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Estimating Growth Rate of *Bryum coronatum, Barbula lambarenensis* and *Hyophila involuta* in the Guinea Savanna Ecological Zone of Nigeria

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Abstracts
Mosses are non-vascular plants that occur on a wide range of habitats. Many species of mosses grow naturally in Nigeria, but there is a paucity of studies on their growth rate. This study investigated the growth rate of three acrocarpous mosses: *Bryum coronatum* Schwaegr; *Barbula lambarenensis* (Hook) Jaeg; and *Hyophila involuta* (Hook) Spreng in Ejiu-Ayegunle and Araromi-Opin, Ekiti Local Government Area of Kwara State. Mosses were randomly collected from their natural habitats at different locations in the study area and taken to the laboratory at two weeks interval for a period of six months where they were identified and used for growth study. The shoot heights were measured fortnightly for a period of 6 months by placing the stems on a clean slide and a thread stretched over each shoot from the base of rhizoid to the apex of the shoot and the measurements were later extrapolated on metre rule. Leaves were detached into a drop of water on a microscope slide with a scalpel and forceps and positioned on the slide, before counting under a dissecting microscope at 40x magnification. The results showed that moss shoot heights ranged between 1mm and 4mm and the growth rate varied among the species and habitats. Of the three species, *Bryum coronatum* recorded the highest mean incremental shoot height of 0.9±0.42mm-3.5±1.13mm per season followed by *Barbula lambarenensis* (0.2±0.04mm-2.1±1.60mm) and *Hyophila involuta* (0.2±0.07mm-1.4±0.14mm) during the period of study. The species also showed a variation in the number of leaves per plant and differed significantly in leaf blade length and blade width. The study concluded that the growth potential of a species determines its degree of success in a particular environment.

Keywords: Mosses, growth, measurements, leaf area, leaf area index.

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Introduction

Mosses are non-vascular plants that occur on a wide range of habitats. They are the most species-rich of the three classes of bryophytes, and the most widely distributed of all seedless tracheophytes (Shaw and Goffinet, 2000). About 15,000 species of mosses are known worldwide (Shaw and Renzaglia, 2004), most of which are abundantly distributed among the different ecosystem, growing on a variety of substrates. Mosses are found growing on soil, rocks, sandcrete materials and upon other plants throughout the world wherever there is sufficient moisture.

Mosses like other bryophytes normally grow in populations or colonies in characteristic growth forms, such as mats, cushions, tufts, or wefts. The micro climate where mosses grow can be quite different from that in general community. There is often a very precise and close relation between acidity and alkalinity of a substrate and the flora which it bears (Watson, 1971). Mosses such as *Tortella tortuosa*, *Fisssidens cristatus* and *Neckera crispa*, prefer soils, with a high lime content and pH. Others such as *Campylopus paradoxus* favour acid soils, while *Sphagnum* moss thrives in bogs with a soil pH as low as 3.5. However, some species of liming- loving moss species can still be found growing on acid soil.

Despite the widespread distribution of bryophytes, little is known about their growth rate throughout the world (Wang *et al.*, 2008) and information concerning research results is very scanty. The reasons for this are the difficulties researchers often have with bryophyte identification, the limited amount of the same species available for analyses due to their inconspicuous position in the ecosystem. The exclusion of many mosses from the guinea savanna ecological zone of Nigeria may have to do with the climatic features and flora composition of this area as these plants occur and grow luxuriantly in an area with high rainfall and abundant plant covers (trees). The aim of the study was to investigate the growth rate of three acrocarpous mosses: *Bryum coronatum* Schwaegr; *Barbula lambarenensis* (Hook) Jaeg; and *Hyophila involuta* (Hook) Spreng in Kwara State. The objectives of the study were to: (a) measure the moss shoot heights; (b) estimate the numbers of leaves in each sampled species; and (c) calculate Leaf Area (LA) and Leaf Area Index (LAI) of the selected mosses.

Materials and Methods

Study area

The study was conducted in Ejiu-Ayegunle and Araromi-Opin, Ekiti Local Government Area (8^0 30^1 N, 50^O 20^1 E) of Kwara State which is situated in the guinea savanna ecological zone of Nigeria. The study area enjoys highly seasonal climate with well defined rainy and dry seasons which vary from year to year, but basically, the rainy season is between March / April and October (Figure 1). The mean annual rainfall within this ecosystem is 400mm. Dry season begins in November and last till late February 2020.

