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Diversity of Aeroterrestrial Fungi and Soil Quality of a Shopping Complex Environment in a Tertiary Institution

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ABSTRACT

The soil quality and diversity of air and soil fungi in the shopping complex environment of Rivers State University Main Campus was investigated. Air and soil samples were collected monthly for the period of twelve months from July 2021 to June 2022. The samples were analyzed for fungi and physicochemical characteristics using standard mycological and analytical techniques. The plates were incubated at ambient temperature for 7 days. Fungi were isolated from the plates and identified using morphological and molecular techniques. The Simpson's diversity index was used to assess the diversity of the fungal communities. The results showed that the diversity of air and soil fungi was high, with a species richness of 15, belonging to different physiological categories. The fungi isolated were identified as *Fusarium proliferatum, Alernaria alternata, Aspergillus fumigatus, Fusarium fujikoroi, Phaeacremonium aleophilum, Fusarium concentricum, Pythium myriotylum, Scedosporium aurantiacum, Aspergillus orizae,* and *Chrysosporium tropicum.* The most common soil fungi were *Fusarium oxysporum, Trichoderma viride,* and *Penicillium chrysogenum*. Nutrient concentrations such as Nitrogen, phosphorus, and potassium, calcium, magnesium, zinc, and sulfate exhibited seasonal variations throughout the year, with generally higher values observed during the wet season. This trend might be linked to increased nutrient input from surface runoff during the wet months. The soil quality was good, with high levels of organic matter and nutrients. The findings of this study offer important knowledge on the variety of air and soil fungi in the setting of the Rivers State University's commercial centre. This study proffers ways to safeguard public health of the university community and establish ways for observing and regulating fungal development in the area.

Keywords: Shopping complex, air, soil quality, fungi, *Chrysosporium*, *Fusarium*, *Scedosporium*.

Introduction

Urbanization and the establishment of shopping complexes have significant impacts on the natural environment, leading to habitat loss, fragmentation, and changes to natural ecosystems. These complexes often require land clearing, resulting in loss of biodiversity and disruption of ecological processes and functions. Additionally, increased population density associated with shopping complexes leads to environmental issues like traffic congestion and waste management challenges. Understanding the impact of shopping complexes on the environment is crucial for developing sustainable practices (Laurence and Singh, 2019).

Fungi play crucial roles in terrestrial ecosystems, such as decomposing organic matter, recycling nutrients, and forming mutualistic associations with plants. They contribute to carbon and nitrogen cycling and soil fertility. Shopping complexes introduce unique environmental conditions that can impact fungal communities. Factors like foot traffic, altered microclimates, soil changes, and the introduction of exotic plant species can influence fungal diversity and composition. Understanding how shopping complex conditions affect fungal communities is important for assessing ecological consequences and preserving diversity (Yuvaraj and Ramasamy, 2020; Tedersoo *et al*., 2014).

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Airborne fungi can enter shopping complexes and have been associated with various health effects in humans. Some species produce spores or mycotoxins that can trigger allergies or respiratory problems. Characterizing airborne fungal composition in shopping complexes is essential for assessing health risks and developing mitigation strategies (Fröhlich-Nowoisky, 2009). Soil fungi are critical for maintaining soil quality and ecosystem functioning. They contribute to nutrient cycling, organic matter decomposition, and symbiotic relationships with plants. Changes in soil fungal communities indicate alterations in soil health. Studying soil fungi in shopping complex environments helps understand the impacts of urbanization on soil ecosystems and implement strategies for preserving fertility (Li *et al*., 2023).

This research aimed to investigate aeroterrestrial fungal samples collected from around a shopping complex in Rivers State University, Nigeria. Standard mycological techniques were used to analyze the samples, including cultivating, enumerating, isolating, characterizing, identifying, and categorizing the fungi. Fungal species diversity and physicochemical parameters of the soils were assessed. Antifungal susceptibility testing was conducted, and resistant fungi were identified. Molecular techniques were used to detect resistance genes and characterize the fungi. Furthermore, the study aimed to establish the relatedness of the characterized fungi by comparing their genetic sequences with those available in GenBank.

Materials and Methods

Study Area

The Shopping Complex of Rivers State University Main Campus in Port Harcourt served as the study area. The inner surroundings of the University are best described as sandy soil, thinly covered in grass, and consistently groomed. The Shopping Complex GPS coordinates are4. 7957226, 6.9791415. The main campus is situated, in the Port Harcourt City Local Government Area of Rivers State. Geographically, it is situated at 4.7965° N and 6.9806° E. Port Harcourt, the capital of Nigeria's Rivers State, and this location have comparable ecological and environmental characteristics.

Due to its on-campus academic, administrative, commercial, and religious activities, Rivers State University has a large population. It shares borders with Ikwerre Road, Agip Oil Company, Eagle Island, and Mile 2 Diobu axis in Port Harcourt, Nigeria.

Sample Collection

Soil samples were collected from six (6) designated substation in the campus shopping complex environment at Monthly intervals for a period of twelve (12) calendar months from July 2021 to June 2022, covering both the wet and dry seasons in the Niger Delta. The soil samples were collected with the aid of a sterile hand held soil auger from a depth of 10 to 15 cm. The samples were collected into sterile plastic zip-lock bags and transported the laboratory for analysis. Samples from the 6 substations were properly mixed together to form a composite soil sample. A total of 72 composite soil samples (each weighing about 50 grams) were analyzed during the study.

Air samples were collected using sedimentation plated method using potato dextrose agar (PDA), Sabauroud Dextrose agar (SDA) and Malt extract agar (MEA) agar.

Sedimentation (Settle plates) using sterile Petri dishes were prepared and labeled appropriately. A total of 72 settle plates were used for monthly sampling. Six plates were used for each substation and each plate was labeled indicating media type, sample type, date, time, sampling location and plate number.

