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Biodiversity and Ecology of Indigenous Edible and Medicinal Mushrooms of Eastern Uganda

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Abstract: Teso region is one of the regions in Uganda where wild edible mushrooms grow abundantly. During the past decades, it has been subject to major ecological changes and therefore deserves specific attention to the conservation of this valuable resource. A study was conducted using 10 narrow strip plots along established transects in each of the four different micro habitat sites. The study showed that mushrooms could grow from any of the four micro habitat sites. A total of fifteen different species were found and most of them growing on ordinary garden soils 51.1% and termite mounds 42.2% during the wetter parts of the seasons 88.3%. They preferred more open areas 60.9% to closed ones 10.9% and grounds covered with leaves 40.9% or bare 51.5% but with a deeper black soil level 29%. It would be interesting if studies were done to investigate specific relationships of these variables to particular edible and medicinal mushroom type.

Key words: Biodiversity, ecology, micro habitats, growth substrate, seasons, canopy cover, organinic matter type, black soil depth, edible and medicinal mushrooms

INTRODUCTION

Mushrooms are diverse and like other species will grow in areas where the environmental conditions support their growth; distribution and abundance will be influenced by the variety of micro sites available for their favorable growth[1,2]. Despite their diversity, mushrooms are rarely seen next to each other and form unique associations determined by their environmental requirements[3]. Mushrooms form a part of ecology of many environments including forests, grasslands and wetlands. They are dependent on the same limiting factors that influence other organisms in a given habitat[3]. It is known that all species of mushrooms have specific requirements for moisture and temperature before they will produce a fruit. Some mushrooms have a very restrictive set of requirements while others have very broad sets of requirements[3]. Various species of mushrooms are found on certain kinds of trees and shrubs[4]. Some mushrooms tend to occur in a variety of habitats but many are restricted in distribution. Unlike those fungi that live on logs and ultimately die when they run out of food, the mycelium of ground dwelling fungi can live for centuries in their natural habitats.

About 1800 species of termites are known and approximately 100 species are fungus growers. These termites grow about 20 mushroom species (Termitomyces mushrooms) in their ecosystems[5,6]. The tropical genus is well represented. Most often occur in areas cleared for cultivation, edges of forests, on or near termite mounds and degraded woodland or bush land in the vicinity of a termite nest. Some species like *Ganoderma* and *Amillaria* species (Saprophytic mushrooms) are found growing on dead roots, wood logs and saw dust from trees. *Lentinulla edodes* always grow on cut ends of tree trunks and other mushrooms are found in association (Symbiotic mushrooms) with other tree roots for example *Cantharellus* and *Lactarius* species[7]. Some other species are found growing on rich soils in gardens, plantations, rubbish heaps or on bush lands. The saprophytic fungi and others that have symbiotic associations with termites are important in ecosystems. In associations, they are vital for plants in poor, dry tropical soils[8]. Saprophytic mushrooms can thus occur in agricultural land, in pastures, in woodlands and forests. The Termitomyces, which live in symbiosis with termites, are important too. Termites culture the mycelium of the fungus in their nests and feed upon it

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and spread it. It is known that this relationship is obligate for both partners Härkönen *et al*[5]; Katende *et al*[9].

MATERIALS AND METHODS

Kumi District is located in Eastern Uganda and lies approximately between latitude 1°10^{1} N, 1°35^{1}N, longitude 33°30^{1}, 34°20^{1}E[10]. It is approximately between 1036 m and 1127 m above sea level with highly effective rainfall which is largely bimodal tending to mono-modal. The vegetation is mainly savannah species, thickets, some forest plantations and riparian vegetation with the geology forming the underlying rock being made up of the basement complex.

Ecological studies: Four micro habitat sites were identified namely woodland, cultivated land, less grazed land (tall grass) and over grazed land (short grass). From each micro habitat site, 10 long narrow strip plots of 10 X 100 m were used as they are more likely to intersect mushrooms in patches than equal-sized circular or square plots[11,12]. Also, because large sample areas and plot sizes are needed, it is easier to keep track of the areas already searched in strip plots than in circular plots (especially in bushy areas). Mushrooms were searched in narrow strip plots along transects that were established at a 10 m distance from each other. Substrate that was potential mushroom habitats was also searched along these transects[4]. The edible and medicinal mushrooms encountered was characteristically recorded and collected. Mushroom habitats or searched sites were stratified and studied according to climatic or seasonal variations and variations in microhabitat factors.