The study area experiences high temperature all over the year round due to its latitudinal location within the tropics. The area records a minimum and maximum temperature of 28^0C and 37^0C, respectively with the highest air temperature usually in March while the minimum during the peak of the rainy season from the data obtained from the Meteorological station (Figure 1).

Sampling design and species study

Three acrocarpous mosses: *Bryum coronatum* (N $08^0 08.74^1$; E 005^0 05.89^1), *Barbula lambarenensis* (N 08^0 01.05^1; E 005^0 16.2^1) and *Hyophila involuta* (N $08^0 04.08^1$;E 005^0 13.92^1) were randomly collected from their natural habitats at different locations in Ejiu-Ayegunle and Araromi- Opin, Ekiti Local Government Area of Kwara State, Nigeria. Moss shoots were taken to the laboratory of the Plant Biology Department, University of Ilorin at two weeks interval for a period of six months where they were identified and used for growth study. The moss samples were washed and cleaned from mechanical impurities before use.

The moss shoot heights were measured fortnightly for a period of 6 months by placing the stems on a clean slide and a thread stretched over each shoot from the base of rhizoid to the apex of the shoot and the measurements were later extrapolated on metre rule. The numbers of leaves were counted under a dissecting microscope at 40x magnification. Forty intact leaves per plant were randomly selected and the length and breadth of each leaf blade was measured with the aid of Ocular micrometer. Leaf Area (LA) and Leaf Area Index (LAI) of the selected mosses were calculated by using the formulae of Simon (1987).

The results obtained were subjected to statistical analysis. Meteorological data of the study area during the period of study were obtained from Meteorological Stations of National Center for Agricultural Mechanization (NCAM), Kwara State.

