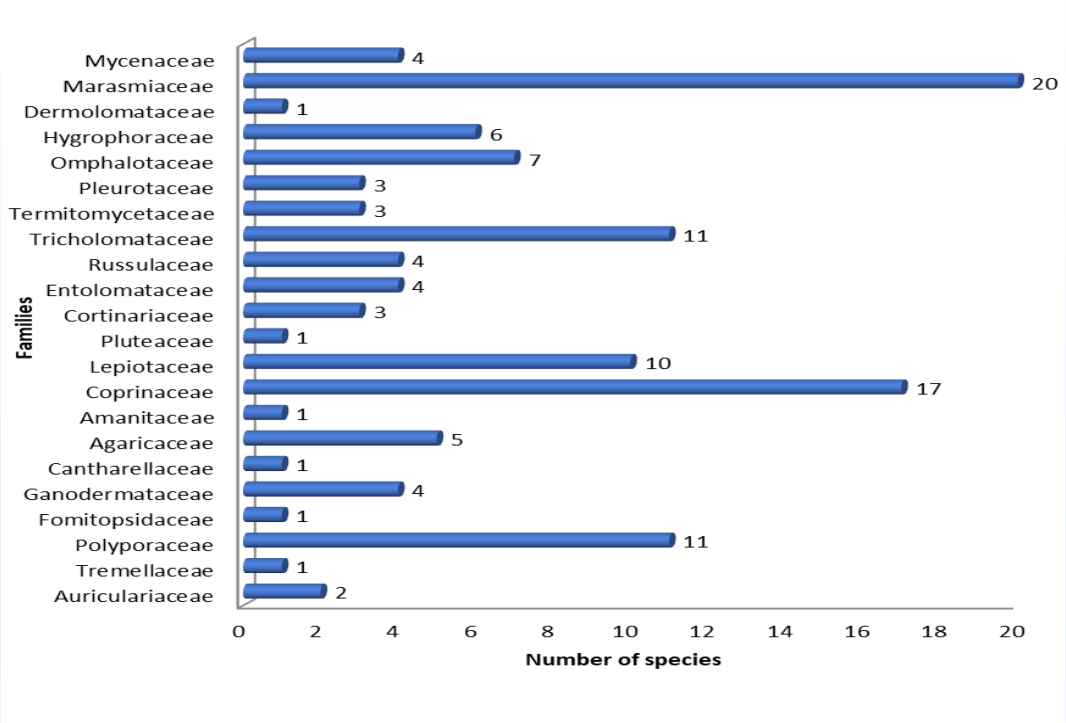

Fig 5. Families and ampleness of macrofungi species in Mpanga forest

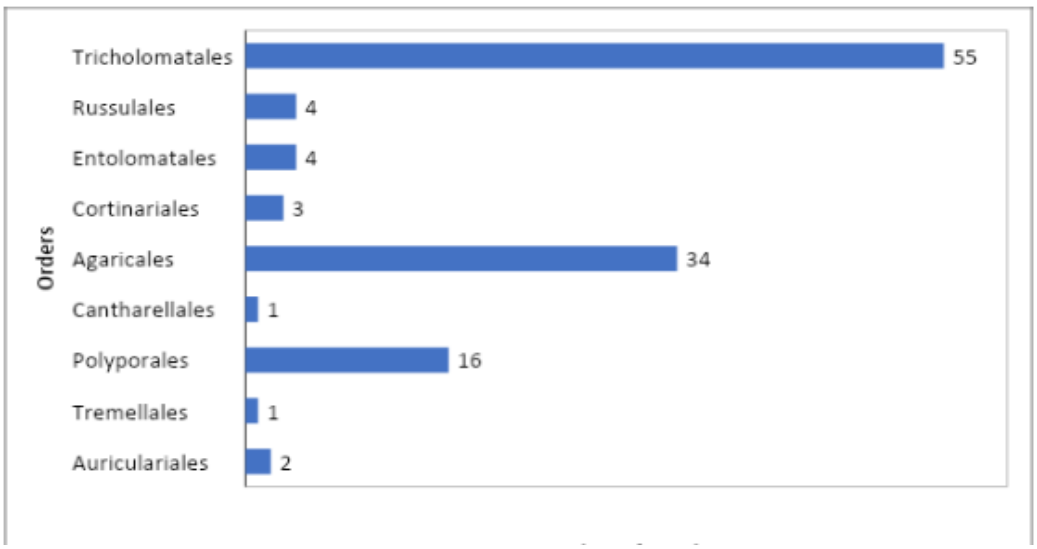

Fig. 6. Orders and ampleness of macrofungi species in Mpanga Forest

Photo 2. The 22 families of macrofungi listed represented by one species: 1. *Cantharellus* sp. (Cantharellaceae); 2. *Oligoporus ptychogaster* (Fomitopsidaceae); 3. *Panus fulvus* (Tricholomataceae); 4. *Auricularia delicata* (Auriculariaceae); 5. *Agaricus arvensis* (Agaricaceae); 6. *Marasmius rotula* (Marasmiaceae); 7. *Cortinarius humicola* (Cortinariaceae); 8. *Tremalla fuciformis* (Tremellaceae); 9. *Volvariella volvacea* (Pluteaceae); 10. *Polyporus tenuiculus* (Polyporaceae); 11, *Coprinellus* sp. (Coprinaceae); 12. *Ganoderma applanatum* (Ganodermataceae); 13. *Amanita sinicoflava* (Amanitaceae) ; 14. *Entoloma conferendum* (Entolomataceae) ; 15. *Pleurotus ostreatus* (Pleurotaceae); 16. *Gymnopus ocior* (Omphalotaceae); 17. *Hygrocybe colemanniana* (Hygrophoraceae); 18. *Macrolepiota africana* (Lepiotaceae); 19. *Termitomyces robustus* (Termitomycetaceae); 20. *Mycena rapiolens* (Mycenaceae); 21. *Cystoderma amianthinum* (Dermolomataceae); 22. *Russula virescens* (Russulaceae)

By considering the ecological distribution of macrofungi in the 4 prospected sites, Fig.9 shows that the saprophyte group still remains dominant in all sites, but this dominance is more pronounced in sites 1 and 3 with 45 and 31 species respectively. These sites (Sites 1 and 3) are however very poor in ectomycorrhizal symbiont species with 2 species in each, while Site 2 harbors the largest number of ectomycorrhizal symbiont species (10 species) followed by Site 4 (7 species). As for species symbionts with termites, they are represented by a single species in sites 1, 3 and 4, and absent in site 2 while the only parasitic species collected was found in site 3.