RESULTS

Mushrooms and micro habitat sites: Fifteen different edible mushroom species were found on the four micro habitat sites established Table 1, with thirteen 87.6% recorded from the cultivated area, eleven 73.3 from over grazed area, thirteen 87.6 from less grazed area and eleven 73.3% from wood land areas. Eight species 53.3% were present in all the four micro habitat sites. The number of species restricted to only one micro habitat site was one 6.7% and the number of species appearing in only two micro habitat sites was three 20% as shown in the Table. More mushrooms were found in the over grazed micro habitat 32.5% and least in the wood land area 20%.

Mushrooms and growth substrate: Different edible mushroom species require certain growing media in the wild Table 2 which may be specific as shown by *Etimijaka (Agraicus* sp.), Emeruka (Not identified), Opungurei (Not identified), imaruk (*Termitomyces* sp.), Esoromantonit (*Termitomyces* sp.) and *Ebekubeku (Termitomyces* sp.*)*. The growth substrates were classed as ordinary garden soils, decaying log, termite mound and the living plant. Ordinary garden soil had the highest encounters 51.1% but with a total of only eight different species. No edible mushroom was located growing on the living plant while two species (*Opungurei* and *Emeruka*) were found growing on the decaying wood and this is 7.7% of the total. Termite mound had the second largest encounters 42.2% and with the highest number of species[12]. This clearly shows that most edible mushroom species either require termite mounds or are associated with the termites to enable their growth.

Mushrooms and growth seasons: The study was conducted in two different periods. The wetter part of the year and the drier part of the year. Table 3 below shows that many mushroom species will appear at specific times. Those that require little rainfall intensities will appear in the drier part of the season and those that require much rainfall intensities will appear during the wetter part of the season. Only three edible mushroom species 20% were found growing on both seasons.

Mushrooms and canopy cover: The edible mushrooms were searched from different canopy covers. These were categorized as opened, slightly opened and closed percentage canopy covers. Table 4 below shows that many mushroom species appear from opened canopy cover. Those that require little sunlight appear under closed canopy covers and those that require more appear under opened canopy. Only five edible mushroom species 33.3% were found growing under one canopy cover.

Mushrooms and organic matter type: Organic matter may contribute a lot to the growth substrate of the mushrooms. These were categorized as leaves/twigs, branches/sticks, poles/logs and none at all (bare ground). Two species were found on logs and nine species on both grounds covered with leaves and bare ground. Five species were found specific on only one organic matter type as shown in the Table 5 below.

Mushrooms and black soil depth: The black soil depth was categorized as shallow, medium and deep Table 2. Termite mounds and decaying wood were omitted and therefore treated as not applicable. Seven species were found only on either termite mounds or decaying wood. Six edible mushroom species were found growing on

Table 1: Edible mushroom occurrence in different micro habitat sites

	Frequency occurrence				%Frequency occurrence			
Species	Cultivated land	Over grazed	Less grazed	Wood land	Cultivated land	Over grazed	Less grazed	Wood land
Okao (*Agaricus* sp.)	0	37	0	0	0	100	0	0
Esiara (*Tricholoma* sp.)	12	4	25	8	24.5	8.2	51.0	16.3
Eguti (*T. aurantiacus*)	0	11	1	0	0	91.7	8.3	0
Echoroi (*Agaricus* sp.)	1	8	10	12	3.2	25.8	32.3	38.7
Etimijaka (*Agaricus* sp.)	2	6	4	0	16.7	50	33.3	0
Eburukunyu (*Agaricus* sp.)	6	4	4	8	27.2	18.2	18.2	36.4
Eswei (*T. microcarpus*)	3	3	2	1	33.3	33.3	22.2	11.1
Emeruka (Not identified)	2	4	4	2	16.7	33.3	33.3	16.7
Opungurei (Not identified)	5	0	3	1	55.6	0	33.3	11.1
Otulelut (*Agaricus sp*)	6	2	1	1	60	20	10	10
Oujoi (*Lepiota* sp.)	2	6	1	1	20	60	10	10
Odilit (*Termitomyces* sp.)	7	4	13	15	17.9	10.3	33.3	38.5
Imaruk (*Termitomyces* sp.)	6	0	2	3	54.5	0	18.2	27.3
Esoromantonit (*T.* sp.)	2	0	4	0	33.3	0	66.7	0
Ebekubeku (*T.* sp.)	2	0	0	3	40	0	0	60
Total	56	89	74	55	20.4	32.5	27	20
Species richness	13	11	13	11	86.7	73.3	86.7	73.3

