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Preliminary study on climate seasonal and spatial variations on the abundance and diversity of fungi species in natural plantation ecosystems of Ile-Ife, South West, Nigeria

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The biodiversity assessment of fungi and the knowledge of the forces that controls the distribution of fungi and their community are becoming more important in the light of climate change and variability. Fungi provide the global foundation for plant as mutualists, decomposers and pathogens. This study deals with the primary screening, characterization and seasonal variations of mycoflora, isolated from medicinal, oil palm and plantain plantations of the Obafemi Awolowo University, Ile-Ife, Nigeria, from February to June. Fungi colonies and different fungal species were screened and identified across different months and weather variability. Data on the weather variations were collected. Soil samples (0 to 30 cm depth) were collected at different locations within the rhizosphere in each plantation, and the physico-chemical properties and fungi microbial load were determined using standard techniques. The result of soil physico-chemical properties showed that the soil type was humus and acidic in nature. A total of 8 fungi genera and 33 species were recorded in the studied plantations. Temperature of the studied areas ranged between 22.5 to 31.06°C, while the relative humidity of the studied sites ranged from 54.6 to 100%. The rainfall data obtained in this study ranged between 0.381 to 0.584 m. The highest microbial load was (8×10^5 CFU/g) and was observed under medicinal plantation in the month of June. The results obtained showed that weather variability's have direct effect on different fungal species sporulation and CFU formation.

Key words: Climate, fungi, soil, microbial load, natural plantation.

INTRODUCTION

Soil is one of the most abundant, valuable and complex natural products of the Earth and can be observed from different angles. Soil is the habitat for fungi, bacteria, plants and animals, resulting in an enormous biodiversity

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of belowground and aboveground soil microorganisms. Soil organisms are major drivers of biogeochemical nutrient cycles (carbon, nitrogen, phosphorous: C, N, P), and hence are indispensable for life on Earth. Soil harbours an enormous diversity of life. A handful of soil can contain literally billions of bacterial cells, and tens of thousands of bacterial (Torsvik et al., 2002) and hundreds of fungal species (Read, 1992).

Changes in climatic conditions such as fluctuations in the abundance and seasonality of rainfall have important consequence at the ecosystem level (Fierer and Schimel, 2002; Waldrop, 2006; Weltzin et al., 2009). An increase in soil temperature, potentially could have a strong impact on the agro-ecosystem (Fuhrer, 2003), leading to determinant effects on the soil microbial community structure and thus the necessity to consider the impact of climate change on microbial community composition (Allison and Martiny, 2008).Temporal variations in soil physico-chemical properties pH, moisture, total organic matter and total nitrogen availability are reported to influence the population status and their species composition of microorganisms in the soil (Bhattacharyya and Jha, 2011; Das and Dkhar, 2011). In addition to these factors, climate variables such as temperature regime and rainfall are also known to have a profound effect on distribution and population structure of soil microorganisms.

Atmospheric and climatic changes also have great impact on both abiotic and biotic drivers in ecosystems and the response of ecosystems to these changes especially in the rain forest region (Castro et al., 2010; Kopp et al., 2010). Tropical rainforest ecosystem plays important role in the purification of air and water, regulation of water flow, detoxification and decomposition of wastes, generation and renewal of soil and soil fertility, carbon sequestration, biodiversity conservation, climate stabilization, moderation of temperature extremes, windbreaks, support for diverse culture and aesthetic beauty and landscape enrichment (Daily, 1997).

Soil microbes are an essential component in the process of decomposition and biogeochemical cycling. Microbes perform a number of critical functions and regulate important ecosystem processes, but it is unclear how the abundance and composition of microbial communities correlate with climatic perturbations interact to effect ecosystem processes. Most microorganisms in soil are known to occur both in the bulk soil region where there is no growth of plants as well as in the rhizosphere region with profound effects of plants root systems. The population and diversity of these organisms have been reported to be higher in the rhizosphere regions where active interaction occurs between microorganisms and the root systems than in bulk soil regions (Brimecombe, 2001; Yang et al., 2013). Distribution and intensity of rhizosphere microbial communities have been reported to differ between plant species, within species and between different developmental stages of a given plant due to physiological effects (Garbeva et al., 2008; Broeckling et al., 2008; Batten et al., 2006). The exact number of fungi on earth has always been a point of discussion and several studies have been intensified and focused on enumerating the world's fungal diversity (Crous, 2006). From the late 1940s, there have been a growing interest in soil mycology and soil borne fungal diseases of plants and this too has motivated the studies on soil fungi and their ecology (Subramanian, 1986).