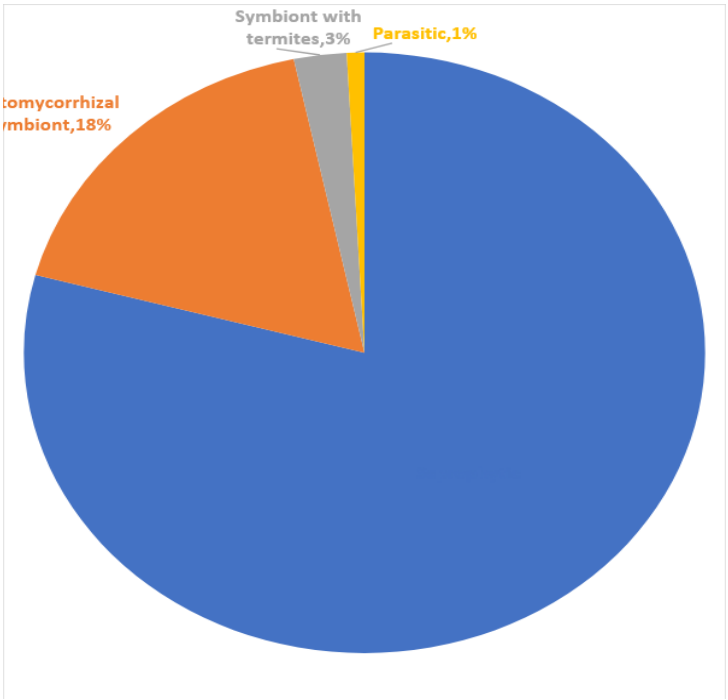

Fig. 7. Ecological distribution of Macrofungi in Mpanga Forest

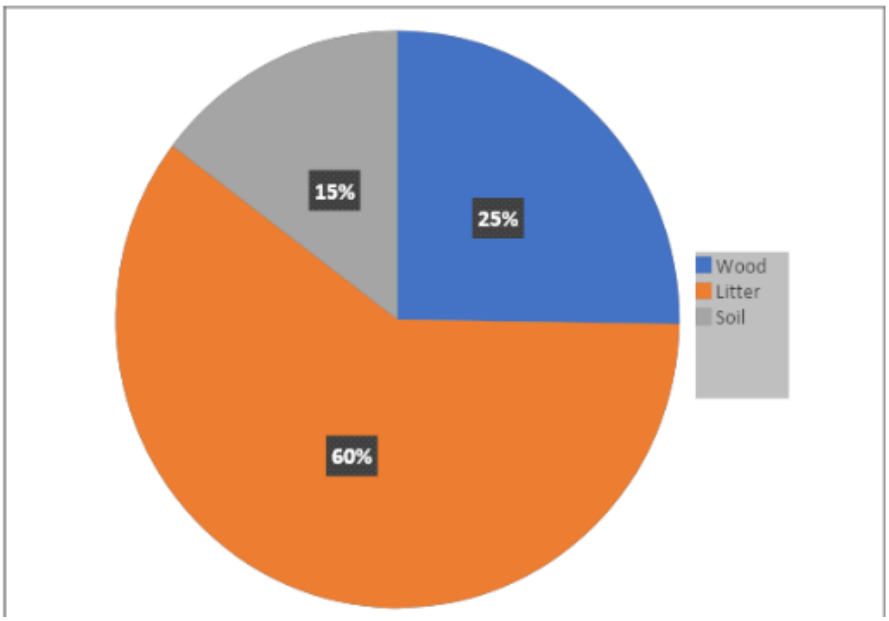

Fig. 8. Distribution of saprophytic macrofungi according to their substrate

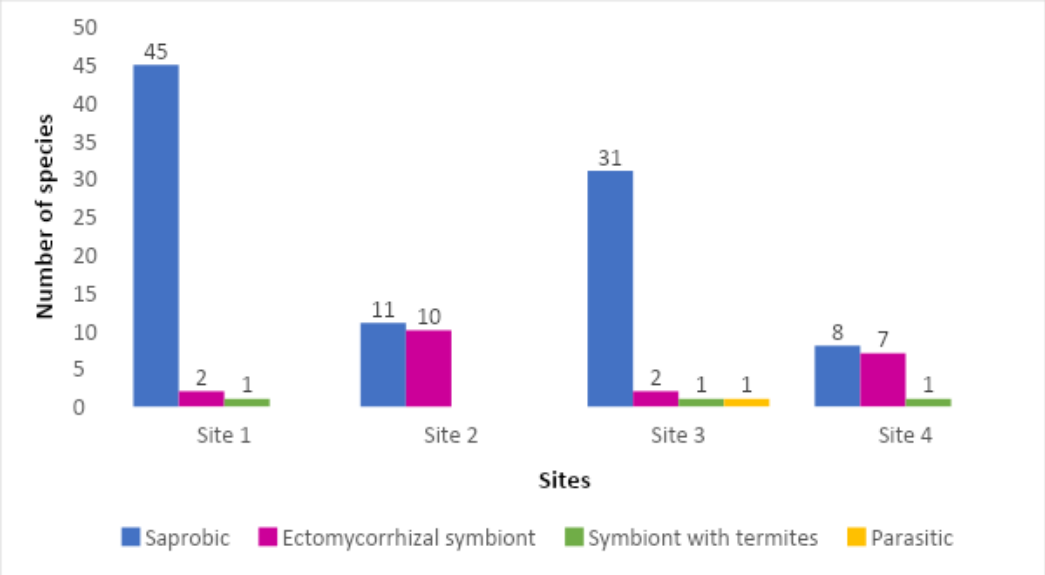

Fig. 9. Ecological distribution of macrofungi within the four prospected sites

3.3 Influence of Seasonality on the Diversity

The harvest of macrofungi was more fruitful during the second rainy season with 101 species against 69 species during the first rainy season. Fifty species were present in the second rainy season only and 18 species were present in the first rainy season only, while 51 species were present both in the first and second rainy seasons (Appendix.2). Moreover, by comparing the values of the diversity indices of Simpson and Shannon during the first rainy season (0.97 & 3.94) and those during the second rainy season (0.99 & 4.44), the values of the latter are significantly higher ($P<0.05$). Macrofungi density and species richness were also significantly ($P<0.05$) higher during the second rainy season than during the first one (Table 1).

3.4 Relationship between the Physicochemical Properties of the Soil and the Abundance of Macrofungi Species

The correlation between the physicochemical properties of the soil and the abundance of macrofungi species only concerned species having the soil as direct substrate (37 species) in order to obtain convincing results.

Generally, the physicochemical properties of the soil of Mpanga forest vary from one site to another, except for silt, the percentage of which is constant at 12% in each of the 4 prospected sites. Apart from the silt, the result of the correlation between the other soil factors and the abundance of the 37 species of macrofungi showed that 16 species were significantly correlated with certain soil factors (Appendix.3). Among these factors, sodium (Na) was significantly correlated with the most species such as *Macrolepiota dolichaula* (-0.951), *Arrhenia obscurata* (-0.995), *Lentinus* sp. (0.986), *Lactarius indigo* (0.988), *Termitomyces microcarpus* (0.965) and *Hygrocybe colemanniana* (0.975). As for calcium (Ca), it was significantly correlated with 3 species which are *Cuphophyllus virgineus* (-0.998), *Tetrapyrgos nigripes* (-0.962) and *Clitocybe fragrans* (-0.983) while clay was significantly correlated with two species which are *Termitomyces clypeatus* (-0.986) and *Clitocybe phaeophtalma* (-0.986). The other parameters were each significantly correlated with a single species of macrofungi. This is the case of potassium (K) with *Inocybe sindonia* (0.953), nitrogen (N) with *Arrhenia velutipes* (0.994), organic carbon (OC) with *Arrhenia velutipes* (0.986), organic matter (OM) with *Arrhenia velutipes* (0.986), phosphorus (P) with *Rhodocybe* sp. (0.976), pH with *Russula aurea* (-0.953) and sand with *Termitomyces clypeatus* (0.986).