Species overlap (similarity index) = 8/15x100 = 53.3%

Table 2: Edible mushroom occurrence in different growth substrate types

	Frequency occurrence				%Frequency occurrence			
Species	Soil	decaying log	termite mounds	living plant	Soil	decaying log	termite mounds	living plant
Okao (*Agaricus* sp.)	29	0	8	0	78.4	0	21.6	0
Esiara (*Tricholoma* sp.)	43	0	6	0	87.8	0	12.2	0
Eguti (*T. aurantiacus*)	10	0	2	0	83.3	0	16.7	0
Echoroi (*Agaricus* sp.)	12	0	19	0	38.7	0	61.3	0
Etimijaka (*Agaricus* sp.)	0	0	12	0	0	0	100	0
Eburukunyu (*Agaricus* sp.)	12	0	10	0	54.5	0	45.5	0
Eswei (*T. microcarpus*)	0	0	9	0	0	0	100	0
Emeruka (Not identified)	0	12	0	0	0	100	0	0
Opungurei (Not identified)	0	9	0	0	0	100	0	0
Otulelut (*Agaricus sp*)	5	0	5	0	50	0	50	0
Oujoi (*Lepiota* sp.)	10	0	0	0	100	0	0	0
Odilit (*Termitomyces* sp.)	19	0	20	0	48.7	0	51.3	0
Imaruk (*Termitomyces* sp.)	0	0	11	0	0	0	100	0
Esoromantonit (*T.* sp.)	0	0	6	0	0	0	100	0
Ebekubeku (*T.* sp.)	0	0	5	0	0	0	100	0
Total	140	21	113	0	51.1	7.7	42.2	0

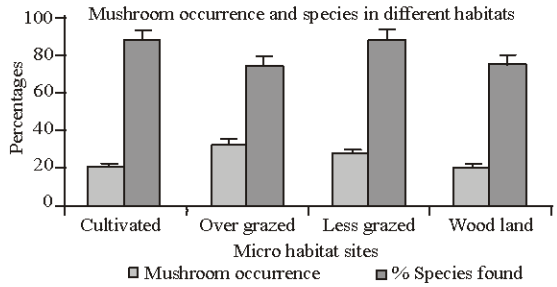

Fig. 1: Relationship between mushroom % encounters and species richness in micro habitat sites

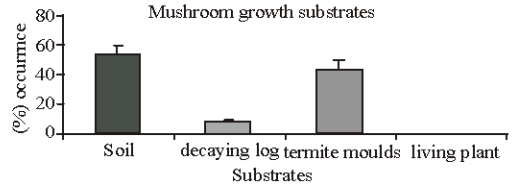

Fig. 2: Different edible mushroom growth substrates in the wild

shallow soils, seven on medium soils and only four were found on deep soils.

Cultivated land and less grazed micro habitats both had over 80% of the total species found and yet they had only about 20% of the total encounters Fig. 1. Over grazed area had the low species total and yet with more mushroom occurrences of the few species found. Wood land area had the least of both the encounters and species totals compared with other micro habitat sites.

The Fig. 2 above shows that most edible mushroom species use ordinary garden soil as their growth substrate. This is followed by termite mounds and least in decaying wood.