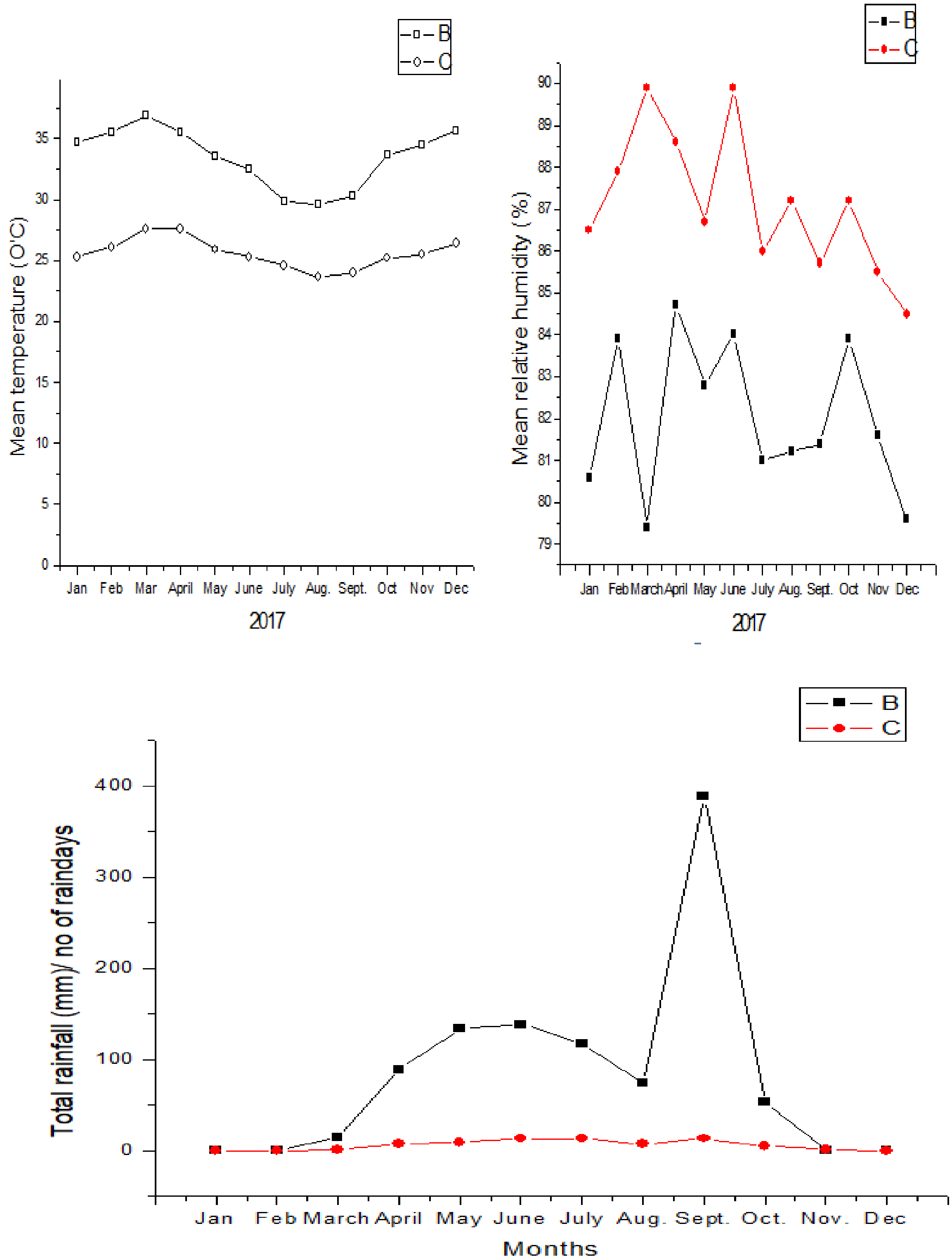

Figure 1: Meteorological data of Kwara State. (i) Mean temperature: B=maximum temp. C=minimum temp. (ii) Mean relative humidity: B=min. C=10.00hr. (iii) Mean rainfall: B=Total rainfall C=No of raindays.

Results

The results of the mean incremental shoot height estimated for 240 shoots sampled from each of *Bryum coronatum* Schwaegr, *Barbula lambarenensis* (Hook) Jaegr *and Hyophila involuta* (Hook) Spreng showed that moss shoot height ranged between 1mm and 4mm and the growth rate varied among the species and habitats (Table 1). *Bryum coronatum* recorded the highest mean incremental shoot height of 0.9±0.42mm-3.5±1.13mm per season followed by *Barbula lambarenensis* (0.2±0.04mm-2.1±1.60mm) and *Hyophila involuta* (0.2±0.07mm-1.4±0.14mm) during the period of study (Table 1). Luxuriant growth in shoot length occurs principally in June and July presumably as a result of continuing assimilation and storage of photosynthetic materials. A comparable cessation of shoot elongation was shown towards the end of growing season in October/November and immediately after the production of capsules.

The three mosses showed periodicity in growth, related to the rainy and dry seasons (Figure 2). The measurements made on 240 field grown stems of three acrocarpous mosses indicated that new shoots were first recorded in April coinciding with the commencement of the rainfall/ rainy period in the study area (Figure 1). Vegetative growth thus occurred principally from March to October with fast and luxuriant growth of the shoots occurring in the midst of rainy seasons (Figure 2).

The mean numbers of leaves of the three selected mosses are shown in Table 2. *Barbula lambarenensis* recorded the highest number of leaves (44) irrespective of the substrates followed by *Bryum coronatum* (21) and *Hyophila involuta* (17).

The results of the morphological measurements made on 240 samples showed that the species differed significantly in leaf blade length and blade width (Table 3). The leaves of *Bryum coronatum* are longer than the leaves of *Barbula lambarenensis* and *Hyophila involuta* while *H. involuta* has the widest leaves closely followed by *Bryum coronatum* and *Barbula lambarenensis* (Table 3). The differences in the leaf dimensions were statistically tested and found not to be significant at 5% level of probability. The differences in the leaf dimensions were statistically tested and found not to be significant at 5% level of probability.

The result of the Leaf Area (LA) of the moss leaves showed that *Bryum coronatum* and *Hyophila involuta* are more or less the same but slightly larger than *Barbula lambarenensis* numerically. However, these values are statistically the same. The smallest leaves are those of *Barbula lambarenensis* (Table 3). The range of the leaf length of *Barbula lambarenensis* was 1.1-2.2mm with the leaf breadth range of 0.2-0.6mm. *Bryum coronatum* had a leaf length ranging between 1.2 and 2.7mm with the leaf breadth range of 0.2-0.7mm. The leaf length of *Hyophila involuta* was between 1.1 and 2.2mm with the breadth range of 0.2-0.6mm. The leaf area ranged between 0.11-5.7mm^2 (*Barbula lambarenensis*), 0.12-7.7 mm^2 (*B. coronatum*) and 0.11-0.66mm^2 (*H. involuta*) as shown in Table 3.