Fungi are one of the most important and functional groups of soil microbes and have been reported to perform essential role for functioning of the ecosystem (Doran and Parkin, 1994, 1996; Hawksworth et al., 1996). Due to their capability to decompose complex macromolecules they are vital for making the nutrients like C, N, P and S accessible in the soil. Although, many researchers have worked on the occurrence and distribution of soil fungi of forest soils, some of these have dealt with the influence of plant community type (Mohanty and Panda, 1991, 1994a, 1998; Manoharchary et al., 2005, 2008; Panda, 2011; Van Maanen et al., 2000; Gourbiere et al., 2001; Cabello and Arambarri, 2002; Schmit and Mueller, 2007; Shivakumar et al., 2012; Zhang et al., 2012), while others have tried to examine the effect of soil depth (Behera et al., 1991; Behera and Mukherji, 1985; Mohanty and Panda, 1994b) and a few have attempted to examine the diversity of these fungi (Nilima et al., 2007). Information is scanty on seasonal variations and fungi population within the rhizosphere of Medicinal, Plantain and Oil palm plantations in Nigeria.

This study was designed as a preliminary investigation on the influence of climate seasonal variations on fungi distribution and diversity in a natural vegetation; tropical rain forest agro-ecological soil land grown with Medicinal, Plantain and Oil palm plantation of the Teaching and Research farm of Obafemi Awolowo University, Ile-Ife, South West, Nigeria.

MATERIALS AND METHODS

Study site

The present study was conducted by collecting soil samples from the rhizosphere of three selected plants and collected from four different locations in the Teaching and Research farm (Lat7°30.458^1 N, Long 4°31.579^1 E) of Obafemi awolowo University, Ile -Ife. Lat7°33.15^1 N, Long 4°32.966^1 E of the campus for plantain plantation, Lat7°33.318^1 N, Long 4°32.926^1 E for medicinal plantation, Lat7°32.318^1 N, Long 4°32.856^1 E for Oil palm plantation and Lat7°33.335^1 N, Long 4°32.912^1 E for the control plantation sites within Obafemi Awolowo University, Ile-Ife, South West, Nigeria.

Sample analysis

Soil samples were collected from fully established Medicinal, Plantain and oil palm plantations of Obafemi Awolowo University, Ile-Ife, Nigeria. Soil samples were collected at depth of 0 to 15 cm

Table 1. Soil Physico-chemical analysis across different Months, Climatic weather conditions and Plantations.

S/N	% Moisture content	Particle size distribution			EC	pH		Organic matter		Ppm			Exchangeable Cationscmol/kg				% Total Nitrogen
		% Sand	% Silk	% Clay		1:1 H_2O	1:2 $CaCl_2$	% OC	% OM	PO_4^{2-}	SO_4^{2-}	NO_3^-	K^+	Na^+	Mg^{2+}	Ca^{2+}	
Medicinal samples (0-30 cm)	2.45±0.65	62.8±1.97	15.25±1.89	18±1.08	5.58±1.01	6.4±0.65	5.48±1.01	0.85±0.13	1.51±0.23	13.4±3.15	70.39±13.17	70.77±9.72	0.24±0.07	0.20±0.006	0.07±0.05	1.59±0.25.	0.25±0.01
Oil palm samples (0-30 cm)	3.45±0.39	69.00±2.80	17.5±0.64	16.5±0.64	9.26±3.23	6.5±0.17	6.1±0.178	1.57±0.23	2.7±0.40	13.08±2.59	57.58±2.64	49.75±3.89	0.25±0.03	0.20±0.01	0.09±0.01	2.06±0.25	0.23±0.02
Plantain Samples (0-30 cm)	3.07±0.92	73.5±1.44	10.75±0.85	15.5±0.65	11.30±2.28	7.05±0.27	6.65±0.29	1.39±0.17	2.38±0.29	12.79±2.27	66.1±7.23	54.59±7.38	0.26±0.07	0.20±0.01	0.09±0.006	3.04±0.37	0.37±0.009
Control (0-30 cm)	2.99±0.05	72.75±0.94	11.5±0.64	19.5±0.64	32.73±0.13	7.58±0.23	6.9±0.10	2.60±0.08	2.02±0.02	39.5±0.15	54.74±0.60	64.68±0.44	0.42±0.02	0.14±0.01	0.11±0.01	5.64	0.33±0.009

Mean values ± SEM across the months.

and 16 to 30 cm of the plant rhizosphere using soil auger. Also, control soil samples were collected from bare agricultural field. 1 kg of rhizosphere soil was collected within the rhizosphere of soil in triplicates from each study site, and the samples were brought to the laboratory in sealed plastic bags and stored at 4 to 10°C in the refrigerator.