All media used and distilled water were sterilized in an autoclave for 15 minutes. Pipettes and other glassware were sterilized in a hot-air oven at 160^{o}C. About 85% alcohol was used to sterilize laboratory benches (Brown *et al*., 2016).

Mycological Analysis of Soil and Air

Mycological analysis was conducted at the Microbiology Laboratory of the Department of Microbiology, Rivers State University, Port Harcourt. The soil-dilution/spread-plate method was utilized for the cultivation, enumeration, and isolation of fungi from the soil. A 10-gram soil sample was taken in a 250 ml Erlenmeyer flask and mixed with 90 ml of sterile distilled water through vigorous shaking, resulting in a 1:10 (or 1/10 or 10^{-1}) dilution.

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Subsequently, two additional ten-fold serial dilutions were prepared from the 10^{-1} dilution stock. From each soil sample, a 0.1 ml aliquot of the 10-3 dilution was aseptically pipetted and spread-plated on duplicate plates using a flame-sterilized and cooled glass spreader. Ampicillin was added to the plates to inhibit the growth of bacterial contaminants.

Air samples were collected using sedimentation/settle plates. The plates were placed face up without lids on a flat rack-tray at the sampling stations, which were positioned 1.5 meters in height and 1.0 meter away from side walls or obstructions. The plates were exposed for 30 minutes, after which the lids were replaced using non-dust transparent tape without touching the agar surface.

The air and soil culture plates were incubated inverted at 30°C for 2 to 5 days. Fungal colonies from the soil and air were enumerated, isolated into pure cultures, and identified based on macroscopic and microscopic observations of morphological features, distinctive microscopic structures, growth rate, and growth medium.

The fungal counts in the soil and air were expressed in colony-forming units per gram (CFU/g) and colony-forming units per minute per square meter (CFU/min-M^2), respectively (Al-Shaarani, *et al*., 2023).

Preparation of fungal isolates for Identification

Distinct fungal colonies from air and soil were isolated into pure cultures, and identified by observing their colonial characteristics by macroscopy and microscopy. Examination by macroscopy included observing morphological features such as surface topography, surface texture, pigmentation, and type of mycelium, medium of growth and pace of growth.

Microscopy included observing distinctive microscopic structures after staining with lactophenol blue and viewing under light microscope using 40x objective magnification (Alsohaili and Bani-Hasan, 2018).

The isolates were identified using. Koneman's colour atlas and textbook of diagnotistic microbiology (6^{th} Ed.) (Koneman *et al*., 1997) and were verified by using reverse image identification schemes (https://imagesift.com; https://yandex.com/images/

Determination of species and physiological diversity of fungi

To assess fungal species diversity, fungi were collected from the air and soil, using appropriate methods. Species diversity was determined using Simpson's Index of diversity/dominance formula

$$D = 1 - \sum_{i=1}^{S} \left(\frac{n_i}{N}\right)^2$$

Where:
n = total no. of organisms for a single species; N = total no. of organisms for all species;
$n_i/N = p_i$ (proportion of individuals of species i), and S = species richness. Physiological diversities where assessed by categorizing the fungal isolates into their functional groups based on already existing reports.

Determination of Soil Quality

Soil quality was determined by estimating physicochemical parameters such as temperature, pH, moisture content, water holding capacity, electrical conductivity, total organic carbon, soil organic matter, available nitrogen, available phosphorus, available potassium, magnesium, calcium, sulfate, and zinc were measured. Soil samples were air-dried, ground to fine particles, sieved through a 2mm mesh sieve, and subjected to physical and chemical analysis using standardized methods (Kekane *et al*., 2015).

Statistical analysis

Statistical analysis was performed using GraphPad Prism Version 8, and data entry and structuring was performed using MS Excel for Windows Version 2010. Results obtained from all methods carried out are presented in the following sections.

Results

The results of this study are presented in this section using tables and figures. Table 1 displays the average monthly counts of air fungi, while Table 2 depicts the average monthly counts of soil fungi at the Shopping Complex environment during the sampling period from July 2021 to June 2022. In Table 1, the counts ($\log_{10}$ CFU/min-M^2) for each month are provided, along with additional statistical information. For example, in July, the count was 5.8 x 10^3, which corresponds to a $\log_{10}$ value of 3.8.

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The minimum count observed was 3.76, and the maximum count was 3.81, resulting in a range of 0.05. The mean fungal count for July was 3.8±0.27 (mean ± standard error of the mean). Similar measurements were conducted for the remaining months, yielding varying counts and statistical values. Overall, the mean monthly counts ranged from 3.1 to 3.9, indicating the presence of air fungi in the outdoor environment of the Shopping Complex throughout the sampling period, with minor fluctuations observed.

In Table 2, the monthly counts (log_{10} CFU/g) of soil fungi during the sampling period are presented, along with additional statistical values.

For instance, in July, the count was 4.3 x 10^5, corresponding to a log10 value of 5.6. The minimum count observed was 4.9, and the maximum count was 5.6, resulting in a range of 0.7. The mean count for July was 5.6±0.178 (mean ± standard error of the mean). Similar measurements were conducted for the remaining months, resulting in varying counts and statistical values.

Overall, the mean monthly counts ranged from 5.0 to 6.5, indicating the presence of soil fungi throughout the sampling period, with fluctuations observed. The standard error of the mean (SEM) values provides an estimate of the variability in the data.