The number of shoot per cm^2 varied among the selected mosses. *Hyophila involuta* recorded the highest number of shoots per cm^2 with a mean average of approximately 132 shoots which was closely followed by *Barbula lambarenensis* and *Bryum coronatum* with an average of 99 and 62 shoots per cm^2, respectively (Table 3). The result of the mean Leaf Area Index (LAI) indicated that *Hyophila involuta* had the largest Leaf Area Index followed by *Barbula lambarenensis* and *Bryum coronatum* (Table 3).

Table 1: Mean incremental shoot height (± SD.) of the three selected mosses

Species	Monthly increment (mm)						Mean
	April	**May**	**June**	**July**	**August**	**September**	
Barbula lambarenensis	1.4±0.36	1.3±0.22	0.8±0.00	2.1±0.43	2.0±0.43	0.2±0.04	1.30mm
Bryum coronatum	0.93±0.18	1.00±0.46	1.8±0.35	3.5±1.13	0.9±0.42	2.1±1.60	1.71mm
Hyophila involuta	0.70±0.10	0.30±0.12	1.4±0.14	1.2±0.06	0.5±0.25	0.2±0.07	0.72mm

Table 2: Mean incremental number of leaves per shoot of the three selected mosses

Species	Mean number of leaves per month (mm)					
	April	**May**	**June**	**July**	**August**	**September**
Barbula lambarenensis	10	21	31	40	41	44
Bryum coronatum	6	11	12	13	19	21
Hyophila involuta	6	10	11	11	15	17

Table 3: Growth parameters: leaf length and leaf breadth, leaf area, number of shoots per cm^2 and Leaf area index

Species	Variable	Measurement on monthly basis						Mean
		April	**May**	**June**	**July**	**Aug.**	**Sept.**	
Barbula lambarenensis	Leaf length (mm)	1.1±0.1	2.2±0.12	2.2±0.3	1.9±0.3	1.6±0.2	1.9±0.1	1.65
	Leaf breadth (mm)	0.2±0.02	0.2±0.1	0.2±0.03	0.6±0.04	0.5±0.1	0.6±0.03	0.38
	Leaf area (mm^2)	0.11	0.12	0.22	0.57	0.4	0.57	0.33
	No of shoots/cm^2	90	95	98	105	100	106	99
	Leaf Area Index (cm^2)	0.10	0.11	0.22	0.60	0.40	0.60	0.34
Bryum coronatum	Leaf length (mm)	1.3±0.1	1.4±0.2	2.3±0.2	2.6±0.4	2.7±0.1	2.2±1.1	2.07
	Leaf breadth (mm)	0.2±0.04	0.3±0.04	0.4±0.2	0.5±0.3	0.5±0.1	0.7±1.1	0.43
	Leaf area (mm^2)	0.12	0.21	0.46	0.65	0.68	0.77	0.48
	No of shoots/cm^2	59	60	61	62	60	68	61.7
	Leaf Area Index (cm^2)	0.07	0.13	0.28	0.40	0.41	0.52	0.30
Hyophila involuta	Leaf length (mm)	1.1±0.2	2.0±1.0	1.8±0.03	1.8±0.2	2.2±0.2	1.9±0.3	1.8
	Leaf breadth (mm)	0.2±0.1	0.5±0.03	0.3±0.01	0.6±0.1	0.6±0.01	0.6±0.02	0.47
	Leaf area (mm^2)	0.11	0.5	0.27	0.54	0.66	0.57	0.44
	No of shoots/cm^2	124	129	130	134	138	135	131.7
	Leaf Area Index (cm^2)	0.14	0.65	0.35	0.72	0.91	0.77	0.59

Discussion

Mosses exhibit a significant growth potential when grown in a suitable substrate medium. The reasons are quite obvious, part of which include favourable conditions and suitable nutritional materials inherent in the medium of growth. The growth rates of mosses that vary among species and habitats could be attributed to the pattern of rainfall and variations in the microhabitats (Ogunbiyi, 2003). The high occurrence of bryophytes in the forest than the savanna or grassland areas could be attributed to the sensitivity of these plants to levels of moisture availability in the atmosphere which are lower in disturbed habitats due to less shade (Fatoba, 2001; Olarinmoye, 1974 and Tamm, 1964).

