



THE ABUNDANCE OF SOIL MICRO FLORA ALONG ALTITUDINAL GRADIENTS OF THE ATLANTIKA MOUNTAINS FOREST, NIGERIA

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ABSTRACT: This study was carried out to study the abundance of soil microorganisms along altitudinal gradients of the Atlantika Mountain forest in Nigeria. The research was set up in a completely randomized design. Five mountains were randomly chosen within the mountain range, and soil samples were collected at five points along a transect along the altitudinal gradient (< 350m asl, 350-400 m asl, 400 – 450 m asl, 450 – 500 m asl and > 500m asl). Soil microbial analysis were carried out using standard laboratory procedures. Results from the study revealed a significant decrease in the abundance of all microorganisms with increase in altitude. The lowest elevation had the highest number of nematodes (440.8) while the highest elevation had the lowest nematode count (153.2), the highest fungal count (43.9) was recorded at the lowest elevation while the lowest count was also at the highest elevation. The lowest bacterial count also occurred at the highest elevation (282) while the highest was at the lowest elevation (901.6). Five different bacteria species were identified, they are *Drechelaria spp*, *staphylococcus spp*, *bacillus spp* and *Streptococci spp*, Micro algal spp. A total of 10 species of nematodes were identified (*Paralongidorus spp*, *Trichodorus Christici*, *Sphaeronema spp*, *Californicum spp*, *Tylenchus spp*, *Meloidogyne spp*, *Xiphinema spp*, *Longidorus spp*, *Heterodera spp* and *Anguina tritici*). Ten species of fungi were also identified in the study, these are *Saccharomyces C.*, *Aspergillus niger*, *Schizosaccharomyces P*, *Aspergillus flavus*, *Aspergillus parssiticus*, *Candida tropicalis*, *Trichoderma Harzianum*, *Hansenia v.* and *Cerevisiae spp*.

Keywords: Mountain Range, Altitudinal gradient, Atlantika mountains, bacterial count

1. INTRODUCTION

Biodiversity changes along altitudinal gradients have fascinated scientists for decades, many studies have been carried out to ascertain changes in biodiversity along mountain gradients and factors driving these changes. Some of the factors identified to be responsible for altitudinal changes are temperature (Korner, 2010),

humidity, soil compaction and solar radiation (Andreas 2006), adiabatic lapse rate, air pressure and solar radiation (Barry, 2008), climate and topography (Rahbek, 1995). McCain (2010) categorised four patterns of distribution of biodiversity along altitudinal gradients, these are decreasing species richness monotonically with increasing elevation, low plateau patterns with consecutively high richness across the lower portion of

the gradient thereafter decrease in richness, low plateau patterns with mid altitudinal peak and mid- altitudinal peak. These categories are however, mostly for plant communities, the distribution of soil micro flora along altitudinal gradients are poorly understood. These patterns cannot be conclusively applied soil microbial communities as conflicting conclusions have been reported (Lin *et al.* 2015), factors driving changes in microbial diversity along altitudinal gradients are therefore, still relatively poorly described (Shen *et al.* 2013). Studying the abundance of microorganisms along altitudinal gradients gives ecologists an understanding of how environmental factors such as temperature, humidity, plant communities, and adiabatic lapse rate affect the distribution of these microbial communities.

The Atlantika Mountains laying on the border between Nigeria and Cameroon is an important hotspot of biodiversity due to its relatively low anthropogenic disturbance. Usman *et al.* (2016) has studied the distribution of woody plant species along altitudinal gradients in this mountain range, this research is therefore, aimed at the distribution of micro flora along this mountain range.

2. MATERIALS AND METHODS

2.1. Study Area

The Atlantika Mountains lies between longitude 8°46'24''N, latitude 12°41'46''E and longitude 8°43'55''N, 12°38'53''E. The mountains are an extension of the Cameroon line of volcanic mountains, spanning the border between Nigeria and Cameroon. The Mountains lie southeast of Yola, the capital of Adamawa state, Nigeria and southwest of the Mandara mountains. In Cameroon, the Mountains are part of the north region. The Atlantika Mountains are north of the Adamawa plateau and west of the Faro national park in Cameroon. The line of mountains of which the Atlantika range is part was taken as a natural boundary between Nigeria and Cameroon by the colonial powers (Breuer, 2005).