Table 1: Mean Monthly Counts (Log_{10} CFU/min.M^2) of Air Fungi during the sampling period

Month (2021 – 2022)	Fungal count	Log10	Minimum	Maximum	Range	Mean ± SEM
Jul	5.8 x 10^3	3.8	3.76	3.81	0.05	3.8±0.27
Aug	2.5 x 10^3	3.4	3.39	3.50	0.11	3.4±0.22
Sep	2.1 x 10^3	3.3	3.31	3.44	0.13	3.3±0.16
Oct	1.1 x 10^3	3.1	3.01	3.24	0.23	3.1±0.24
Nov	2.8 x 10^3	3.5	3.44	3.54	0.10	3.5±0.27
Dec	6.9 x 10^3	3.8	3.83	3.88	0.04	3.8±0.24
Jan	6.3 x 10^3	3.8	3.79	3.84	0.05	3.8±0.28
Feb	7.4 x 10^3	3.9	3.86	3.90	0.04	3.9±0.20
Mar	4.3 x 10^3	3.6	3.62	3.69	0.07	3.6±0.28
Apr	3.6 x 10^3	3.6	3.54	3.62	0.08	3.6±0.33
May	4.2 x 10^3	3.6	3.61	3.68	0.07	3.6±0.15
Jun	4.5 x 10^3	3.7	3.64	3.71	0.07	3.7±0.23

Key: Log_{10} – Logarithm to base 10; CFU/min.M^2 – Colony Forming Units per minutes per metre squared; SEM – Standard error of the mean.

Table 2: Mean Monthly Counts (Log_{10} CFU/g) of soil Fungi during the sampling period

Month (2021 – 2022)	Fungal count	Log10	Minimum	Maximum	Range	Mean ± SEM
Jul	4.3 x 10^5	5.6	4.9	5.6	0.7	5.6±0.17
Aug	2.7 x 10^5	5.4	5.2	6.0	0.8	5.4±0.17
Sep	2.6 x 10^5	5.4	5.1	5.8	0.7	5.4±0.14
Oct	2.4 x 10^5	5.4	5.0	5.4	0.4	5.4±0.08
Nov	7.8 x 10^5	5.9	5.4	6.0	0.6	5.9±0.13
Dec	1.1 x 10^6	6.0	5.9	6.0	0.1	6.0±0.02
Jan	3.3 x 10^6	6.5	5.9	6.5	0.6	6.5±0.14
Feb	4.9 x 10^5	5.7	5.6	5.7	0.1	5.7±0.02
Mar	2.1 x 10^6	6.3	6.3	6.7	0.4	6.3±0.09
Apr	2.1 x 10^5	6.3	5.9	6.3	0.4	6.3±0.08
May	3.3 x 10^5	5.5	5.4	5.8	0.4	5.5±0.08
Jun	1.0 x 10^5	5.0	4.6	5.0	0.4	5.0±0.09

Key: Log_{10} – Logarithm to base 10; CFU/g - Colony forming unit per gramme; SEM – Standard error of the mean

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Figures 1 and 2 illustrate the air and soil populations at the shopping complex during the sampling period while Figure 3 and 4 illustrates the populations of air and soil fungi for the sampling periods during the Dry and Wet seasons. In Figure 1, the population of Air fungi ranged from 2.05 to 2.87 Log_{10} CFU/min-$M^{2,}$ which were the lowest and highest fungal populations were recorded in October 2021 and February 2022 respectively. From the initial sampling in July 2021, the air fungal population was 2.77, which decreased to a minimum of 2.05 in October of same year. Then the population increased sharply to 2.84 in December 2021, then almost maintained an apparent stationery phase with slight increase to the highest population of 2.87 in February 2022.

In Figure 2, the population of soil-borne fungi varied between 4.8 and 6.7 Log_{10} CFU/g. The highest average fungal population was recorded in March 2022, while the lowest average population was recorded in June 2022. There was regular fluctuation throughout the sampling period, terminating in lowest counts of 4.8 in June 2022.

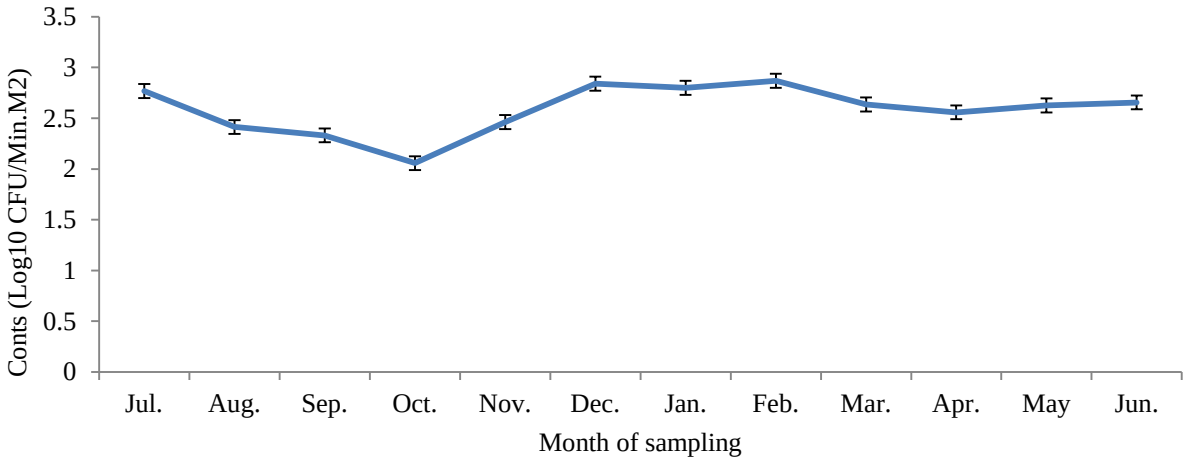

Figure 1: Mean monthly populations of air fungi at shopping complex

Key: Log_{10} – Logarithm to base 10; CFU/min.M^2 – Colony Forming Units per minutes per metre squared