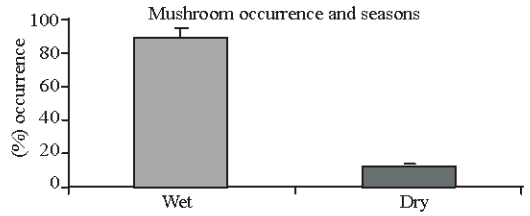

Fig. 3: Edible mushroom species % occurrence and their growing seasons

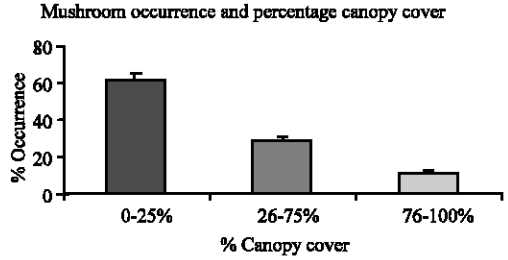

Fig. 4: Edible mushroom species % occurrence and % canopy cover

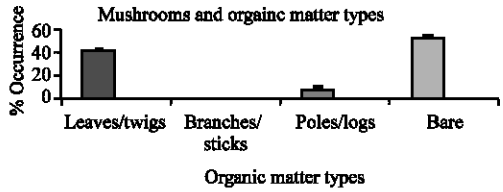

Fig. 5: Different organic matter types found where edible mushrooms grow

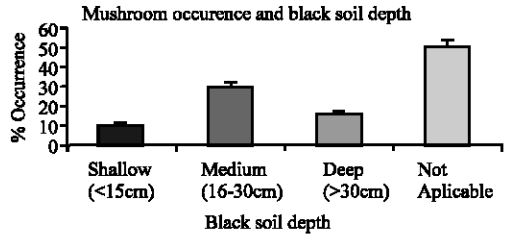

Fig. 6: Edible mushroom Percent occurrence and the depth of the black soils

From the Fig. 3 above, most mushroom species appeared during the wetter part of the season 88.3% compared to the drier part of the season 11.7%. Nine of the fifteen species encountered 60% appeared only during the wetter part of the season.

From the Fig. 4 above, most mushroom species prefer opened percentage canopy cover 60.9. This is followed by slightly opened percentage canopy cover 28.1% and least in the closed percentage cover 10.9%.

The bare ground had the largest percentage 51.5%. This was followed by leaves/twigs with 40.9% and least in the poles and logs which accounted for only 7.7%. Other categories did not account for any mushroom growth Fig. 5.

Most edible mushroom species were found growing where it was not possible to find the level of black soils 48.9%. Medium black soil depth 16-30 cm had the highest number of mushrooms 29% followed by deep black soil depth (>30 cm) with 15% and least in the shallow soils (=15 cm) with 9.1% Fig. 6.

DISCUSSION

Apart from some perennial bracket fungi, fruit bodies of mushrooms are relatively short lived (approximately 1-20 days). Different species appear at different times of the year, although individual species may not appear every year. Single samples thus do not suffice to characterize the myco-flora of the plot. Sampling must be carried out at intervals through out the year and over several years. The total number of the species present on the site may not be found until more than 5 years of sampling[11]. Nevertheless the relatively higher number of species in cultivated land and less grazed area could be that they provided better growing conditions for the mushrooms than the other micro habitats. It could also be that the presence of the termite mounds (termites) and the wood could have provided these sites with better conditions as shown in Table 2.

Most mushroom species are associated to termites as shown in Table 2. This kind of association helps the *Termitomyces* species to grow when their appropriate conditions are reached. Since about 42% of the occurrences were with the termite mounds, then their contribution is highly evident. This is in line with other observations[7] which reported that termites grow about 20 species of *Termitomyces* sp. alone. The high numbers in the garden soils could have been because some termite mounds could not be easily seen and therefore the termite activity in this study not noted. It could also be that the soils had some other activities and materials that mushroom growth would require such as the organic matter needed by saprophytic mushrooms and reported earlier[8].