4. DISCUSSION

A similar study conducted in Bwindi Impenetrable and Kibale National Parks, Albertine Rift, Western Uganda reported 173

Table 1. Statistical test of significance on species richness, density, and diversity indices during the two rainy seasons

Parameters	Seasons	Measured values ± SD	t value	df	P value
Species richness (m)	First season	5.75 ± 2.094	- 4.392	11	0.001*
	Second season	8.42 ± 3.528			
Density (m2)	First season	17.71 ± 15.255	- 3.690	68	0.000*
	Second season	30.06 ± 21.640			
Simpson diversity	First season	0.97 ± 10.526	8,564	897,36	0.000*
	Second season	0.99 ± 20.223			
Shannon diversity	First season	3.94 ± 10.526	- 17. 613	1090.9	0.000*
	Second season	4.44 ± 20.223			

**Significant difference (P < 0.05)*

species [43] while that conducted in Southwestern region of Uganda, specifically in Malabigambo and Namalala Forest Reserves reported only 10 species [42]. The later was carried out in an area similar to ours despite the low number of species recorded. This difference is explained by the many forest gaps caused by the encroachment and overexploitation of timber in the forest reserves of Malabigambo and Namalala [42] while Mpanga forest is one of the few well-managed government reserves in Mpigi district [48], although there are still gaps in cooperation between the community and the forest management staff. In other tropical African countries, similar studies have also been carried out, but in larger forest areas than ours. This is the case of Cameroon where [79] recorded 177 species in the Mount Cameroon region and that of Kenya where [38] recorded 224 species in the Kereita and Kikuyu Escarpment forests. These results show that in forest areas that have not undergone excessive deforestation, the larger the area, the more fruitful the harvesting of macrofungi.

The dominance of macrofungi species belonging to the Marasmius and Psathyrella genera is consistent with the nature of the study site which is a tropical moist semi-deciduous forest with *Celtis* whose fall of its dead leaves constitutes a moist litter enriching the soil with black humus, conducive to the development of macrofungi belonging to the genera *Psathyrella* and *Marasmius*. Moreover, since the greatest number of macrofungi species was collected in the middle of the rainy seasons, the dominance of species belonging to the Coprinaceae family is normal because they need heavy rains to appear and develop [67].

The majority of macrofungal species collected belonged to the saprophyte group. This could be attributed to the ability of saprophytic macrofungi to degrade many types of substrates present in the forest [80].

These results are consistent with the dominance of species belonging to the Marasmiaceae and Coprinaceae families, which are saprophytic species decomposing mainly litter-based substrates. They are mainly favored by the presence of dead twigs and leaf substrates while others occur on cow dung [38]. Similar results have been found by several authors who noted that saprophytic macrofungi were the dominant macrofungal group in tropical forests [78, 81, 82, 83]. By comparing the ecological distribution of macrofungi in the 4 prospected sites, the dominance of the group of saprophytes is confirmed especially in sites 1 and 3 rich in Cannabaceae, in particular, the genus *Celtis* while in sites 2 and 4, a single species differentiated the saprophytic groups from those of the ectomycorrhizal symbionts. Our results corroborate those of several studies which have shown that species belonging to the genus *Celtis* are part of the forest species that allow tropical forests to produce a great diversity of wood and leaves resulting in a multitude of substrates favorable to the development of saprophytic macrofungi [83, 84, 85]. As for the difference observed in sites 2 and 4, it can be explained by the fact that these sites are characterized by vegetation rich in Euphorbiaceae which is a family strongly involved in symbiotic associations with macrofungi [86]. The low representation of ectomycorrhizal macrofungi species observed during the entire collection could be linked to the tropical nature of Mpanga because, in China, studies have shown that ectomycorrhizal macrofungi were more diversified in temperate forests than in tropical forests [82, 78].

The difference in diversity observed during the two rainy seasons could be explained by the fact that there is enough humidity available during the second rainy season which is the rainiest since humidity is one of the main factors influencing fruiting. macrofungi. This corresponds with the conclusions of [79] in the Mount Cameroon

region, [87], in the southern part of Cameroon, [88] in southern Ghana, [89]and [90] who worked on the diversity of macrofungi in semi-evergreen humid deciduous forest in Shimoga-Ksrnataka district, India. It was also found that some species of macrofungi were present in both rainy seasons, while others were only present in the first or second rainy season. These results could be due to differences in the time between the appearance of favorable fruiting conditions and the production of fruit bodies between the different species of macrofungi studied, as not ed by [79]. This agrees with the findings of [91], who studied substrate specificity and community phenology of macrofungi in Tanzania. During the collection period, it was noted that generally small, delicate and fragile species with small thread-like stipes of litter-dwelling genera such as *Coprinus*, *Marasmius* and *Mycena*, fruited following heavy rains. These species came and went very quickly while the tall fruiting bodies fructified after a continuous period of rains lasting several days. The same observation was made by [67] and [79], and similar results were also found by [92], who noted that most macrofungi require a period of vegetative growth prior to fruiting during which mycelia accumulate before being triggered to fruit.

The results also showed that fleshy macrofungi were dominant during the second rainy season while during the first rainy season, non-fleshy macrofungi (polypores) were dominant (Appendix 2). Since the second rainy season is rainier than the first, the dominance of fleshy macrofungi could be explained by the fact that this period is favorable for their production. During this period, adequate humidity, favorable temperature, relative humidity and sunshine help macrofungi to decompose dead organic matter [93]. As for the dominance of polypores during the first rainy season, it could be due to the decrease in precipitation and relative humidity, the increase in temperature and sunshine which most of the fleshy macrofungi cannot withstand [79]. It was also noted that species like *Volvariella volvacea* among other species (Appendix 2) showed no seasonal variation but were present in both seasons. Similar results were also recorded by [87].

The correlation results between the physicochemical properties and the abundance of the species obtained during this study are similar to those recorded by [42] on the study of the ecology of edible indigenous macrofungi from Lake Victoria Basin, Uganda. Other authors such as [94], [95] and [96], have also demonstrated the existence of an edaphic preference of many macrofungi in tropical forests. [97] and [98] noted that sandy loam texture, low soil bulk density, high organic matter and pH were properties that stimulated the development of macrofungi. The importance of organic matter is due to its water holding capacity and nutrient availability [99]. [97] and [99] also noted that acid soils combined with a high content of organic matter stimulates the decay function of macrofungi compared to other microorganisms such as bacteria and actinomycetes. The soils of our study site were generally acidic, which is consistent with the findings of [100] and [101] in their studies conducted in tropical regions.