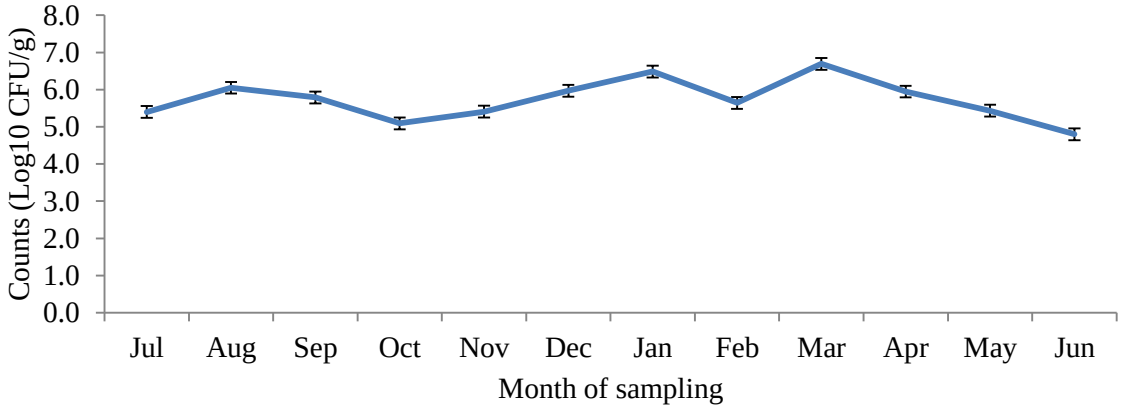

Figure 2: Mean monthly populations of soil fungi at the Shopping complex

Key: Log_{10} – Logarithm to base 10; CFU/g - Colony forming units per gramme

Figure 3 illustrates the mean seasonal populations of air fungi (Log_{10} CFU/min.M^2) during the sampling seasons. Dry season population ranged from 3.45 to 3.67 Log_{10} CFU/min.M^2, while the Wet seasonal air fungal population ranged from 3.33 to 3.45 Log_{10} CFU/min-M^2.

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The mean fungal populations for the dry and wet seasons were3.38 and 3.54 Log_{10} CFU/min.M^2 respectively. The air fungal population during the Dry season was higher and significantly different from the populations during the Wet season at $p < 0.05$.

Similarly, data on mean seasonal population (Log_{10} CFU/g) of soil fungi are illustrated in Figure 4. Populations at the Dry season (5.9 Log_{10} CFU/g) was higher and significantly different from the fungal population during the Wet season (5.4 Log_{10} CFU/g) at $p < 0.05$.

Figure 5 shows graphic representation of multiple comparisons of quarterly counts of air fungi during sampling period. Quarterly means of air fungal counts were 3.77, 3.67, 3.5 and 3.47 for First to fourth quarters respectively. Mean quarterly counts ranged from 3.4 to 3.7 which are the lowest and highest counts in Fourth (Q4) and First Quarters (Q1) respectively. Differences in counts amongst quarters were observed, but there was no statistical significant difference (ns) amongst them at $P < 0.05$ (Quarters 1 and 2 ($P = 0.4463$), Quarters 1 and 3 ($p = 0.53693$), Quarters 1 and 4 (P=0.4463).

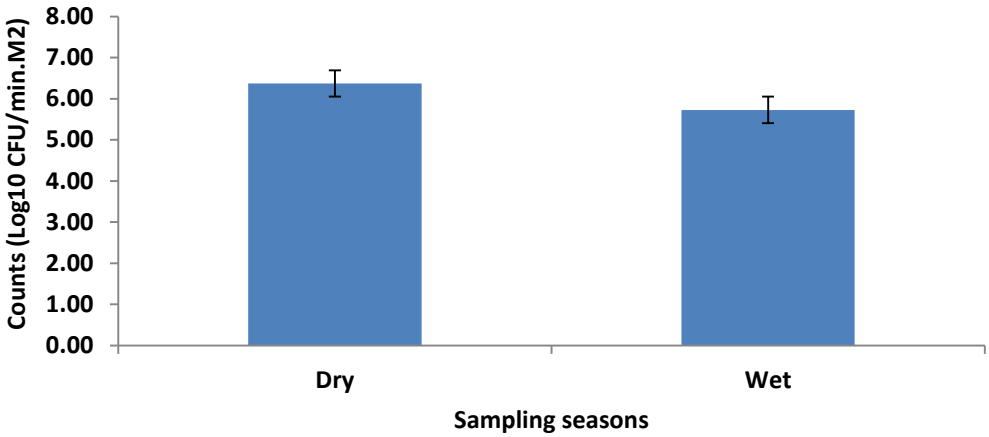

Figure 3: Mean seasonal counts of air fungi during the sampling seasons
Key: Log_{10} – Logarithm to base 10; CFU/min.M^2 – Colony Forming Units per minutes per metre squared

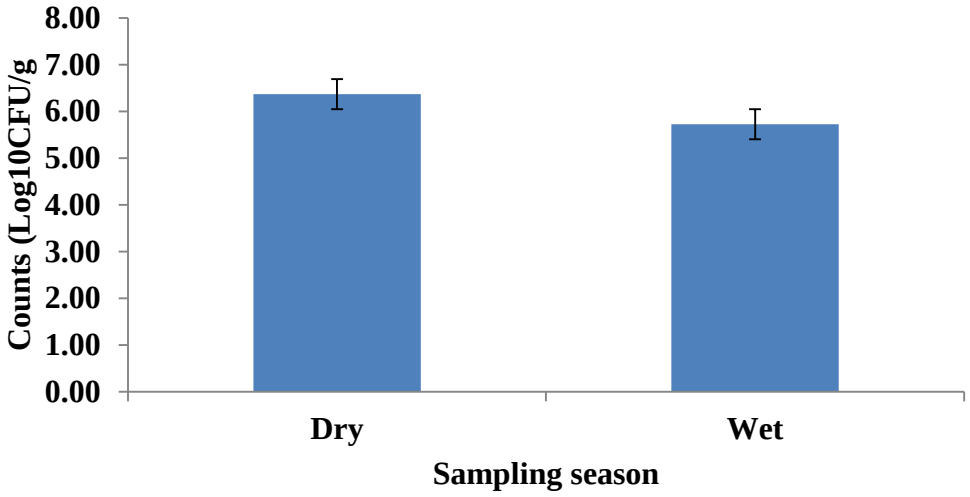

Figure 4: Mean seasonal counts of soil fungi during the sampling seasons
Key: Log_{10} – Logarithm to base 10; CFU/min.M^2 – Colony Forming Units per minutes per metre squared