Physico-chemical analysis of soil

Soil temperature was determined using soil thermometer and soil pH was determined in a soil water suspensions. Their bulk density was determined following the method of Blake and Hartge (1986) using soil corer, while soil organic carbon was determined using rapid titration method as described by Walkley and Black's in Tropical soil biology and fertility (Anderson and Ingram, 1993).

Microbial population analysis

Soil microbial populations were assessed through culture dependent method, following the serial dilution technique. 10 g fresh soil was suspended in 90 ml sterile water and thoroughly shaken for 15 min in a mechanical shaker. Fungi were isolated from the representative sample by following the serial dilution plate technique, 10^{-3} and 10^{-4} was obtained and used for isolation of fungus. 1 ml of suspension from respective dilution was transferred aseptically into petri dishes containing the medium separately. The organism was isolated from soil samples by using different mycological media that include Saboraud Dextrose Agar (SDA), Malt Extract Agar (MEA), Cornmeal Agar, Rose Bengal Agar, and Potato Dextrose Agar (PDA) medium. The fungal colonies were picked up and purified by streaking and incubated at 30°C for 7 to 8 days (Babu and Pallavi, 2013). The isolates were identified using Barnett and Hunter (1992), method. The isolated culture was kept on PDA slant inside a refrigerator.

Climate Data

The climatic data (rainfall, relative humidity and temperature) used in this study were collected from the Micrometeorology unit, Physics Department, Obafemi Awolowo University, O.A.U, Ile-Ife, being the closest weather station to the study site.

Statistical analysis

Pearson correlation coefficient and one way analysis of variance (ANOVA) was used to study the variation on distribution pattern of fungi population between sites and seasons respectively, using SPSS version 20.

RESULTS

The soil physicochemical analysis was carried out for all plantation sites throughout the months of this research work and the average results obtained is presented in Table 1. While having an intercomparison of data among the sites on fungal growth profile to that of the nutrient it revealed that sites with low temperature, high moisture and better nutrient status harbored more fungi. Soil pH was highest in the control soil (7.58±023) while the lowest (5.48±0.24) was recorded in medicinal plantation. Similarly, soil organic carbon was highest in samples collected from control plantation (2.60±0.08) followed by oil palm plantation (1.39±0.17) and the lowest value was recorded in medicinal plantation (1.0±0.1). Percentage moisture content was highest from oil-palm plantation (3.45±0.39) followed by plantain plantation (3.07±0.92) and the lowest was obtained from medicinal plantations (2.45±0.65). Statistical analysis of soil physico-chemical parameters and fungal diversity of the samples collected from different plantation locations, within the studied site showed significant variation in soil pH ($F=8.369$, $P=0.03$), soil organic carbon ($F=19.460$, $P= 0.000$), total nitrogen ($F=3.124$, $P=0.066$), and soil organic matter ($F=3.497$, $P=0.05$) (Table 2).

Table 2. Analysis of variance for soil parameter obtained from the different plantations across different months.