2.2.1. Climate and Vegetation

The climate of the area is characterised by wet season starting from April to October, and dry season lasts from November to March. The average rainfall is 197mm, with wettest months in August and September. The mean annual temperature is around 28 degrees Celsius. There is also the harmattan period when the dust laden north-easterly winds from the Sahara desert have marked effect. The period is cold and dry with an annual temperature of 15.2°C and 39.7°C maximum. (Adamawa state Government, 2014). The study area is located within the northern guinea savannah vegetation zone. This zone

is characterised by thick tall grasses and trees. This vegetation zone is a by-product of centuries of tree devastation by man and fire, and continuous attempts by the plants to adapt themselves to the climatic environment (Online Nigeria, 2015). The true vegetation of the area has for years been modified by human activities, hence, traces of climatic climax are difficult to come by. Among the common trees found in the area are *Vitex doniana*, *Tamarindus indica*, *Annona senegalensis*, *Piliostigma reticulatum*, *Cordia africana*, *Isobertia doka*, *I. tomentosa*, *Daniella oliveri*, *Butyrospermum parkii*, *Magnifera indica* etc. (Adamawa State Government, 2014). Tall grasses are also found in the area, however, their appearance is dependent on the season as the rainy season brings the lush green of the grasses to full view. Common grasses found in the area includes *Andropogon gayanus*, *Brachiaria decumbens*, *Cenchrus ciliaris*, *Chloris gayanus*, *Cynodon dactylon*, and *Panicum maximum*, (FAO, 2015).

2.2.2. Demography

The Atlantika Mountains is inhabited by the Koma people who are hill-dwelling ethnic group in northern Adamawa and they share border with southern Cameroon. These hill dwellers are spread throughout the south and southwest of these mountains including on the Cameroonian side. There are 21 Koma villages on the Cameroonian side of the mountains and 17 villages on the Nigerian side. Koma is part of the seven districts of Jada local government in Adamawa state (Breuer, 2005).

2.3. Sampling Procedure

2.3.1. Sampling site

A reconnaissance survey was carried out to ascertain the conditions of the Atlantika Mountains for the research. After the survey a total of 10 mountain sites were chosen as being less exploited by the people living in the area. This was done by visitation and with the aid of the communities. Out of the ten mountains 5 were chosen randomly for carrying out this research. The five mountains were Sadaki, Komni, Wagi, Wari and Rangi.

2.3.2. Demarcation of altitudinal gradients

Height of the mountains were measured in metres above sea level (m asl) using Garmin GPS reader. Based on these gradients were taken from the bottom to the peak of the mountain. Five sampling plots (20m x 20m) were laid along the gradients at the following elevations.

1. Altitude 1 (<350m asl)
2. Altitude 2 (350-400m asl)
3. Altitude 3 (400-450m asl)

4. Altitude 4 (450-500m asl)
5. Altitude 5 (>500m asl)

The highest peaks for the sampled mountains are;

1. Sadaki 745m asl
2. Komni 667m asl
3. Wagi 708m asl
4. Wari 692m asl
5. Rangi 719m asl

2.4. Soil Microbial Assessment

2.4.1. Nematode extraction

Extraction of nematodes was done using the modified Baermann funnel method (Viglierchio and Schmitt, 1993).

2.4.2. Total viable bacterial count

The serial dilution method was done to enable counting, the sample was cultured on nutrient agar which was followed by gram staining (Sohrabi and Habashi, 2011).

2.4.3. Total viable fungal count

The sample from the serial dilution was plated on potato dextrose agar (PDA) for 72 hours. Fungal growth was observed and mould count was taken for each sample using colony counter. Slides are then prepared and fungi identified using compound microscope (Sohrabi and Habashi, 2011).

2.5. Study Design

The abundance of microorganisms along the altitudinal gradient was analysed using completely randomised design (CRD) of analysis of variance of the general model

$$Y_{ij} = \mu + T_j + e$$

where;

Y = individual observation μ = general mean

T_j = effect of the jth treatment

e = experimental error

Duncan Multiple Range Test was used in separation of means

3. RESULTS AND DISCUSSION

The results for the abundance of soil microorganisms are presented in Table 1. The results indicated that there was significant difference ($p < 0.05$) in the abundance of bacteria along the altitudinal gradients between the

elevations. The highest number was 901.6 recorded in the first elevation which significantly differed ($p < 0.05$) from the other elevations. There was also a consistent decrease in bacterial count with increase in elevation, the least count was recorded at the highest elevation (282.4). The bacterial count for altitude 2, 3 and 4 were 436.6, 388 and 325 respectively. There was also a decrease in the abundance of fungi with increased altitude. The lowest elevation differed significantly ($p < 0.05$) with the other elevations (43.9). The highest elevation recorded the lowest count of 5.40. The fungal count for altitude 2, 3, and 4 were 14.4, 10.6 and 6.2 respectively. The nematode count also followed the same pattern of significant ($p < 0.05$) decrease in abundance with increase in altitude. The lowest elevation recorded the highest count (440.8) while the lowest count was recorded at the highest altitude (153.2). The values for altitudes 2, 3, and 4 were 381.4, 257.6 and 182 respectively.