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In Figure 6, results of multiple comparisons of quarterly counts of soil fungi during the sampling period are illustrated. Mean quarterly counts of soil fungi ranged from 5.5 to 6.1 which are the lowest and highest counts in Third (Q3) and First Quarters (Q1) respectively. There was slight fluctuation in counts from the first (Q1) to the last (Q4) quarters of sampling, values being 5.1, 5.6, 5.5 and 5.8 for Q1 to Q4 respectively.

Differences in counts amongst quarters recorded, but showed no significant difference (ns) amongst them at $P < 0.05$ (Quarters 1 and 2 ($P = 0.4127$), Quarters 1 and 3 (p = 0.2571), Quarters 1 and 4 (P=0.46690).

Species of fungi isolated from the Shopping Complex which represented their nominal species diversity were *Fusarium proliferatum, Alernaria alternata, Aspergillus fumigatus, Fusarium fujikoroi, Phaeacremonium aleophilum, Phoma selaginellicola, Fusarium concentricum, Pythium myriotylum, Scedosporium aurantiacum, Aspergillus orizae, Chrysosporium tropicum, Aspergillus nidulans, Penicillium vanluykii.*

The fungi isolates from the shopping complex environment were classified into physiological categories based on their natural and functional applications as shown in Table 3.

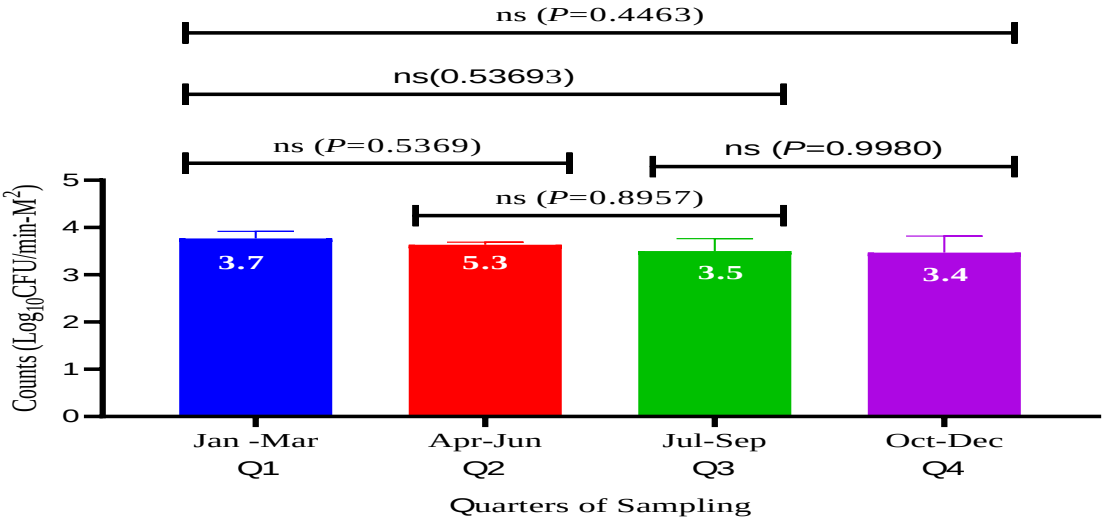

Figure 5: Multiple comparison of quarterly counts of air fungi during sampling period

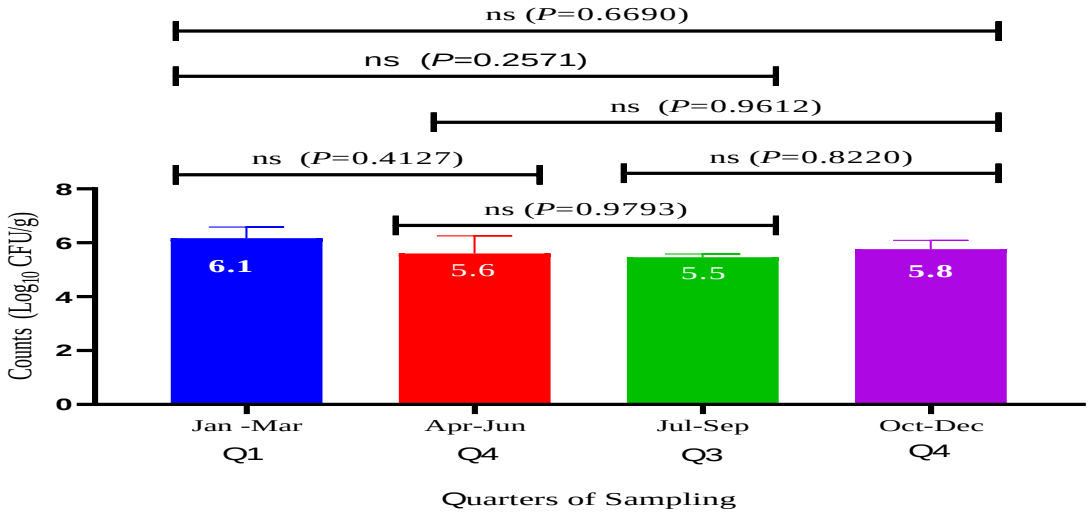

Figure 6: Multiple comparison of quarterly counts of soil fungi during sampling period