Soil properties	Source of error	Sum of square	Degree of freedom	Mean square	Fcalculated	Significance
Moisture content	Monthly samples	2.031	3	0.677	0.472	0.707
	Error	17.20	12	1.433	-	-
	Total	19.231	15	-	-	-
Sand	Monthly samples	289.50	3	96.5	6.561	0.007
	Error	176.5	12	1.47	-	-
	Total	41.66	15	-	-	-
Silk	Monthly samples	121.50	3	40.500	7.902	0.004
	Error	61.50	12	5.125	-	-
	Total	183.00	15	-	-	-
Clay	Monthly samples	36.750	3	12.250	-	-
	Error	29.00	12	2.417	5.069	0.017
	Total	65.750	15	-	-	-
Electrical conductivity	Monthly samples	1796.809	3	598.936	35.875	0.000
	Error	200.341	12	16.695	-	-
	Total	1997.151	15	-	-	-
H_2O	Monthly samples	3.547	3	1.182	5.379	0.14
	Error	2.637	12	0.220	-	-
	Total	6.184	15	-	-	-
$CaCl_2$	Monthly samples	4.807	3	1.602	8.369	0.03
	Error	2.297	12	1.191	-	-
	Total	7.104	15	-	-	-
Organic Carbon	Monthly samples	6.290	3	2.097	19.460	0.000
	Error	1.293	12	0.108	-	-
	Total	7.583	15	-	-	-
Organic matter	Monthly samples	3.127	3	1.042	3.497	0.05
	Error	3.572	12	0.298	-	-
	Total	6.705	15	-	-	-
PO_4^{2-}	Monthly samples	2098.325	3	699.442	32.048	0.00
	Error	261.901	12	21.825	-	-
	Total	2360.226	15	-	-	-
$NO3^-$	Monthly samples	1088.452	3	362.817	2.210	0.140
	Error	1970.425	12	164.202	-	-
	Total	30.58.877	15	-	-	-
$SO4^{2-}$	Monthly samples	637.135	3	362.81	2.210	0.140
	Error	2796.973	12	164.202	-	-
	Total	3434.108	15	-	-	-
K+	Monthly samples	0.086	3	0.029	2.274	0.132
	Error	0.152	12	0.013	-	-

Table 2. Contd.

	Total	0.239	15	-	-	-
	Monthly samples	0.009	3	0.003	6.999	0.006
Na+	Error	0.005	12	0.000	-	-
	Total	0.014	15	-	-	-
	Monthly samples	0.004	3	13.094	49.397	0.000
Mg^{2+}	Error	0.003	12	0.265	-	-
	Total	0.007	15	-	-	-
	Monthly samples	39.252	3	0.018	3.124	0.066
Ca^{2+}	Error	3.181	12	0.006	-	-
	Total	42.463	15	-	-	-

Table 3. Average weather parameters of plantation sites across different months.

Months	Temperature (°C)	Humidity (%)	Rainfall (m)
February	31.06±1.25	54.21±7.73	0.00±0.00
March	26.04±0.33	77.96±3.99	0.381±0.148
April	27.8±0.176	75.17±1.51	0.00±0.00
May	25.37±1.10	90.1±6.61	0.0508±0.339
June	22.50±0.238	100±0.00	0.584±0.193
P level	***	***	**

Values are Means±SEM. ***Mean squares significant at P<0.001. **Mean squares significant at P< 0.01.

The climatic data (rainfall, relative humidity and temperature) used in this study indicated that the average weather data for Temperature of the studied areas ranged from 22.5 to 31.06°C, while the relative humidity of the studied sites ranged from 54.6 to 100%. The rainfall data obtained in this study ranged from 0.381 to 0.584 m. The results for climatic data parameters are shown in Table 3.

A total of 8 genera and 33 species were recorded in the studied plantations. Deuteromycotina was the largest phylum with 4 genera followed by Zygomycotina. The relative abundance and diversity of the microbes encountered in different plantations are indication that soils under forest cover are very rich in microorganisms that are very important for humus formation. This is responsible for the usual fertile land under forest cover. The abundance richness and diversity of the different species of fungi identified in different plantation sites are presented in (Figures 1 and 2).

The Pearson correlation analysis indicated that there was a strong negative correlation between temperature and the count of *Aspergillus fumigatus*, as well as between temperature and the count of *Aspergillus wentii*. Also, there was a strong positive correlation between humidity and the count of *A. fumigatus* and *A. wentii*. Higher temperature had positive effect on the count of *Trichoderma viride*, while humidity had a negative effect on it. These results are shown in Tables 4, 5 and 6, respectively.

Fungal maximum load, colony forming unit (CFU) were recorded in medicinal plantation for the month of June (8×10^5 CFU) as shown in Table 7, followed by oil-palm plantation. The lowest microbial load was observed in the control plantation (1.1×10^5 CFU) for the month of March. More so, the results obtained from this study showed that the colony counts increases as the months for the study progresses, while the counts for the control plantation decreases as the season progressives. The results encountered in this research may be due to the increase in moisture content and low temperature which might have given room for high proliferation of the microorganisms. The results obtained in this study are represented in Tables 1 to 7 and Figures 1 and 2.