Various species of bacteria, fungi and nematodes were isolated and identified during laboratory analysis. Five different bacteria species were identified at the different research sites. This is presented in Table 2. The identified species were *Drechelaria spp*, *staphylococcus spp*, *bacillus spp* and *Streptococci spp*, Micro algal spp. A total of 10 species of nematodes were identified during the research. The identified nematode species were *Paralongidorus spp*, *Trichodorus Christici*, *Sphaeronema spp*, *Californicum spp*, *Tylenchus spp*, *Meloidogyne spp*, *Xiphinema spp*, *Longidorus spp*, *Heterodera spp* and *Anguina tritici* (Table 3).

A total of ten species of fungi were identified in this study, the identified species were *Saccharomyces C.*, *Aspergillus niger*, *Schizosaccharomyces P*, *Aspergillus flavus*, *Aspergillus parssiticus*, *Candida tropicalis*, *Trichoderma Harzianum*, *Hansenia v.* and *Cerevisiae spp* (Table 4).

The abundance of soil microorganisms along altitudinal gradients in this study showed consistent decrease in the abundance of these microorganisms with increase in altitude, this finding agrees with the finding of Sophiya *et al* (2012). Their work on the diversity of culturable micro fungi along altitudinal gradients of eastern Himalayas found significant positive correlation between altitude and microbial abundance. There is a higher distribution of plants at the lower altitudes with decrease with increase in altitude, this most likely affects the abundance of microorganisms along the gradients. Olson (1994), has stated that microorganisms are also generally known to live in symbiotic relationship with plants, the plants provide organic materials, food, and the habitat for micro floral development. It is clear that plants provide the much needed microclimate by conservation of

moisture, shade and organic matter which aid the development of microorganisms.

The positive correlation of plant diversity and microorganisms can also be explained by the relationship between abundance of microorganisms and organic matter in soils (Goyal *et al.* 2009). Skopp *et al.* (2000) also showed the positive relationship between soil moisture and abundance of microorganisms, the lower altitudes are very likely to have more moisture as well as the ability to conserve the available moisture due to the available plant cover. Plant cover also regulates the surface soil temperature which affects the abundance of microorganisms. Zogg *et al.* (2007) has shown that abundance of soil microorganisms is regulated by temperature they are exposed to. Degens *et al.*, (2010) also related organic materials to the abundance of microorganisms, which can be used to explain the relationship between species richness and microorganism diversity. Joergensen and Castillo (2011) also related

some soil nutrient contents and microorganisms. Organic carbon, pH, and nitrogen were shown to correlate with microorganism abundance.

Table 1: Abundance of Microorganisms along the Altitudinal Gradients

Altitude (m asl)	Nematode	Fungi	Bacteria
	Count		
0-350	440.8 ^a	43.9 ^a	901.6 ^a
350-400	381.4 ^{ab}	14.4 ^b	436.6 ^b
400-450	257.6 ^{bc}	10.6 ^b	388 ^b
450-500	182 ^c	6.2 ^b	325 ^b
>500	153.2 ^c	5.4 ^b	282 ^b

*Means carrying the same superscripts on the same column do not significantly differ

Table 2: Bacteria Species Identified in the Study after Samples Were Plated on NA and Gram Staining

S/N	Sample	Species identified	Remark/ growth pattern
1.	SDK1	Micro algal spp	Numerous at 10 ⁻⁶
2.	SDK2	<i>Drechelaria</i> spp	Scanty at 10 ⁻⁶
3.	SDK3	<i>Staphylococcus</i> spp	Numerous at 10 ⁻⁶
4.	SDK4	Micro algal and <i>staphylococcus</i> spp	Scanty at 10 ⁻⁶
5.	SDK5	<i>Bacillus</i> spp	Scanty at 10 ⁻⁶
6.	KM1	<i>Staphylococcus</i> and Micro algal spp	Numerous at 10 ⁻⁶
7.	KM2	<i>Staphylococcus</i> spp	Numerous at 10 ⁻⁶
8.	KM3	<i>Staphylococcus</i> and <i>Drechelaria</i> spp	Scanty at 10 ⁻⁶
9.	KM4	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
10.	KM5	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
11.	WR1	Microalgal, <i>Staphylococcus</i> and <i>Bacillus</i> spp	Numerous at 10 ⁻⁶
12.	WR2	<i>Staphylococcus</i> and <i>bacillus</i> spp	Numerous at 10 ⁻⁶
13.	WR3	<i>Staphylococcus</i> and <i>Drechelaria</i> spp	Scanty at 10 ⁻⁶
14.	WR4	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
15.	WR5	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
16.	WG1	<i>Staphylococcus</i> and <i>Streptococci</i> spp	Numerous at 10 ⁻⁶
17.	WG2	<i>Staphylococcus</i> spp	Numerous at 10 ⁻⁶
18.	WG3	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
19.	WG4	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
20.	WG5	<i>Staphylococcus</i> spp	Scanty at 10 ⁻⁶
21.	RG1	<i>Staphylococcus</i> spp	Numerous at 10 ⁻⁶
22.	RG2	<i>Bacillus</i> spp	Scanty at 10 ⁻⁶
23.	RG3	<i>Streptococci</i> spp	Scanty at 10 ⁻⁶
24.	RG4	<i>Staphylococcus</i> spp and <i>Streptococci</i> spp	Numerous at 10 ⁻⁶
25.	RG5	<i>Staphylococcus</i> spp	Numerous at 10 ⁻⁶