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Table 3: Physiological diversity of fungal isolates from soil around the Campus shopping complex

Fungi	Pathogenic	Phytopathogenic	Enthopmo-pathopgenic	Nematho-pathopgenic	Toxigenic	Saprophytic	Dermatophyte	Antibiotic Producing Fungi
Alternaria alternata	+	+	-	-	+	+	-	-
Aspergillus fumigatus	+	op	-	-	+	+	-	-
Aspergillus fumigatus	+	op	-	-	+	+	-	-
Aspergillus fumigatus	+	op	-	-	+	+	-	-
Aspergillus nidulans	+	op	-	-	+	+	-	+
Aspergillus nidulans	+	op	-	-	+	+	-	+
Aspergillus oprizae	+	+	-	-	+	+	-	-
Chrysopspoprium troppicum	+	+	-	-	+	+	-	-
Fusarium copncentricum	+	+	-	-	+	+	-	-
Fusarium copncentricum	+	+	-	-	+	+	-	-
Fusarium fujikuropi	+	+	-	-	+	+	-	-
Fusarium propliferatum	+	+	-	-	+	+	-	-
Fusarium propliferatum	+	+	-	-	+	+	-	-
Penicillium vanluykii	+	op	-	-	+	+	-	+
Phaeacremopnium aleopphilum	+	+	-	-	+	+	-	-
Phopma selaginellicopla	+	+	-	-	+	+	-	-
Pythium myrioptylum	+	+	-	+	+	+	-	-
Scedopspoprium aurantiacum	+	op	-	-	+	+	-	-

Key: + (classified under the group); - (not classified under the group); op (Opportunistic)

Table 4: Mean monthly physicochemical characteristics of soil at the Campus shopping complex

Physicochemical Characteristics	Sampling Months (July 2021 – June 2022)											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
ATT (^oC)	27.4	28	30.3	27.5	33.8	37.8	32.5	37.7	33.5	35.9	33.7	35.5
ST(^oC)	27.7	28.2	29.7	27.7	32.6	35.4	32.2	34.8	32.9	33.1	34.3	37.8
pH	6.4	6.9	7.6	6.7	7.4	7	7.5	6.9	7	6.2	6.7	6.5
MoiC (% w/w)	17	13.5	10	16.7	27.5	15	7.5	3.3	18	10	20	22
WHC (%)	33.7	24.4	23.9	30.4	31.9	33.5	31.6	37.4	31.2	30.1	22.8	33.7
EC (µS cm^{-1}).	79	102	98	90	163	93	118	95	26	49	181	109
TOC (%)	0.4	5.4	7.4	0.7	10.1	2.4	9.9	14.1	0.6	7.4	2.6	4.6
SOM (%)	0.69	9.3	12.8	1.2	17.4	4.1	17.1	24.3	1.0	12.8	4.5	7.9
N (mg Kg^{-1})	10	50	100	150	200	125	50	40	30	150	155	158
P (mg Kg^{-1})	10	20	15	10	20	20	20	35	50	50	35	28
K (mg Kg^{-1})	160	120	70	20	20	70	120	85	50	80	120	110
Ca [mg Kg^{-1})	7.2	36	72	108	14.4	90	36	28.8	21.6	17.28	23.04	46.08
Mg (mg Kg^{-1})	4	20	40	60	8	16	24	3.2	6.4	9.6	1.28	2.6
Zn (mg Kg^{-1})	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.05	0.08	0.08	0.05	0.04
SO^{3-}	8.5	17.1	12.8	8.5	17.1	17.1	17.1	29.9	42.7	42.7	29.9	23.9

Key: ATT (Atmospheric temperature); ST(Soil temperature); pH(Hydrogrn ion index; MoiC (Soil moisture content); WHC (Soil water holding capacity); EC (Electrical conductivity); TOC (Total organic carbon); SOM (Soil organic matter); N (Available nitrogen); P (Available phosphorus); K (available potassium); Ca (Calcium); Mg (Magnesium); Zn (Zinc); SO^{3-} (Sulphate).

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Discussion

The results of this study for air fungi populations during the sampling period were highest and lowest in the months of February and October respectively. The mean monthly population values indicate the presence of air fungi in the outdoor environment throughout the sampling period, with minor fluctuations observed. Previous studies have also reported the presence of air fungi in outdoor environments. For example, Al-Shaarani *et al*. (2023) found similar 7 in a study conducted in a different location. This consistency in findings suggests that air fungi are commonly found in outdoor environments. The findings of this study are significant as they contribute to the understanding of the presence and variability of air fungi in the studied environment. This information can be valuable for assessing air quality, identifying potential health risks, and implementing appropriate mitigation measures. However, it is important to acknowledge the limitations of the study. One limitation is that, the study presents and focused data on a single location, which limit the generalizability of the findings to other designated locations of the environments.

The findings of this study showed that mean monthly counts soil fungi during the sampling period soil fungi populations fluctuated regularly throughout the year. The highest counts were recorded in March and the Lowest in June. The counts show minor fluctuations throughout the sampling period, with no clear increasing or decreasing trend. The mean counts for each month indicates the presence of air fungi during the entire sampling period. Similar to the air fungi the counts exhibit variability but without a distinct pattern.

Comparing these findings with previous research, there have been several studies examining fungal populations in soil. For instance, Frac *et al*. (2018) conducted a similar study in a different region and reported corresponding results, which aligns with the findings in this study. Furthermore, He *et al*. (2021) investigated soil fungi and found fungal consistent with the findings in this study. These comparisons indicate that the fungal populations observed in this study are within the expected range based on previous findings.