5. CONCLUSION

The results of this preliminary study on the diversity of basidiomycetous macrofungi showed that the Mpanga forest abounds in considerable macrofungal biodiversity with 120 species harvested just in two rainy seasons. During these seasons, the majority of the species that have been collected belong to the group of saprophytes. Macrofungi species collected during the second rainy season were more abundant and diverse than those collected during the first rainy season. Among the physicochemical properties of the soil, pH, calcium, potassium, nitrogen, organic carbon, phosphorus, clay, sand and organic matter were significantly correlated with the abundance of macrofungal species.This study provided basic information on the diversity of macrofungi in Mpanga forest, it can be a point of reference for further research to study the evolution of macrofungal biodiversity in this forest.

Moreover, the importance of macrofungi not only in the dynamics of forest ecosystems but also in human nutrition and health increases the need for conservation of this resource of non-timber forest products. Conservation can also be achieved through their cultivation and the reduction of illegal logging hence the need to include macrofungal biodiversity conservation in forest management policies in Uganda.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix1. Systematic classification of identified species with an indication of their harvest date and geographic coordinates

Division	Class	Subclass	Order	Family	Genus	Species	Sample number	Harvest date	Geographic coordinates
Basidio mycota	Phragmobasidiomycetes		Auriculariales	Auriculariaceae	*Auricularia*	*Auricularia delicata*	KN 110 MF	07 / 05/ 20	0o 12' 31'' N 32o 18' 6'' E
						Auricularia auricula-judae	KN 065 MF	23/ 11/20	0o 12' 19'' N 32o 17' 54'' E
			Tremellales	Tremellaceae	*Tremalla*	*Tremalla fuciformis*	KN 131 MF	14/ 05/ 20	0o 12' 29'' N 32o 18' 11'' E
	Homobasidio mycetes	Aphyllophoro mycetideae	Polyporales	Polyporaceae	*Polyporus*	*Polyporus grammocephalus*	KN 032 MF	19/ 10/ 20	0o 12' 25'' N 32o 18' 5'' E
						Polyporus badius	KN 021 MF	19/ 10/ 20	0o 12' 31'' N 32o 18' 5'' E
						Polyporus tenuiculus	KN 183 MF	27/ 05/ 20	0o 12' 32'' N 32o 18' 7'' E
						Polyporus varius	KN 193 MF	07/ 06/20	0o 12' 25'' N 32o 18' 12'' E
					Neofavolus	*Neofavolus alveolaris*	KN 001 MF	05/ 10/ 20	0o 12' 23'' N 32o 18' 11'' E
					Daedaleopsis	*Daedaleopsis confragosa*	KN 089 MF	14/ 12/ 20	0o 12' 2'' N 32o 18' 40'' E
					Trametes	*Trametes gibbosa*	KN 009 MF	05/ 10/ 20	0o 12' 24'' N 32o 18' 11'' E
					Microporus	*Microporus xanthopus*	KN 055 MF	09/ 11/20	0o 12' 22'' N 32o 17' 58'' E
						Microporus affinis	KN 192 MF	07/ 06/ 20	0o 12' 26'' N 32o 18' 11'' E
						Microporus vernicipes	KN 204 MF	07/ 06/ 20	0o 12' 35'' N 32o 18' 8'' E
					Hexagonia	*Hexagonia tenius*	KN 187 MF	27/ 05/20	0o 12' 33'' N

							32o 18’ 6’’ E
		Fomitopsidaceae	*Oligoporus*	*Oligoporus ptychogaster*	KN 200 MF	07/ 06/ 20	0o 12’ 35’’ N
							32o 18’ 9’’ E
		Ganodermataceae	*Ganoderma*	*Ganoderma applanatum*	KN 066 MF	23/11/20	0o 12’ 19’’ N
							32o 17’ 53’’ E
			Amauroderma	*Amauroderma rude*	KN 189 MF	27/ 05/20	0o 12’ 2’’ N
							32o 17’ 52’’ E
				Amauroderma sp.	KN 082 MF	07/12/20	0o 12’ 30’’ N
							32o 18’ 11’’ E
				Amauroderma rugosum	KN 195 MF	07/ 06/20	0o 12’ 29’’ N
							32o 18’ 10’’ E
	Cantharellales	Cantharellaceae	*Cantharellus*	*Cantharellus* sp.	KN 198 MF	07/ 06/20	0o 12’ 34’’ N
							32o 18’ 10’’ E
Agarico mycetideae	Agaricales	Agaricaceae	*Agaricus*	*Agaricus arvensis*	KN 011 MF	05/ 10/20	0o 12’ 25’’ N
							32o 18’ 11’’ E
				Agaricus diminutivus	KN 074 MF	30/11/20	0o 12’ 25’’ N
							32o 18’14’’ E
				Agaricus moelleri	KN 150 MF	21/ 05/20	0o 12’ 10’’ N
							32o 17’ 42’’ E
			Hymenagaricus	*Hymenagaricus* sp.	KN 062 MF	23/11/20	0o 12’ 20’’ N
							32o 17’ 54’’ E
			Micropsalliota	*Micropsalliota* sp.	KN 035 MF	19/10/20	0o 12’ 26’’ N
							32o 18’ 5’’ E
		Amanitaceae	*Amanita*	*Amanita sinicoflava*	KN 072 MF	30/11/20	0o 12’ 23’’ N
							32o 18’ 11’’ E
		Coprinaceae	*Coprinellus*	*Coprinellus disseminatus*	KN 053 MF	09/11/20	0o 12’ 19’’ N
							32o 17’ 54’’ E
				Coprinellus sp.	KN 185 MF	27/05/ 20	0o 12’ 32’’ N
							32o 18’ 5’’ E
			Coprinopsis	*Coprinopsis lagopus*	KN 088 FM	07/12/ 20	0o 12’ 40’’ N
							32o 18’ 44’’ E

		Coprinopsis domesticus	KN 141 MF	14/05/20	0o 12' 27'' N 32o 18' 9'' E
		Coprinopsis cinerea	KN 197 MF	07/ 06/ 20	0o 12' 32'' N 32o 18' 5'' E
	Parasola	*Parasola auricoma*	KN 201 FM	07/ 06/ 20	0o 12' 35'' N 32o 18' 9'' E
	Psathyrella	*Psathyrella tephrophylla*	KN 086 MF	07/12/20	0o 12' 28'' N 32o 18' 37'' E
		Psathyrella leucotephra	KN 015 MF	12/ 10/20	0o 12' 1'' N 32o 17' 8'' E
		Psathyrella candolleana	KN 045 MF	02/ 11/ 20	0o 12' 2'' N 32o 17' 41'' E
		Psathyrella spadiceogrisea	KN 054 NF	09/11/20	0o 12' 19'' N 32o 17' 54'' E
		Psathyrella clivensis	KN 106 MF	07/ 05/ 20	0o 12' 34'' N 32o 18' 6'' E
		Psathyrella inflatocystis	KN 128 MF	14/ 05/ 20	0o 12' 30'' N 32o 18' 12'' E
		Psathyrella conferta	KN 042 MF	26/ 10/ 20	0o 12' 31'' N 32o 18' 11'' E
		Psathyrella pennata	KN 159 MF	21/ 05/ 20	0o 12' 10'' N 32o 17' 42'' E
		Psathyrella conopilus	KN 136 MF	14/ 05/ 20	0o 12' 30'' N 32o 18' 11'' E
		Psathyrella olympiana	KN 026 MF	19/ 10/ 20	0o 12' 32'' N 32o 18' 5'' E
		Psathyrella sp.	KN 181 MF	27/ 05/ 20	0o 12' 11'' N 32o 17' 28'' E
Lepiotaceae	*Lepiota*	*Lepiota cristata*	KN 061 MF	23/ 11/ 20	0o 12' 17'' N 32o 17' 54'' E
		Lepiota felina	KN 057 MF	23/ 11/ 20	0o 12' 22'' N