The three mosses show high and luxuriant growth potentials in all their natural habitats particularly those found near road side embankment and drainage where they presumably receive more moisture and hence exhibit more growth than others found on other substrates. This result compared favourably with the findings of Ogunbiyi (2003) and Tamm (1964) that maximum growth often occurs beneath spruce tips where precipitates often exceed that in the open field. The incremental growth rate of moss species reported in this study further confirmed the slow growing nature of mosses. The inability of mosses to compete with higher plants for nutrients is partly due to their slow growing nature (Fatoba, 1997 and Oyesiku, 2012). Longton (1982) attributed the slow growth rate in mosses to the presence of free living haplophase which raises the potential problem of sheltering recessive genes.

Although the amount of shoot elongation varied considerably from species to species, the pattern of growth throughout the year is similar in each species. The new gametophytes that are common at the end of April shows that the protonemal stage must have developed earlier coinciding with a period of occasional rainfall or moisture availability (Ogunbiyi, 2020 and Olarinmoye, 1974). The main phase of shoot elongation that takes place from March or April to October or November coincides with the period of moisture availability that permits growth. The growth pattern recorded in this study is essentially similar to that previously reported for mosses, *Trichosteleum papillosum* and *Thuidium gratum* in the tropical rainforest (Fatoba, 2001). The growth of bryophytes is generally assumed to be directly proportional to the total duration of the wet state (Proctor, 1972). The intimate dependence on water together with their physiological and ecological traits is reflected in the distributions of the bryophytes with their highest species diversity and abundance found at higher latitudes and altitudes and in temperate regions.

The growth rate of these mosses increased as their habitat moisture content increased and vice versa. The coincidence of the commencement of growth stages of these mosses and total rainfall cum raindays observed in this study indicate a relationship between growth and rainfall particularly water. This observation is in agreement with the findings of Fatoba (2001) in his study on *Trichosteleum papillosum* and *Thuidium gratum* in the tropical rainforest. The rates of drying and length of active periods are influenced by the spatial organization of individual species within the colony, leading to correlation between growth form and habitat. Apparently, physiological activity is prolonged where shoot density is high, because evaporative water loss is reduced (Proctor, 1982) and growth is therefore often best in dense stands (Bates, 1988; Okland and Okland, 1996).

In mosses, the numbers of leaves per shoot increase with incremental growth rates, but the growth rates do not necessarily determine the size of the leaves as in higher plants. The variation in the leaf sizes could be attributed to the inherent genetic characteristics of each moss species. Although there may be inherent differences in abundance of leaves among plants within the species in nature, substrate characteristics may in part strongly affect the number of leaves produced. The suitability of substrate where the mosses grow to a large extent determine the growth performance of the plant and hence the number and size of the leaves. This is in agreement with the findings of Shaw (1990) who attributed the variation in gametophytic leaf dimensions among the mosses in nature to both genetic and environmentally induced factors.

The total area of living leaves within a unit area of the moss tufts strongly influence the humidity and temperature of the soil (substrate) by intercepting precipitation needed for growth and reproduction. This observation is in agreement with the findings of many authors that leaves of mosses aid water retention (Bayfield, 1973; Gimingham and Smith, 1971) thereby facilitating growth. Moss tufts may also be significant from a geological stand point: the extensive leaf surfaces remove carbon dioxide from the atmosphere (Simon, 1987). The appearances of mosses are often very different when wet and dry: in the dry state, they expose much less leaf area. A large leaf area seems to be an effective adaptation to the high carbon dioxide concentration close to the ground surface especially within moss tufts (Simon, 1987). This is favourable for intense photosynthesis provided that adequate sunlight is available. This result is in agreement with the findings of Fatoba and Ogunbiyi (2006) who reported that autotrophic plants are directly affected by the intensity of light which drives photosynthesis and provide the necessary ingredients for plant growth and development.

The differences observed in the moss Leaf area indices in this study shows that Leaf Area Index (LAI) is more dependent on the number of shoot per cm^2. This agrees with the report of Simon (1987) that leaf area indices vary among moss species. It is likely that the tufts strongly influence the humidity and temperature of the substrate by intercepting precipitation.

Height measurements, for acrocarpous moss species, and the use of thread to assess shoot elongation, proved to be reliable method of assessing growth in bryophytes. This study has provided the first long term growth measurements for mosses in guinea savanna, confirming that moss shoots grow extremely slow, elongating between 1mm and 4mm annually. The growth potential of a species determines its degree of success in a particular environment.

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