The significance of these findings lies in understanding the dynamics of fungal populations in the environment.

Fungi play crucial roles in nutrient cycling, soil health, and air quality. Monitoring their presence and abundance provides insights into ecosystem functioning and potential impacts on agriculture. In conclusion, the study revealed the presence of air and soil fungi throughout the sampling period. These findings are consistent with previous research and contribute to our knowledge of fungal populations in the environment. Further research, encompassing multiple locations and species identification, would enhance our understanding of fungal ecology and potential implications for human and environmental health.

Seasonal counts of air and soil fungi showed a similar results, with both air and soil populations recording higher in the dry season than in the Wet. Our findings revealed significant differences in airborne and soil fungal populations between the dry and wet seasons. During the dry season, both airborne and soil-borne fungal populations were significantly higher compared to the wet season ($p < 0.05$). These observations are consistent with previous studies conducted in various locations in Lagos, Nigeria, which reported higher fungal concentrations during dry periods (Odebode *et al*., 2020). One potential explanation for this trend is the influence of weather conditions on fungal growth and dispersal. Dry seasons are often characterized by reduced precipitation and increased air circulation, which can favor the spread of airborne fungal spores (Anees-Hill *et al*., 2022). Additionally, dry conditions can stress vegetation, making them more susceptible to fungal colonization, which could contribute to the observed increase in soilborne fungi (Sinha *et al*., 2019).

Our findings highlight the dynamic nature of fungal communities and their dependence on environmental factors. Further investigations are warranted to explore the specific fungal species present during each season and their potential ecological and health implications. Additionally, studies investigating the mechanisms underlying these seasonal variations would provide valuable insights into the ecology and dispersal of airborne and soil-borne fungi.

Our findings revealed no statistically significant differences in the quarterly populations of either airborne or soilborne fungi at the shopping complex ($p > 0.05$).

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While the mean air fungal counts ranged from 3.47 (Q4) to 3.77 CFU/min.m^2 (Q1), and soil fungal counts ranged from 5.5 CFU/g (Q3) to 6.1 CFU/g (Q1), these variations were not statistically significant. These observations are in contrast to some previous studies, which have reported seasonal variations in fungal populations. For instance, a study conducted by Lin *et al*., (2016) in abandoned ancient rice terraces found significantly higher airborne fungal counts during the dry season compared to the wet season.

Several factors could potentially explain the absence of significant seasonal variations in our study. One possibility is that the sampling period may not have captured the full extent of seasonal fluctuations in fungal populations. Extending the study duration and incorporating additional sampling points throughout the year could provide a more comprehensive picture of seasonal trends.

Another possibility is that the unique microclimate of the shopping complex, potentially influenced by factors such as building materials, ventilation systems, and human activity, may have mitigated the impact of seasonal weather patterns on fungal communities.

Furthermore, the specific location of the shopping complex within the Rivers State University environment might influence the types and abundance of fungi present. However, our study did not detect statistically significant quarterly variations in airborne or soil-borne fungal populations at the shopping complex. While these findings differ from some previous reports, they highlight the potential influence of various factors, including study design, microclimatic conditions, and the surrounding urban environment, on the dynamics of fungal communities.

Further research with extended sampling periods, broader geographical contexts, and consideration of additional environmental factors is warranted to gain a more comprehensive understanding of the seasonal dynamics of airborne and soil-borne fungi in shopping complexes and similar environments. Species diversity of fungi isolated from shopping complex revealed multiple noteworthy fungal genera with *Fusarium* being one of them.

Fusarium consists of various species that are recognized as pathogens for plants and animals (Sinha *et al*., 2019). Their presence within the shopping complex environment raises potential risks for nearby vegetation and humans. Alongside *Fusarium*, other genera identified in this setting were *Alternaria* and *Aspergillus*. *Alternaria* is categorized as an allergenic fungus, and its spores present in the air can contribute to respiratory issues in humans (DeMers, 2022). *Aspergillus*, on the other hand, includes certain species that act as opportunistic pathogens for humans, particularly those with compromised immune systems (Paulussen *et al*., 2017). It is important to note that the presence of these fungi does not necessarily indicate harm. However, their identification emphasizes the potential need for further monitoring and management practices, particularly in areas frequented by individuals who may be more susceptible to fungal infections or allergies. The shopping complex environment exhibited a unique combination of fungal isolates, encompassing species commonly found in soil (e.g., *Fusarium* and *Pythium*) as well as airborne fungi like *Alternaria* and *Aspergillus*. This diversity likely reflects the intricate interplay of factors that influence fungal communities in such environments, including vegetation, human activity, and microclimate.

With regards to physiological diversity of fungi at the shopping complex, the study isolated and identified eighteen (18) selected fungal species belonging to nine (9) genera of aeroterrestrial fungi from air and soil samples. The most common genera found were *Aspergillus* and *Fusarium*. The presence of certain fungi, such as *Aspergillus fumigatus* and *Fusarium* species, can have implications for human health and plant health. The study also identified physiological categories of fungi, including pathogenic, phytopathogenic, entomopathogenic, nematophagous, toxigenic, saprophytic, dermatophytes, industrial, and antibiotic-producing fungi. The diversity and abundance of fungi were higher in soil than in air samples. Dominant fungal species varied between air and soil samples, indicating differences in fungal species composition. Statistical analysis confirmed significant differences in fungal diversity between air and soil samples. The findings highlight the impact of environmental conditions on fungal diversity and abundance and have implications for managing fungal growth in different environments for various purposes, including air quality and agricultural production.