Micro habitats during the wetter parts of the year appear to provide more adequate condition for the fruiting bodies more than the micro habitats during the drier parts of the year. This could be because mushrooms growths depend so much on the rainfall conditions that are appropriate for them. This is in line with the assertions[11] that macro fungi will appear when conditions for their growth are favorable. The number of edible mushroom species could have been underestimated because only fruit bodies found were identified; any mushroom that

Table 3: Edible mushroom species and their seasons of growth

	Frequency occurrence		% Frequency occurrence	
Species	Wet	Dry	Wet	Dry
Okao (*Agaricus* sp.)	37	0	100	0
Esiara (*Tricholoma* sp.)	49	0	100	0
Eguti (*T. aurantiacus*)	12	0	100	0
Echoroi (*Agaricus* sp.)	31	0	100	0
Etimijaka (*Agaricus* sp.)	12	0	100	0
Eburukunyu (*Agaricus* sp.)	18	4	81.8	18.2
Eswei (*T. microcarpus*)	6	3	66.7	33.3
Emeruka (Not identified)	12	0	100	0
Opungurei (Not identified)	6	3	66.7	33.3
Otulelut (*Agaricus sp*)	10	0	100	0
Oujoi (*Lepiota* sp.)	10	0	100	0
Odilit (*Termitomyces* sp.)	39	0	100	0
Imaruk (*Termitomyces* sp.)	0	11	0	100
Esoromantonit (*Termitomyces* sp.)	0	6	0	100
Ebekubeku (*Termitomyces* sp.)	0	5	0	100
Total	242	32	88.3	11.7

Table 4: Edible mushroom species occurrence and % canopy cover

	Frequency occurrence/%canopy			% Frequency occurrence		
Species	0-25%	26-75%	76-100%	0-25%	26-75%	76-100%
Okao (*Agaricus* sp.)	31	6	0	83.8	16.2	0
Esiara (*Tricholoma* sp.)	27	19	3	55.1	38.8	6.1
Eguti (*T. aurantiacus*)	12	0	0	100	0	0
Echoroi (*Agaricus* sp.)	15	11	5	48.4	35.5	16.1
Etimijaka (*Agaricus* sp.)	6	4	2	50	33.3	11.1
Eburukunyu (*Agaricus* sp.)	9	3	10	40.9	13.6	45.5
Eswei (*T. microcarpus*)	2	4	3	22.2	44.4	33.3
Emeruka (Not identified)	11	1	0	91.7	8.3	0
Opungurei (Not identified)	9	0	0	100	0	0
Otulelut (*Agaricus sp*)	5	5	0	50	50	0
Oujoi (*Lepiota* sp.)	10	0	0	100	0	0
Odilit (*Termitomyces* sp.)	17	18	4	43.6	46.2	10.2
Imaruk (*Termitomyces* sp.)	11	0	0	100	0	0
Esoromantonit (*Termitomyces* sp.)	0	6	0	0	100	0
Ebekubeku (*Termitomyces* sp.)	2	0	3	40	0	60
Total	167	77	30	60.9	28.1	10.9

Opened = (0-25%), slightly opened / slightly closed = (26-75%), Closed = (76-100%)

Table 5: Types of organic matter found where edible mushroom grow

	Frequency occurrence/ organic matter				% Frequency occurrence			
Species	Leaves/twigs	Branches/sticks	Poles/logs	Bare	Leaves/twigs	branches/sticks	Poles/logs	Bare
Okao (*Agaricus* sp.)	4	0	0	33	10.8	0	0	8912
Esiara (*Tricholoma* sp.)	21	0	0	28	42.9	0	0	57.1
Eguti (*T. aurantiacus*)	0	0	0	12	0	0	0	100
Echoroi (*Agaricus* sp.)	19	0	0	12	61.3	0	0	38.7
Etimijaka (*Agaricus* sp.)	12	0	0	0	100	0	0	0
Eburukunyu (*Agaricus* sp.)	11	0	0	11	50	0	0	50
Eswei (*T. microcarpus*)	6	0	0	3	66.7	0	0	33.3
Emeruka (Not identified)	0	0	12	0	0	0	100	0
Opungurei (Not identified)	0	0	9	0	0	0	100	0
Otulelut (*Agaricus sp*)	5	0	0	5	50	0	0	50
Oujoi (*Lepiota* sp.)	0	0	0	10	0	0	0	100
Odilit (*Termitomyces* sp.)	18	0	0	21	46.6	0	0	53.8
Imaruk (*Termitomyces* sp.)	7	0	0	4	63.6	0	0	36.4
Esoromantonit (*Termitomyces*)	6	0	0	0	100	0	0	0
Ebekubeku (*Termitomyces* sp.)	3	0	0	2	60	0	0	40
Total	112	0	21	141	40.9	0	7.7	51.5