DISCUSSION

Seasonal variations due to changes in climate, as well as edaphic factors, affect the number and nature of microbial diversity in general. Although, factors like root

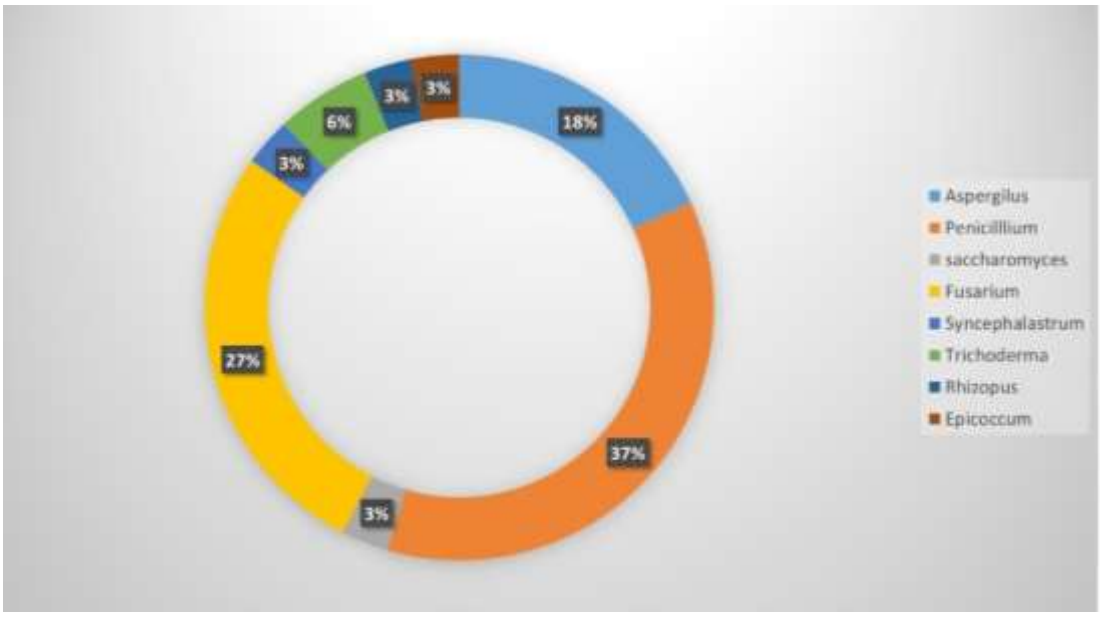

Figure 1. Percentage occurrence of the fungi genera isolated from the different plantation sites.