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Several key observations can be made from the physiological categories. First, *Alternaria alternata* is pathogenic, toxigenic, and saprophytic but does not exhibit phytopathogenic, entomopathogenic, nematopathogenic, dermatophyte, or antibiotic-producing traits. This aligns with previous reports (Meena *et al*., 2017), highlighting the consistent nature of these characteristics.

Aspergillus fumigatus is an opportunistic pathogen, capable of producing toxins and exhibiting saprophytic behavior. However, it does not display phytopathogenic,entomopathogenic, nematopathogenic, dermatophyte, or antibiotic-producing properties. The presence of *Aspergillus fumigatus* in multiple instances in the table suggests its significance and prevalence in various contexts (Bastos *et al*., 2020).

Similarly, *Aspergillus nidulans* is an opportunistic pathogen and shares several characteristics with *Aspergillus fumigatus*, including toxigenicity and saprophytic nature. However, *Aspergillus nidulans* is also capable of producing antibiotics (Jones *et al*., 2020), distinguishing it from *Aspergillus fumigatus* in this regard (Paulussen *et al*., 2017).

Fusarium species, including *Fusarium concentricum*, *Fusarium fujikuroi*, and *Fusarium proliferatu*m, show similarities in their characteristics. They are pathogenic, toxigenic, and saprophytic but do not exhibit phytopathogenic, entomopathogenic, nematopathogenic, dermatophyte, or antibiotic-producing traits. These findings are consistent with previous studies on *Fusarium* species (Dmitry *et al*., 2022).

Penicillium vanluykii, in addition to being an opportunistic pathogen, displays dermatophyte properties and is capable of producing antibiotics (García-Effron *et al*., 2022). This unique combination of characteristics sets it apart from other fungi in the Table.

Phaeacremonium aleophilum and *Phoma selaginellicola* exhibit pathogenic, toxigenic, and saprophytic traits, similar to the other fungi listed. However, they do not possess phytopathogenic, entomopathogenic, nematopathogenic, dermatophyte, or antibiotic-producing properties. These observations are consistent with previous reports on these species (Sridhar and Tripathy 2022).

Pythium myriotylum is notable for its nematopathogenic nature, in addition to being pathogenic, toxigenic, and saprophytic. This characteristic distinguishes it from other fungi in the table and underscores its potential impact on nematode populations (Poveda *et al*., 2020).

Scedosporium aurantiacum like *Aspergillus fumigatus*, is an opportunistic pathogen that exhibits toxigenicity and saprophytic behavior. However, it does not possess phytopathogenic, entomopathogenic, nematopathogenic, dermatophyte, or antibiotic-producing properties. This finding is consistent with previous studies on *Scedosporium aurantiacum* (Mello *et al*., 2018).

The findings in this study highlight the diverse characteristics of various fungal species. These findings are in line with previous reports, validating the consistency of these traits across different studies. Understanding the specific characteristics of fungi is crucial for comprehending their roles in pathogenesis, ecological interactions, and potential applications, such as antibiotic production.

The study presents mean monthly values of various physicochemical characteristics depicting soil quality at the shopping complex throughout the year. The air temperature (ATT) ranged from 27.4°C in July to 37.8°C in December, with the highest values recorded during the dry season (December to February). Similarly, soil temperature (ST) followed the same trend, although with slightly lower values. These findings align with previous studies in [insert relevant region] which reported a rise in temperature during the dry season (Edori and Iyama, 2017).

The pH ranged from 6.2 in May to 7.6 in September, indicating slightly acidic to neutral conditions throughout the year. The EC values varied considerably, with the highest value (26 µS cm-1) recorded in February and the lowest (49 µS cm-1) in August. While limited data is available for direct comparison, previous studies suggest that the EC range observed in this study falls within the expected range (Deekae, and Alfred-Ockiya, 2010).

Moisture Content and Water Holding Capacity displayed a seasonal pattern, with the highest values recorded during the wet season (July to September) and the lowest during the dry season (December to

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February). This trend is likely linked to seasonal variations in precipitation. The WHC remained relatively stable throughout the year, ranging from 22.8% in November to 37.4% in February. These findings suggest that the soil at the sampling station has a moderate capacity to retain water and that the soils samples are virtually mixed in content. These are in line with the report of Zhang *et al*., 2021.

The total organic carbon and soil organic matter content exhibited similar trends, with the highest values observed during the dry season (December to February). This accumulation of organic matter during the dry season could be attributed to the decomposition of plant litter under drier conditions. Previous studies in [insert relevant region] have reported similar seasonal patterns of OM content (Querejeta *et al*., 2021).

Nutrients concentrations such as Nitrogen (N), phosphorus (P), and potassium (K) displayed variations throughout the year, with generally higher values observed during the wet season. This trend might be linked to increased nutrient input from surface runoff during the wet months. The observed ranges for N, P, and K are comparable to studies reported by Antonio *et al*., (2021). Concentrations of other parameters such as calcium (Ca), magnesium (Mg), zinc (Zn), and sulfate (SO^{3-}) also exhibited seasonal variations, but further studies are needed to elucidate the underlying factors influencing these patterns.

Understanding the seasonal variations of these physicochemical parameters is crucial for effective ecological management, environmental monitoring and proper evaluation of soil quality at the shopping complex. The physicochemical parameters estimated provides valuable insights into the baseline conditions at the shopping complex and can serve as a reference for future monitoring efforts. It is important to note that the data from this study represents a single sampling station, and broader conclusions about the entire university environment would be required to give a more elaborate idea about the environment.

In conclusion, this study revealed a high diversity of air and soil fungi in the shopping complex environment. The study identified 15 different fungal species and found the soil quality to be good, with ample organic matter and nutrients.

These findings have implications for public health and provide a foundation for monitoring and regulating fungal development in the area. The study highlights the importance of managing fungal populations to maintain a healthy environment and offers insights for developing strategies to control and prevent fungal issues.

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