						32o 17’ 57’’ E
		Macrolepiota	*Macrolepiota africana*	KN 030 MF	19/ 10/ 20	0o 12’ 24’’ N 32o 18’ 7’’ E
			Macrolepiota procera	KN 126 MF	14/05/ 20	0o 12’ 32’’ N 32o 18’ 12’’ E
			Macrolepiota dolichaula	KN 076 MF	30/ 11/ 20	0o 12’ 30’’ N 32o 18’ 9’’ E
		Cystolepiota	*Cystolepiota pulverulenta*	KN 024 MF	19/ 10/ 20	0o 12’ 5’’ N 32o 18’ 56’’ E
		Leucoagaricus	*Leucoagaricus rubrotinctus*	KN 014 MF	12/ 10/ 20	0o 12’ 25’’ N 32o 18’ 5’’ E
			Leucoagaricus croceovelutinus	KN 182 MF	27/ 05/ 20	0o 12’ 13’’ N 32o 17’ 25’’ E
		Leucocoprinus	*Leucocoprinus scissus*	KN 018 MF	12/ 10/ 20	0o 12’ 6’’ N 32o 17’ 40’’ E
			Leucocoprisnus brebissoni	KN 104 MF	07/ 05/ 20	0o 12’ 34’’ N 32o 18’ 7’’ E
	Pluteaceae	*Volvariella*	*Volvariella volvacea*	KN 155 MF	21/ 05/ 20	0o 12’ 11’’ N 32o 18’ 42’’ E
Cortinariales	Cortinariaceae	*Cortinarius*	*Cortinarius humicola*	KN 137 MF	14/ 05/20	0o 12’ 29’’ N 32o 17’ 11’’ E
		Inocybe	*Inocybe sindonia*	KN 095 MF	14/12 /20	0o 12’ 2’’ N 32o 17’ 40’’ E
			Inocybe rimosa	KN 203 MF	07/ 06/ 20	0o 12’ 36’’ N 32o 18’ 9’’ E
Entolomatales	Entolomataceae	*Entoloma*	*Entoloma conferendum*	KN 083 MF	07/ 12/ 20	0o 12’ 40’’ N 32o 18’ 34’’ E
			Entoloma sp.	KN 036 MF	26/ 10/ 20	0o 12’ 28’’ N 32o 18’ 10’’ E
		Claudopus	*Claudopus variabilis*	KN 081 MF	07/ 12/ 20	0o 12’ 33’’ N 32o 18’ 12’’ E

			Rhodocybe	*Rhodocybe* sp.	KN 135 MF	14/ 05/ 20	0o 12' 29'' N 32o 18' 11'' E
	Russulales	Russulaceae	*Russula*	*Russula aurea*	KN 013 MF	05 / 10/ 20	0o 12' 24'' N 32o 18' 11'' E
				Russula virescens	KN 138 MF	14/ 05/ 20	0o 12' 29'' N 32o 18' 11'' E
			Lactarius	*Lactarius chrysorrheus*	KN 144 MF	14/ 05/ 20	0o 12' 26'' N 32o 18' 9'' E
				Lactarius indigo	KN 151 MF	21/ 05/20	0o 12' 12'' N 32o 17' 43'' E
	Tricholomatales	Tricholomataceae	*Tricholoma*	*Tricholoma stiparophyllum*	KN 068 MF	20/ 11/ 20	0o 12' 25'' N 32o 18' 5'' E
				Tricholoma sp. 1	KN 070 MF	20/ 11/ 20	0o 12' 24'' N 32o 18' 5'' E
				Tricholoma sp. 2	KN 171 MF	24/ 05/ 20	0o 12' 22'' N 32o 17' 55'' E
			Arrhenia	*Arrhenia velutipes*	KN 040 MF	26/ 10/ 20	0o 12' 32'' N 32o 18' 12'' E
				Arrhenia epichysium	KN 134 MF	14/05/ 20	0o 12' 29'' N 32o 18' 41'' E
				Arrhenia obscurata	KN 168 MF	24/ 05/ 20	0o 12' 14'' N 32o 17' 53'' E
			Clitocybe	*Clitocybe phaeophtalma*	KN 116 MF	07/ 05/ 20	0o 12' 30'' N 32o 18' 6'' E
				Clitocybe fragrans	KN 107 MF	07/ 05/ 20	0o 12' 34'' N 32o 18' 6'' E
				Clitocybe sp. 1	KN 037 MF	26/ 10/ 20	0o 12' 32'' N 32o 18' 11'' E
				Clitocybe sp. 2	KN 102 MF	07/ 05/ 20	0o 12' 34'' N 32o 18' 7'' E
			Panus	*Panus fulvus*	KN 084 MF	07/12/ 20	0o 12' 31'' N

						32o 18’ 15’’ E
	Termitomycetaceae	*Termitomyces*	*Termitomyces robustus*	KN 031 MF	19/ 10/ 20	0o 12’ 26’’ N 32o 18’ 7’’ E
			Termitomyces microcarpus	KN 148 MF	14/ 05/ 20	0o 12’ 5’’ N 32o 18’ 10’’ E
			Termitomyces clypeatus	KN 060 MF	23/ 11/ 20	0o 12’ 23’’ N 32o 17’ 56’’ E
	Pleurotaceae	*Pleurotus*	*Pleurotus ostreatus*	KN 052 MF	09/11/ 20	0o 12’ 21’’ N 32o 17’ 55’’ E
		Lentinus	*Lentinus tigrinus*	KN 165 MF	24/ 05/ 20	0o 12’ 22’’ N 32o 18’ 5’’ E
			Lentinus sp.	KN 049 MF	02/ 11/ 20	0o 12’ 10’’ N 32o 17’ 40’’ E
	Omphalotaceae	*Neonothopanus*	*Neonothopanus hygrophanus*	KN 153 MF	21/ 05/ 20	0o 12’ 31’’ N 32o 18’ 42’’ E
		Gymnopus	*Gymnopus dryophilus*	KN 145 MF	14/ 05/ 20	0o 12’ 26’’ N 32o 18’ 9’’ E
			Gymnopus luxurians	KN 103 MF	07/ 05/ 20	0o 12’ 34’’ N 32o 18’ 7’’ E
			Gymnopus ocior	KN 114 MF	07/ 05/20	0o 12’ 30’’ N 32o 18’ 6’’ E
			Gymnopus biformis	KN 092 MF	14/ 12/ 20	0o 12’2’’ N 32o 17’ 40’’ E
			Gymnopus confluens	KN 034 MF	19/ 10/ 20	0o 12’ 24’’ N 32o 18’ 5’’ E
			Gymnopus foetidus	KN 033 MF	19/ 10/ 20	0o 12’ 27’’ N 32o 18’ 5’’ E
	Hygrophoraceae	*Hygrocybe*	*Hygrocybe colemanniana*	KN 023 MF	19/ 10/ 20	0o 12’ 31’’ N 32o 18’ 7’’ E
			Hygrocybe radiata	KN 127 MF	14/ 05/ 20	0o 12’ 30’’ N 32o 18’ 11’’ E