Twigs = <0.5 cm, sticks/branches = 0.6-15 cm, poles/logs = >15 cm

Table 6: Edible mushroom % occurrence and the depth of black soils

	Frequency occurrence/ Black soil depth				% Frequency occurrence			
Species	Shallow <15 cm	Medium 16-30 cm	Deep > 30 cm	Not App.	Shallow <15cm	Medium 16-30 cm	Deep > 30 cm	Not App.
Okao (*Agaricus* sp.)	0	0	29	8	0	0	78.4	21.6
Esiara (*Tricholoma* sp.)	3	30	10	6	6.1	61.2	20.4	12.3
Eguti (*T. aurantiacus*)	7	2	1	2	58.3	16.7	8.3	16.7
Echoroi (*Agaricus* sp.)	3	9	0	19	9.7	29	0	61.3
Etimijaka (*Agaricus* sp.)	0	0	0	12	0	0	0	100
Eburukunyu (*Agaricus* sp.)	0	13	0	9	0	59.1	0	40.9
Eswei (*T. microcarpus*)	0	0	0	9	0	0	0	100
Emeruka (Not identified)	0	0	0	12	0	0	0	100
Opungurei (Not identified)	0	0	0	9	0	0	0	100
Otulelut (*Agaricus sp*)	1	4	0	5	10	40	0	50
Oujoi (*Lepiota* sp.)	4	6	0	0	40	60	0	0
Odilit (*Termitomyces* sp.)	7	10	1	21	17.9	25.6	2.6	53.8
Imaruk (*Termitomyces* sp.)	0	0	0	11	0	0	0	100
Esoromantonit(*Termitomyces* sp.)	0	0	0	6	0	0	0	100
Ebekubeku (*Termitomyces* sp.)	0	0	0	5	0	0	0	100
Total	25	74	41	134	9.1	29	15	48.9

Not App. = Not Applicable = (growing on either termite mound or wood)

fruited between sampling seasons or not at all during the study could have been missed. The mushroom species that appeared in both seasons could be that they have a broader range of temperature and moisture requirements. This is in agreement with other findings[3] that under proper conditions, mushrooms will appear.

From Fig. 4 most mushroom species preferred opened percentage canopy cover followed by slightly opened percentage canopy cover and least in the closed percentage cover. This could be that under opened canopy, it was easier to locate the mushroom than in the closed canopy. The relationship of mushroom presence decreasing with increased percentage canopy cover seems evident here although earlier attempts in some species show either as reported elsewhere[13]. The difference could have been brought about by the fact that under opened percentage canopy, the moisture from the rain would easily reach the mushrooms and aid their growth than in closed percentage canopy where we expect the dense cover above ground to trap most of the moisture and therefore mushrooms are disadvantaged and not many grow.

The bare ground had the largest percentage. This was followed by ground covered by leaves/twigs and least in the poles and logs. This clearly shows that the above woody or organic matter types was not an important factor in the mushroom habitats. This is in contrast to reports that some mushrooms are associated to some woody ground debris[13]. Although ground debris was not identified as important as shown by most mushrooms growing on bare grounds, this may be important in retention of moisture and supporting growth.

Most edible mushroom species were found growing where it was not possible to find the level of black soils (for example termite mounds and logs) nevertheless medium black soil depth had the highest number of mushrooms followed by deep black soil and least in the shallow soils. It seems the mushrooms prefer deeper soils to shallower ones. This could be because the organic matter in the black soils helps provide the required soil conditions for the mushrooms. This is in agreement with earlier reports[13] that some land use practices that remove duff may be detrimental to some mushroom species.

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