Table 3: Nematode Species Identified in the Study after Samples Were Subjected to Sedimentation Treatment

S/N	Sample	Species identified
1.	SDK1	<i>Paralongidorus spp</i>
2.	SDK2	<i>Trichodorus christici</i>
3.	SDK3	<i>Sphaeronema spp, californicum</i>
4.	SDK4	<i>Tylenchus spp, californicum</i>
5.	SDK5	<i>Tylenchus spp</i>
6.	KM1	<i>Paralongidorus, californicum</i>
7.	KM2	<i>Meloidogyne spp, xiphinema</i>
8.	KM3	<i>Longidorus, heterodera</i>
9.	KM4	<i>Anguina tritici, meloidogyne</i>
10.	KM5	<i>Tylenchus, meloidogyne spp</i>
11.	WR1	<i>Paralogidorus, tylenchus</i>
12.	WR2	<i>Meloidogyne, californicum</i>
13.	WR3	<i>Tylenchus</i>
14.	WR4	<i>Anguina, paralogidorus</i>
15.	WR5	<i>Meloidogyne</i>
16.	WG1	<i>Californicum, meloidogyne spp, tylenchus</i>
17.	WG2	<i>Meloidogyne, californicum</i>
18.	WG3	<i>Tylenchus, paralogidorus</i>
19.	WG4	<i>Meloidogyne spp</i>
20.	WG5	<i>Californicum, tylenchus</i>
21.	RG1	<i>Longidorus, meloidogyne</i>
22.	RG2	<i>Paralongidorus spp</i>
23.	RG3	<i>Longidorus spp</i>
24.	RG4	<i>Tylenchus spp</i>
25.	RG5	<i>Meloidogyne spp</i>

Table 4: Fungal Species Identified in the Study after Samples Were Plated on PDA and Incubated for 72 Hours

S/N	Sample	Species identified
1.	SDK1	<i>Aspergillus flavus, candida Tropicalis, A. Parasiticus</i>
2.	SDK2	<i>A. Flavus, A. niger, C. tropicalis</i>
3.	SDK3	<i>A. Parasiticus, A. niger,</i>
4.	SDK4	<i>Schizosaccharomyces, A. flavus</i>
5.	SDK5	<i>Hansenia V, A. flavus</i>
6.	KM1	<i>A. niger, A parasiticus, C. tropicalis</i>
7.	KM2	<i>T. harzianum, C. tropicalis</i>
8.	KM3	<i>Hansenia V</i>
9.	KM4	<i>Schizosaccharomyces</i>
10.	KM5	<i>A. niger, A. flavus</i>
11.	WR1	<i>A. parasiticus, C. tropicalis, A. niger</i>
12.	WR2	<i>Saccharomyces, A. flavus</i>
13.	WR3	<i>A. flavus, Saccharomyces</i>
14.	WR4	<i>C. tropicalis, Hansenia V</i>
15.	WR5	<i>Hansenia V</i>
16.	WG1	<i>Schizosaccharomyces, A. parasiticus</i>
17.	WG2	<i>Schizosaccharomyces, A. parasiticus</i>
18.	WG3	<i>A. flavus, A. niger</i>
19.	WG4	<i>Hansenia V, A. flavus</i>
20.	WG5	<i>C. tropicalis, Hansenia V</i>
21.	RG1	<i>T. harzianum, C. tropicalis, A. niger</i>
22.	RG2	<i>T. harzianum, C. tropicalis, Schizosaccharomyces</i>
23.	RG3	<i>A. niger, A. flavus,</i>
24.	RG4	<i>Schizosaccharomyces</i>
25.	RG5	<i>Schizosaccharomyces</i>

4. CONCLUSION

The distribution pattern of soil microbes along altitudinal gradients has not been clearly defined in literature, in this study however,

1. a clear significant decrease in the abundance of bacteria, fungi and nematodes has been revealed with increase in elevation.
2. The atlantika mountain forest has also been shown to be rich with various species of these microorganisms.

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