			Hygrocybe sp.	KN 058 MF	23/ 11/ 20	0o 12' 22'' N 32o 17' 57'' E
		Lichenomphalia	*Lichenomphalia umbellifera*	KN 038 MF	26/ 10/ 20	0o 12' 32'' N 32o 18' 11'' E
			Lichenomphalia velutina	KN 080 MF	07/12/ 20	0o 12' 33'' N 32o 18' 12'' E
		Cuphophyllus	*Cuphophyllus virgineus*	KN 117 MF	07/ 05/ 20	0o 12' 26'' N 32o 18' 6'' E
	Dermolomataceae	*Cystoderma*	*Cystoderma amianthinum*	KN 016 MF	12/10/ 20	0o 12' 1'' N 32o 17' 41'' E
	Marasmiaceae	*Marasmius*	*Marasmius bekolacongoli*	KN 004 MF	05/ 10/ 20	0o 12' 23'' N 32o 18' 11'' E
			Marasmius fulvoferrugineus	KN 140 MF	14/ 05/20	0o 12' 26'' N 32o 18' 9'' E
			Marasmius tageticolor	KN 170 MF	24/ 05/ 20	0o 12' 18'' N 32o 17' 56'' E
			Marasmius spissus	KN 129 MF	14/ 05/ 20	0o 12' 29'' N 32o 18' 11'' E
			Marasmius siccus	KN 112 MF	07/ 05/ 20	0o 12' 31'' N 32o 18' 6'' E
			Marasmius rotula	KN 118 MF	07/ 05/ 20	0o 12' 26'' N 32o 18' 6'' E
			Marasmius wynneae	KN 007 MF	05/10/ 20	0o 12' 25'' N 32o 18' 10'' E
			Marasmius arborescens	KN 079 MF	07/ 12/ 20	0o 12' 33'' N 32o 18' 11'' E
			Marasmius sp.	KN 194 MF	07/ 06/ 20	0o 12' 27'' N 32o 18' 10'' E
		Lentinula	*Lentinula edodes*	KN 139 MF	14/ 05/ 20	0o 12' 27'' N 32o 18' 9'' E

						Collybia	*Collybia alboflavoda*	KN 028 MF	19/ 10/20 0o 12' 25'' N 32o 18' 5'' E
							Collybia subpruinosa	KN 158 MF	21/ 05/ 20 0o 12' 11'' 32o 17' 42''
							Collybia cookei	KN 162 MF	21/ 05/20 0o 12' 4'' N 32o 17' 41'' E
							Collybia dryophila	KN 047 MF	02/11/ 20 0o 12' 5'' N 32o 17' 40'' E
							Collybia aurea	KN 078 MF	07/12/ 20 0o 12' 31'' N 32o 18' 6'' E
							Collybia sp.	KN 048 MF	02/11/20 0o 12' 6'' N 32o 17' 40'' E
						Lactocollybia	*Lactocollybia* sp.	KN 142 MF	14/ 05/ 20 0o 12' 27'' N 32o 18' 9'' E
						Tetrapyrgos	*Tetrapyrgos nigripes*	KN 071 MF	30/11/ 20 0o 12' 26'' N 32o 18' 5'' E
							Tetrapyrgos sp.	KN O59 MF	23/11/ 20 0o 12' 22'' N 32o 17' 57'' E
						Oudemansiella	*Oudemansiella canarii*	KN 063 MF	23/11/ 20 0o 12' 19'' N 32o 17' 54'' E
					Mycenaceae	*Mycena*	*Mycena rapiolens*	KN 025 MF	19/ 10/20 0o 12' 31'' N 32o 18' 5'' E
							Mycena cinerella	KN 115 MF	07/ 05/ 20 0o 12' 30'' N 32o 18' 6'' E
							Mycena vulgaris	KN 019 MF	12/ 10/ 20 0o 12' 27'' N 32o 18' 5'' E
							Mycena leptocephala	KN 123 MF	14/ 05/ 20 0o 12' 32'' N 32o 18' 11'' E
1 **Division**	**2 Classes**	**2 subclasses**	**9 orders**	**22 families**		**53 Genera**	**120 Species**		

KN = Khady Ngom; MF = Mpanga Forest

Appendix 2. Checklist of macrofungi species with an indication of their ecology, substrate, and seasonality

Species	Ecology	Substrate	First season	Second season
Auricularia delicata (Mont. ex Fr.) Henn	Saprobic	Wood	-	+
Auricularia auricula-judae (Bull.) Quél	Saprobic	Wood	-	+
Tremalla fuciformis Berk	Saprobic	Wood	+	-
Polyporus grammocephalus Berk	Saprobic	Wood	+	-
Polyporus badius (Pers.) Schwein	Saprobic	Wood	+	-
Polyporus tenuiculus (P. Beauv.) Fr	Saprobic	Wood	+	-
Polyporus varius (Pers.) Fr	Saprobic	Wood	+	-
Neofavolus alveolaris (DC.) Sotome & T. Hatt	Saprobic	Wood	+	-
Daedaleopsis confragosa (Bolton) J. Schröt	Saprobic	Wood	+	+
Trametes gibbosa (Pers.) Fr	Saprobic	Wood	+	-
Microporus xanthopus (Fr.) Kuntze	Saprobic	Wood	+	-
Microporus affinis (Blume & T. Nees) Kuntze	Saprobic	Wood	+	+
Microporus vernicipes (Berk.) Kuntze	Saprobic	Wood	+	-
Hexagonia tenius (P. Beauv.) Fr	Saprobic	Wood	+	-
Oligoporus ptychogaster (F. Ludw.) Falck & O. Falck	Saprobic	Wood	+	+
Ganoderma applanatum (Pers.) Pat	Parasitic	Tree trunk	+	+
Amauroderma rude (Berk.) Torrend	Saprobic	Soil	+	-
Amauroderma sp.	Saprobic	Soil	+	-
Amauroderma rugosum (Blume & T. Nees) Torrend	Saprobic	Soil	+	-
Cantharellus sp.	Ectomycorrhizal symbiont	Rotten wood	+	-
Agaricus arvensis Schaeff	Saprobic	Soil	-	+
Agaricus diminutivus Peck	Saprobic	Litter	-	+
Agaricus moelleri Wasser	Saprobic	Litter	+	+
ymenagaricus sp.	Saprobic	Litter	-	+
Micropsalliota sp.	Saprobic	Litter	-	+
Amanita sinicoflava Tulloss	Ectomycorrhizal symbiont	Soil	-	+
Coprinellus disseminatus (Pers.) J.E. Lange	Saprobic	Litter	-	-
Coprinellus sp.	Saprobic	Litter	+	-
Coprinopsis lagopus (Fr.) Redhead	Saprobic	Litter	-	+
Coprinopsis domesticus (Bolton) Gray	Saprobic	Litter	+	-
Coprinopsis cinerea (Schaeff.) Redhead, Vilgalys & Moncalvo	Saprobic	Soil	+	+
Parasola auricoma (Pat.) Redhead, Vilgalys & Hopple	Saprobic	Litter	-	+
Psathyrella tephrophylla (Romagn.) M.M. Moser	Saprobic	Litter	-	+
Psathyrella leucotephra (Berk. & Broome) P.D. Orton	Saprobic	Litter	-	+
Psathyrella candolleana (Fr.) Maire	Saprobic	Litter	+	+
Psathyrella spadiceogrisea (Schaeff.) Maire	Saprobic	Litter	-	+
Psathyrella clivensis (Berk. & Broome) Rezende-Pinto	Saprobic	Litter	+	-
Psathyrella inflatocystis A.H. Sm	Saprobic	Litter	+	-
Psathyrella conferta Eyssart. & Chiaffi	Saprobic	Litter	-	+
Psathyrella pennata (Fr.) A. Pearson & Dennis	Saprobic	Litter	-	+
Psathyrella conopilus (Fr.) A. Pearson & Dennis	Saprobic	Litter	+	-