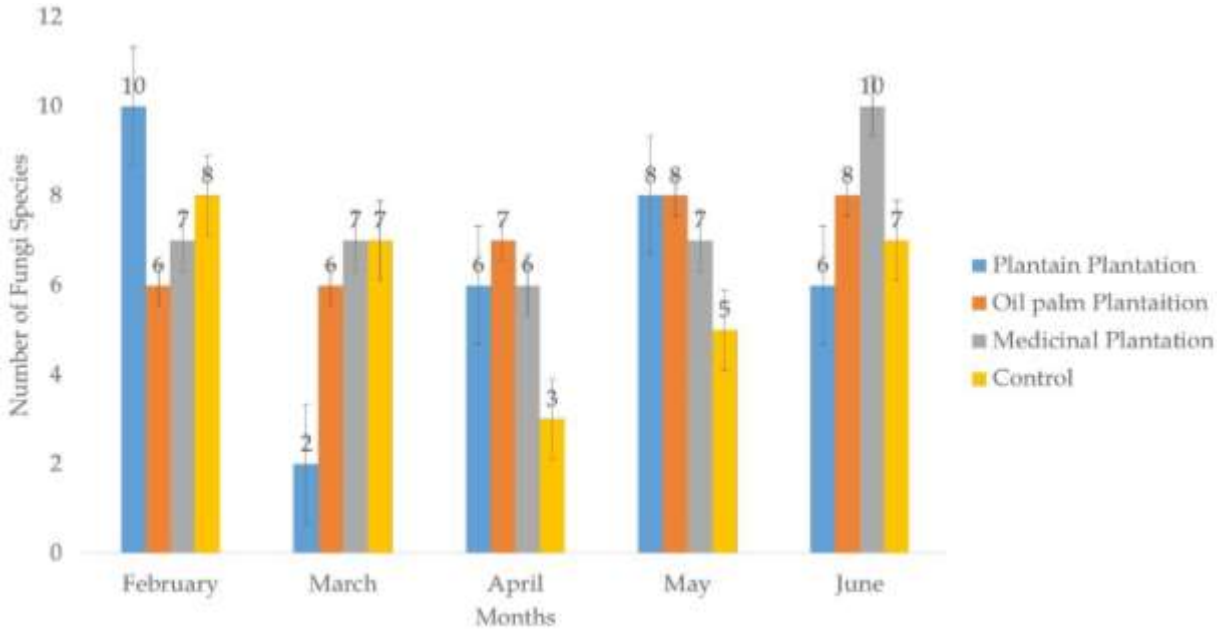

Figure 2. The Number of Fungi species Isolated from the samples obtained from the different plantations between the months of February to June.

exudates and age of the host plants also affect the micro flora associated with a given rhizosphere (Pandey et al., 2006). The impact of the seasonal climate variations on the abundance and diversity of soil fungi from the rhizospheric soil of three plantations in a tropical rainforest ecological zone in Ile-Ife, Nigeria, was investigated in this study. This present study was undertaken to assess the effects of changes in the rainfall pattern, relative humidity and temperature on the culture-dependent isolation, abundance and diversity of soil fungi. More so, the results of soil physicochemical parameters obtained in this study was similar to that of Bhattacharyya and Jha (2011) who reported that population of fungi during wet season could be due to

Table 4. Pearson correlation of selected climate variables on fungi microbial load between the months of February and June.

Variable		Temperature	Humidity	Rainfall	*A. fumigatus*	*A. flavus*	*A. wentii*	*S. cerevisiae*
Temperature	Pearson Correlation	1						
	Sig. (2-tailed)							
	N	15						
Humidity	Pearson Correlation	-0.972**	1					
	Sig. (2-tailed)	0.000						
	N	15	15					
Rainfall	Pearson Correlation	-0.774**	0.650**	1				
	Sig. (2-tailed)	0.001	0.009					
	N	15	15	15				
A. fumigatus	Pearson Correlation	-0.663**	0.701**	0.342	1			
	Sig. (2-tailed)	0.007	0.004	0.212				
	N	15	15	15	15			
A. flavus	Pearson Correlation	0.282	-0.247	-0.379	0.091	1		
	Sig. (2-tailed)	0.308	0.374	0.163	0.747			
	N	15	15	15	15	15		
A. wentii	Pearson Correlation	-0.525*	0.529*	0.258	0.538*	-0.222	1	
	Sig. (2-tailed)	0.044	0.043	0.354	0.039	0.425		
	N	15	15	15	15	15	15	
S. cerevisiae	Pearson Correlation	-0.407	0.435	0.005	0.435	-0.190	0.387	1
	Sig. (2-tailed)	0.132	0.105	0.985	0.105	0.499	0.154	-
	N	15	15	15	15	15	15	15

favorable temperature and moisture contents of the rhizosphere soil which favors rapid multiplication and growth of microbes.

The research question investigated was that: Do the seasonal weather parameter variations affect the abundance and diversity of fungi isolates from the rhizospheric soil?

The study indicated that the relative abundance and diversity of the isolated fungi was impacted by the climatic data. The highest fungi abundance and diversity was observed in the month of June, with the highest rainfall of 0.584 m ± 0.193. This could be due to the fact that rainfalls do alter the amount of and the qualities of litter inputs into the soil ecosystem, and these changes might have

Table 5. Pearson Correlation of Selected Climate variables on Fungi Microbial load between the months of February and June.

Variable		Temperature	Humidity	Rainfall	*F. pallidorosium*	*P. glabrum*	*A. niger*	*T. viride*
Temperature	Pearson Correlation	1						
	Sig. (2-tailed)							
	N	15						
Humidity	Pearson Correlation	-0.972**	1					
	Sig. (2-tailed)	0.000						
	N	15	15					
Rainfall	Pearson Correlation	-0.774**	0.650**	1				
	Sig. (2-tailed)	0.001	0.009					
	N	15	15	15				
F.pallidorosium	Pearson Correlation	-0.054	0.193	-0.524*	1			
	Sig. (2-tailed)	0.848	0.490	0.045				
	N	15	15	15	15			
P.glabrum	Pearson Correlation	-0.292	0.455	-0.230	0.707**	1		
	Sig. (2-tailed)	0.291	0.088	0.410	0.003			
	N	15	15	15	15	15		
A.niger	Pearson Correlation	0.137	-0.247	0.309	-0.426	-0.428	1	
	Sig. (2-tailed)	0.628	0.374	0.262	0.113	0.112		
	N	15	15	15	15	15	15	
T.viride	Pearson Correlation	0.568*	-0.602*	-0.518*	0.203	-0.085	0.127	1
	Sig. (2-tailed)	0.027	0.018	0.048	0.468	0.764	0.653	
	N	15	15	15	15	15	15	15

indirectly alter the fungal community. In addition, the fungal abundance and diversity in the month of June, with the highest rainfall data could be explain as a direct influence of the wet season on the soil moisture that impacted on the fungi community. This result is in tandem with the study of Kardol et al. (2010) that showed that changes in rainfall altered soil microbial community composition. The relative humidity (100%) was also at the highest level during the month of June, and also impacted on the abundance and diversity of the fungi community. The atmospheric temperature (22.5°C ±0.238) was the lowest in the month of June, which also corresponds to the peak period in terms of fungi abundance

Table 6. Pearson correlation of selected climate variables on fungi microbial load between the months of February and June.

Variable		Temperature	Humidity	Rainfall	*T. harzanium*	*R. stolonifer*	*F. oxysporium*
	Pearson correlation	1					
Temperature	Sig. (2-tailed)	-					
	N	15					
	Pearson correlation	-0.972**	1				
Humidity	Sig. (2-tailed)	0.000	-				
	N	15	15				
	Pearson correlation	-0.774**	0.650**	1			
	Sig. (2-tailed)	0.001	0.009	-			
Rainfall	N	15	15	15			
	Sig. (2-tailed)	0.027	0.018	0.048			
	N	15	15	15			
	Pearson correlation	0.589*	-0.625*	-0.325	1		
T. harzinarum	Sig. (2-tailed)	0.021	0.013	0.237	-		
	N	15	15	15	15		
	Pearson correlation	0.664**	-0.685**	-0.577*	0.664**	1	
R. stolonifer	Sig. (2-tailed)	0.007	0.005	0.024	0.007	-	
	N	15	15	15	15	15	
	Pearson correlation	-0.125	0.146	0.053	0.253	0.068	1
F. oxysporium	Sig. (2-tailed)	0.657	0.604	0.851	0.363	0.809	-
	N	15	15	15	15	15	15

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

and diversity. Numerous studies (De Angelis et al., 2015; Castro et al., 2010; Berg et al., 2010; Briones et al., 2014) reported that variation in temperatures led to alteration of the relative abundance of both soil bacteria and fungal community. These studies are in agreement with the results of this study.

More so, studies by Kaisermann et al. (2015) indicated that climatic variations, during non-extreme wet-dry cycles do lead to shift in soil fungal communities.

The relative abundance and diversity of the microbes encountered in the different plantation sites was an indication that the seasonal fluctuations of fungi population are due to climate and soil variables that affect the total number of fungi in the soil. The other reasons for higher population of fungi during rainy season could be

Table 7. Average colony forming unit (CFU × 10^5) of fungi, identified from different plantation soils across the months.