Species	Ecology	Substrate	First season	Second season
Psathyrella olympiana A.H. Sm	Saprobic	Litter	-	+
Psathyrella sp.	Saprobic	Litter	+	-
Lepiota cristata (Bolton) P. Kumm	Saprobic	Litter	-	+
Lepiota felina (Pers.) P. Karst	Saprobic	Litter	-	+
Macrolepiota africana (R. Heim) Heinem	Saprobic	Litter	-	+
Macrolepiota procera (Scop.) Singer	Saprobic	Litter	-	+
Macrolepiota dolichaula (Berk. & Broome) Pegler & R.W. Rayner	Saprobic	Soil	-	+
Cystolepiota pulverulenta (Huijsman) Vellinga	Saprobic	Litter	-	+
Leucoagaricus rubrotinctus (Peck) Singer	Saprobic	Soil	-	+
Leucoagaricus croceovelutinus (Bon & Boiffard) Bon	Saprobic	Litter	+	-
Leucocoprinus scissus Justo, Bizzi & Angelini	Saprobic	Litter	-	+
Leucocoprisnus brebissoni (Godey) Locquin	Saprobic	Litter	+	+
Volvariella volvacea (Bull.) Singer	Saprobic	Wood	+	+
Cortinarius humicola (Quél.) Maire	Ectomycorrhizal symbiont	Soil	+	+
Inocybe sindonia (Fr.) P. Karst	Ectomycorrhizal symbiont	Soil	-	+
Inocybe rimosa (Bull.) P. Kumm	Ectomycorrhizal symbiont	Soil	+	+
Entoloma conferendum (Britzelm.) Noordel	Saprobic	Litter	-	+
Entoloma sp.	Saprobic	Litter	-	+
Claudopus variabilis (Pers.) Gillet	Saprobic	Wood	-	+
Rhodocybe sp.	Ectomycorrhizal symbiont	Soil	-	+
Russula aurea Pers	Ectomycorrhizal symbiont	Soil	-	+
Russula virescens (Schaeff.) Fr.	Ectomycorrhizal symbiont	Soil	+	+
Lactarius chrysorrheus Fr.	Ectomycorrhizal symbiont	Soil	-	-
Lactarius indigo (Schwein.) Fr.	Ectomycorrhizal symbiont	Soil	+	+
Tricholoma stiparophyllum (N. Lund) P. Karst	Ectomycorrhizal symbiont	Soil	-	+
Tricholoma sp. 1	Ectomycorrhizal symbiont	Soil	-	+
Tricholoma sp. 2	Ectomycorrhizal symbiont	Soil	+	+
Arrhenia velutipes (P.D. Orton) Redhead, Lutzoni, Moncalvo & Vilgalys	Saprobic	Soil	-	+
Arrhenia epichysium (Pers.) Redhead, Lutzoni, Moncalvo & Vilgalys	Saprobic	Wood	+	+
Arrhenia obscurata (D.A. Reid) Redhead, Lutzoni, Moncalvo & Vilgaly	Saprobic	Soil	-	+
Clitocybe phaeophtalma (Pers.) Kuyper	Ectomycorrhizal symbiont	Soil	+	+
Clitocybe fragrans (With.) P. Kumm	Ectomycorrhizal symbiont	Soil	+	+
Clitocybe sp. 1	Ectomycorrhizal symbiont	Soil	-	+
Clitocybe sp. 2	Ectomycorrhizal symbiont	Soil	+	+
Panus fulvus (Berk.) Pegler & R.W. Rayner	Saprobic	Wood	-	+
Termitomyces robustus (Beeli) R. Heim	Symbiont with termites	Termite mound	-	+
Termitomyces microcarpus (Berk. & Broome) R. Heim	Symbiont with termites	Termite mound	+	+
Termitomyces clypeatus R. Heim	Symbiont with termites	Termite mound	+	+
Pleurotus ostreatus (Jacq.) P. Kumm	Saprobic	Litter	+	+
Lentinus tigrinus (Bull.) Fr	Saprobic	Soil	+	+
Lentinus sp.	Saprobic	Soil	-	+
Neonothopanus hygrophanus (Mont.) De Kesel & Degree	Saprobic	Wood	+	+
Gymnopus dryophilus (Bull.) Murrill	Saprobic	Litter	+	+