S/N	Fungi	February				March				April				May				June			
		P	O	M	C	P	O	M	C	P	O	M	C	P	O	M	C	P	O	M	C
1	*Aspergillus fumigatus*	5.0	4.0	2.0	-	-	6.8	7.4	3.1	7.2	7.4	7.1	3.4	7.0	6.8	6.2	3.4	7.4	7.6	8.0	-
2	*Aspergilus flavus*	-	3.4	-	2.0	4.5	4.2	3.7	1.9	7.0	-	6.4	4.4	-	-	-	7.4	-	-	-	-
3	*Penicillium digitanum*	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-	-	-	4.5	-
4	*Penicillium aurantigriseum*	3.0	-	-	-	-	-	-	-	4.0	-	-	-	-	-	-	-	-	-	4.0	-
5	*Aspergillus parasiticus*	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7	-	-	-	-	-	-
6	*Aspergillus wentii*	-	-	-	-	-	2.4	-	1.1	5.2	-	3.1	-	-	-	5.4	2.9	-	6.0	5.8	-
7	*Saccharomyces cerevisiae*	-	-	-	-	-	-	-	-	5.4	4.7	-	-	5.9	5.0	-	-	7.6	-	-	2.3
8	*Fusarium pallidorosium*	-	-	5.0	-	-	-	-	-	6.8	6.1	-	3.0	7.0	7.1	6.9	2.4	-	2.7	-	-
9	*Penicillium citrinum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	*Penicillium variable*	-	-	-	-	-	-	-	-	4.8	-	-	-	-	-	-	-	-	-	-	-
11	*Epicoccum nigrum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	*Fusarium avenceum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	*Fusarium gramineanum*	-	-	-	-	-	-	-	-	-	-	-	-	4.3	4.9		-	-	-	-	-
14	*Fusarium solani*	-	-	-	-	-	-	-	-	-	3.7	-	-	4.0	-	-	-	-	-	-	-
15	*Syncephalastrum racemosun*	-	-	-	-	-	-	-	-	-	-	-	-		3.1	-	-	-	-	-	-
16	*Penicillium glabrum*	-	-	-	-	-	-	-	-	-	-	3.0	2.6	5.1	5.2	4.8	3.0	-	-	4.4	-
17	*Aspergillus niger*	6.5	6.1	-	4.5	2.6	-	3.0	-	-	-	-	2.3	-	-	-	-	-	5.8	6.0	3.2
18	*Aspergillus tamari*	-	-	-	-	-		2.1	-	-	-	-	2.1	-	-	-	3.5	3.2	-	3.5	3.7
19	*Trichoderma viride*	6.5	4.9	3	-	-	4.3	4.7	1.2	5.0	5.2	-	2.2	-	5.6	2.6	-	-	-	-	2.6
20	*Trichoderma harzianum*	6.0	5.1	-	-	-	-	3.4	-	-	-	3.8	-	-	-	-	-	-	-	-	-
21	*Penicillium brasilianum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.3	-	3.4	-	-	-
22	*Rhizopus stolonifer*	-	4.2	3.6	1.8	-	-	-	-	-	3.9	4.3	-	-	-	-	-	-	-	-	-
23	*Fusarium oxysporium*	2.5	-	-	-	-	-	-	1.5	-	-	2.3	-	-	-	-	-	3.8	-	4.1	-
24	*Penicillium brevicompactum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-	-
25	*Penicillium chrysogenium*	-	-	-	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-	-
26	*Penicillium roqueforti*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2.8	-	-
27	*Penicillium italicum*	-	-	-	-	-	-	-	1.7	-	-	-	-	-	-	-	-	4.6	-	-	2.5
28	*Fusarium poae*	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-	1.9	-	-
29	*Penicillium verucosum*	-	-	-	-		4.0	3.8	-	3.2	-	-	3.7	-	-	-	-	-	-	-	-
30	*Fusarium culmorum*	-	-	-	-	-	-	-	-	-	-	-	5.0	5.3	-	-	-	-	-	-	4.0
31	*Fusarium verticilloides*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	*Fusarium sporotrichoides*	-	-	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	*Penicillium rusulosum*	3.9	4.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

P: Plantain plantation; O: oil palm plantation; M: medicinal plantation; C: control.

attributed to favorable temperature and moisture contents of the rhizospheric soil which favors rapid multiplication and growth of microbes. This agrees with the findings by Bhattacharyya and Jha (2011).

Conclusion

The results of this study have revealed that direct and interactive impacts of seasonal variations do influence the abundance and diversity of fungi in the soil samples from the different plantation ecosystems. The results also showed that changes in rainfall pattern in particular will be vital in predicting the response of fungi community composition and abundance in the future. Further, it was found out that the interactive effect of lower temperature, maximum relative humidity and optimum rainfall data have apparent effects both directly and indirectly on fungal abundance and diversity composition. These results have illustrated complex microbial changes in community of terrestrial ecosystem under climate change scenario, and therefore, there is need for further study on the physiology and ecology of the microorganisms in terms of the effects of climate change on microbial community and how the ecosystem will respond to this change.

Conflict of interests

The authors have not declared any conflict of interests.

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