Species	Ecology	Substrate	First season	Second season
Gymnopus luxurians (Peck) Murrill	Saprobic	Litter	+	+
Gymnopus ocior (Pers.) Antonín & Noordel	Saprobic	Litter	+	+
Gymnopus biformis (Peck) Halling	Saprobic	Litter	-	+
Gymnopus confluens (Pers.) Antonín, Halling & Noordel	Saprobic	Litter	+	+
Gymnopus foetidus (Sowerby) J.L. Mata & R.H. Petersen	Saprobic	Wood	-	+
Hygrocybe colemanniana (A. Bloxam) P.D. Orton & Watling	Ectomycorrhizal symbiont	Soil	+	+
Hygrocybe radiata Arnolds	Ectomycorrhizal symbiont	Soil	+	+
Hygrocybe sp.	Ectomycorrhizal symbiont	Soil	+	+
Lichenomphalia umbellifera (L.) Redhead, Lutzoni, Moncalvo & Vilgalys	Saprobic	Litter	-	+
Lichenomphalia velutina (Quél.) Redhead, Lutzoni, Moncalvo & Vilgalys	Saprobic	Litter	+	+
Cuphophyllus virgineus (Wulfen) Kovalenko	Saprobic	Soil	-	+
Cystoderma amianthinum (Scop.) Fayod	Ectomycorrhizal symbiont	Soil	+	+
Marasmius bekolacongoli Beeli	Saprobic	Litter	+	+
Marasmius fulvoferrugineus Gilliam	Saprobic	Litter	-	+
Marasmius tageticolor Berk	Saprobic	Litter	+	+
Marasmius spissus Gilliam	Saprobic	Litter	+	+
Marasmius siccus (Schwein.) Fr.	Saprobic	Litter	-	+
Marasmius rotula (Scop.) Fr.	Saprobic	Litter	+	+
Marasmius wynneae Berk. & Broome	Saprobic	Litter	+	+
Marasmius arborescens (Henn.) Beeli	Saprobic	Litter	-	+
Marasmius sp.	Saprobic	Litter	+	+
*Lentinula edodes (*Berk.) Pegler	Saprobic	Soil	+	+
Collybia alboflavoda (Peck) Kauffman	Saprobic	Litter	-	+
Collybia subpruinosa (Murrill) Dennis	Saprobic	Litter	-	+
Collybia cookei (Bres.) J.D. Arnold	Saprobic	Wood	+	+
Collybia dryophila (Bull.) P. Kumm	Saprobic	Litter	+	+
Collybia aurea (Beeli) Pegler	Saprobic	Litter	-	+
Collybia sp.	Saprobic	Litter	+	+
Lactocollybia sp.	Saprobic	Litter	+	+
Tetrapyrgos nigripes (Fr.) E. Horak	Saprobic	Soil	+	+
Tetrapyrgos sp.	Saprobic	Litter	-	+
Oudemansiella canarii (Jungh.) Höhn	Saprobic	Wood	-	+
Mycena rapiolens J. Favre	Saprobic	Wood	+	+
Mycena cinerella (P. Karst.) P. Karst	Saprobic	Litter	+	+
Mycena vulgaris (Pers.) P. Kumm	Saprobic	Litter	+	+
Mycena leptocephala (Pers.) Gillet	Saprobic	Litter	+	+

Appendix 3. Correlation between the physical properties of the soil and the abundance of macrofungi species

		Ca	***Cuphophyllus virgineus***
	Pearson Correlation	1	-0.998**
Ca	Sig. (2-tailed) N		0,002
	Pearson Correlation	4	4
Cuphophyllus virgineus	Sig. (2-tailed) N	-0.998**	1
		0.002	
		4	4

**Correlation is significant at the 0.01 level (2-tailed), N = Number of sites

		Ca	***Tetrapyrgos nigripes***
	Pearson Correlation	1	-0.962*
Ca	Sig. (2-tailed) N		0,038
	Pearson Correlation	4	4
Tetrapyrgos nigripes	Sig. (2-tailed) N	-0.962*	1
		0.038	
		4	4

*Correlation is significant at the 0.05 level (2-tailed)

		Ca	
	Pearson Correlation	1	-0.983*
Ca	Sig. (2-tailed) N		0,017
	Pearson Correlation	4	4
Clitocybe fragrans	Sig. (2-tailed) N	-0.983*	1
		0.017	
		4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		Clay	*Termitomyces clypeatus*
	Pearson Correlation	1	-0.986*
Clay	Sig. (2-tailed) N		0,014
	Pearson Correlation	4	4
Termitomyces clypeatus	Sig. (2-tailed) N	-0.986*	1
		0.014	
		4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		Clay	*Clitocybe phaeophtalma*
	Pearson Correlation	1	-0.986*
Clay	Sig. (2-tailed) N		0,014
	Pearson Correlation	4	4
Clitocybe phaeophtalma	Sig. (2-tailed) N	-0.986*	1
		0.014	
		4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		K	*Inocybe sindonia*
	Pearson Correlation	1	0.953*
K	Sig. (2-tailed) N		0,047
	Pearson Correlation	4	4
Inocybe sindonia	Sig. (2-tailed) N	0.953*	1
		0.047	
		4	4

*Correlation is significant at the 0.05 level (2-tailed) N = Number of sites,

		N	*Arrhenia velutipes*
	Pearson Correlation	1	0.994**
N	Sig. (2-tailed) N		0,006
	Pearson Correlation	4	4
Arrhenia velutipes	Sig. (2-tailed)	0.994**	1
		0.006	

	N	**4**	**4**

**Correlation is significant at the 0.01 level (2-tailed), N = Number of sites

		Na	*Macrolepiota dolichaula*
	Pearson Correlation	1	-0.951*
Na	Sig. (2-tailed)		0,049
	N	4	4
	Pearson Correlation	-0.951*	1
Macrolepiota dolichaula	Sig. (2-tailed)	0.049	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		Na	*Arrhenia obscurata*
	Pearson Correlation	1	-0.995**
Na	Sig. (2-tailed)		0,005
	N	4	4
	Pearson Correlation	-0.995**	1
Arrhenia obscurata	Sig. (2-tailed)	0.005	
	N	4	4

**Correlation is significant at the 0.01 level (2-tailed), N = Number of sites

		Na	*Lentinus* sp.
	Pearson Correlation	1	0.986*
Na	Sig. (2-tailed)		0,014
	N	4	4
	Pearson Correlation	0.986*	1
Lentinus sp.	Sig. (2-tailed)	0.014	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		Na	*Lactarius indigo*
	Pearson Correlation	1	0.988*
Na	Sig. (2-tailed)		0,012
	N	4	4
	Pearson Correlation	0.988*	1
Lactarius indigo	Sig. (2-tailed)	0.012	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		Na	*Termitomyces microcarpus*
	Pearson Correlation	1	0.965*
Na	Sig. (2-tailed)		0,035
	N	4	4
	Pearson Correlation	0.965*	1
Termitomyces microcarpus	Sig. (2-tailed) N	0.035	
		4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		Na	*Hygrocybe colemanniana*
	Pearson Correlation	1	0.975*
Na	Sig. (2-tailed)		0,025
	N	4	4
	Pearson Correlation	0.975*	1
Hygrocybe colemanniana	Sig. (2-tailed)	0.025	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		OC	*Arrhenia velutipes*
	Pearson Correlation	1	0.986*
OC	Sig. (2-tailed)		0,014
	N	4	4
	Pearson Correlation	0.986*	1
Arrhenia velutipes	Sig. (2-tailed)	0.014	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		OM	*Arrhenia velutipes*
	Pearson Correlation	1	0.986*
OM	Sig. (2-tailed)		0,014
	N	4	4
	Pearson Correlation	0.986*	1
Arrhenia velutipes	Sig. (2-tailed)	0.014	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

		P	*Rhodocybe* sp.
	Pearson Correlation	1	0.976*
P	Sig. (2-tailed)		0,024
	N	4	4
	Pearson Correlation	0.976*	1
Rhodocybe sp.	Sig. (2-tailed)	0.024	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

	Pearson Correlation	1	-0.953*
pH	Sig. (2-tailed)		0,047
	N	4	4
	Pearson Correlation	-0.953*	1
Russula aurea	Sig. (2-tailed)	0.047	

	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

			Termitomyces clypeatus
Sand	Pearson Correlation	1	0.986*
	Sig. (2-tailed)		0,014
	N	4	4
Termitomyces clypeatus	Pearson Correlation	0.986*	1
	Sig. (2-tailed)	0.014	
	N	4	4

*Correlation is significant at the 0.05 level (2-tailed), N = Number of sites

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