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ABUNDANCE OF FUNGI UNDER RHIZOSPHERE SOIL OF INDIGENOUS DROUGHT TOLERANT TREE SPECIES IN SUDAN SAVANNAH ECOZONE OF NORTHERN NIGERIA

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ABSTRACT
The rhizosphere has a high potential for natural resources and contains many microorganisms that remain unexplored in the zone. This study was conducted to assess the fungal abundance under rhizosphere soil of indigenous drought-tolerant tree species in the Sudan Savannah ecozone of Northern Nigeria. Some indigenous drought-tolerant tree species in the Sudan Savannah ecozone of Northern Nigeria were identified. Pour plate technique was used to evaluate the abundance of fungi in the rhizosphere of indigenous drought-tolerant tree species and it is recorded in spore forming unit per gram (SFU/g). Fungi were isolated on potato dextrose agar and identified using macroscopic and microscopic characterization. Twelve (12) indigenous drought-tolerant tree families were identified with 81 individual tree species. The Fabaceae family had the highest number with 33 (40.74%) individuals. This was followed by Mimosoideae with 12 (14.81%) individuals. The least family obtained was Aracaceae with 1 (1.24%) individual member. At a depth of 0–30 cm, the most abundant tree species obtained was Balanites aegyptiaca with fungal count of 5.0x10^4 SFU/g. However, at the depth of 30–60 cm, Balanites aegyptiaca was also found to have the most abundant fungal count of 9.0x10^4 SFU/g. The fungi were identified as Fusarium and Aspergillus. At the depth of 0–30 cm, Aspergillus niger was the most abundant fungus isolated with 22 (47.83%), followed by Aspergillus fumigatus with 13 (28.26%). Fusarium solani with 4.35% was the least abundant isolate. However, at the depth of 30 –60 cm, the most abundant fungal species was Aspergillus niger with 17 (36.16%), followed by Aspergillus flavus with 14 (30.43%). Hence, there is a large number of indigenous drought-tolerant tree species in the Sudan Savannah with an abundance of fungal species. These microbes help in the breaking down of available nutrients in the soil for easy uptake by the tree plants, there by promoting the growth of the trees in the area.
Keywords: Rhizosphere, Sudan, Savannah, Indigenous trees, Drought-Tolerant Species

INTRODUCTION

Fungi are eukaryotic microorganisms with diverse groups such as yeast, molds and mushrooms. According to Tedersoo *et al.* (2019) they are essential in a number of many ecological processes, including nutrient cycling, decomposition, and symbiotic connections with plants. By secreting enzymes that convert complex organic substances into simpler molecules that can be taken by the fungal cells, fungi get nutrition through extracellular digestion (Tedersoo *et al.,* 2019). Fungi are crucial for the recycling of nutrients in ecosystems because of their capacity to break down organic matter (Klein *et al.,* 2018). They are also found in association with many plant roots forming mycorrihizal associations.

Mycorrhizal associations are symbiotic interactions between fungal populations and plants in which the former facilitates the nutrient intake in return for carbohydrates from the latter (Poosakkannu *et al.,* 2019). Athlete's foot, ringworm, and agricultural illnesses are among the ailments that certain fungi can cause in plants (Fisher *et al.,* 2019). Fungi can interact with plants as pathogens, symbiotic mutualists, decomposers, and one of the most diverse groups of microbes in soil environment (Juan-Ovejero *et al.,* 2020). The quantity of fungi in the rhizosphere soil influences the distribution and abundance of aboveground tree species ecologically and is crucial to the functioning of terrestrial ecosystems (Tedersoo *et al.* (2019).

The rhizosphere is home to a number of advantageous rhizo-microorganisms that can safeguard trees, improve soil quality, increase tree growth, preserve natural resources, and eventually lead to safer environments and more sustainable forest production (Adamo *et al.*, 2021). According to IUCN, (2023), tree species that can withstand drought are acclimated to the soil composition, climate, and other environmental conditions of their natural habitat. A tree is said to be drought-tolerant if it is not susceptible to the negative impacts of the drought, which can take many different forms, such as stunted growth, wilting, leaf drop, root damage etc. (IUCN, 2023). Due to the regions intense land use and drought, certain tree species that are thought to be drought-tolerant are more prevalent in northern Nigeria (Ebenezer, 2015). The earth rhizosphere is home to one of the most diverse and abundant microbial ecosystems, primarily composed of bacteria and fungi (Gu *et al.*, 2021). This study aimed to characterize the variety of fungi present in the rhizosphere soil of indigenous drought-resistant tree species in the Sudan Savannah ecozone of Northern Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted at the New campus of Bayero University, Kano, which is located along Gwarzo Road, Ungogo Local Government Area, of Kano State, Nigeria (Fig 1), at latitude of $11^0 11'07''$ N and longitude of $8^0 31'22''$ E. The vegetation on the Bayero University new sites is characterized by Savannah woodland with scattered trees and shrubs interspersed with grasses. Common trees found in this region are; *Azadirachta indica, Mangifera indica, Ceiba pentandra, Adansonia digitata, Parkia biglobosa, Tamarindus indica, Anarcadium occidentale, Ziziphus spinachristi, Diospyros mesopilformis* etc.

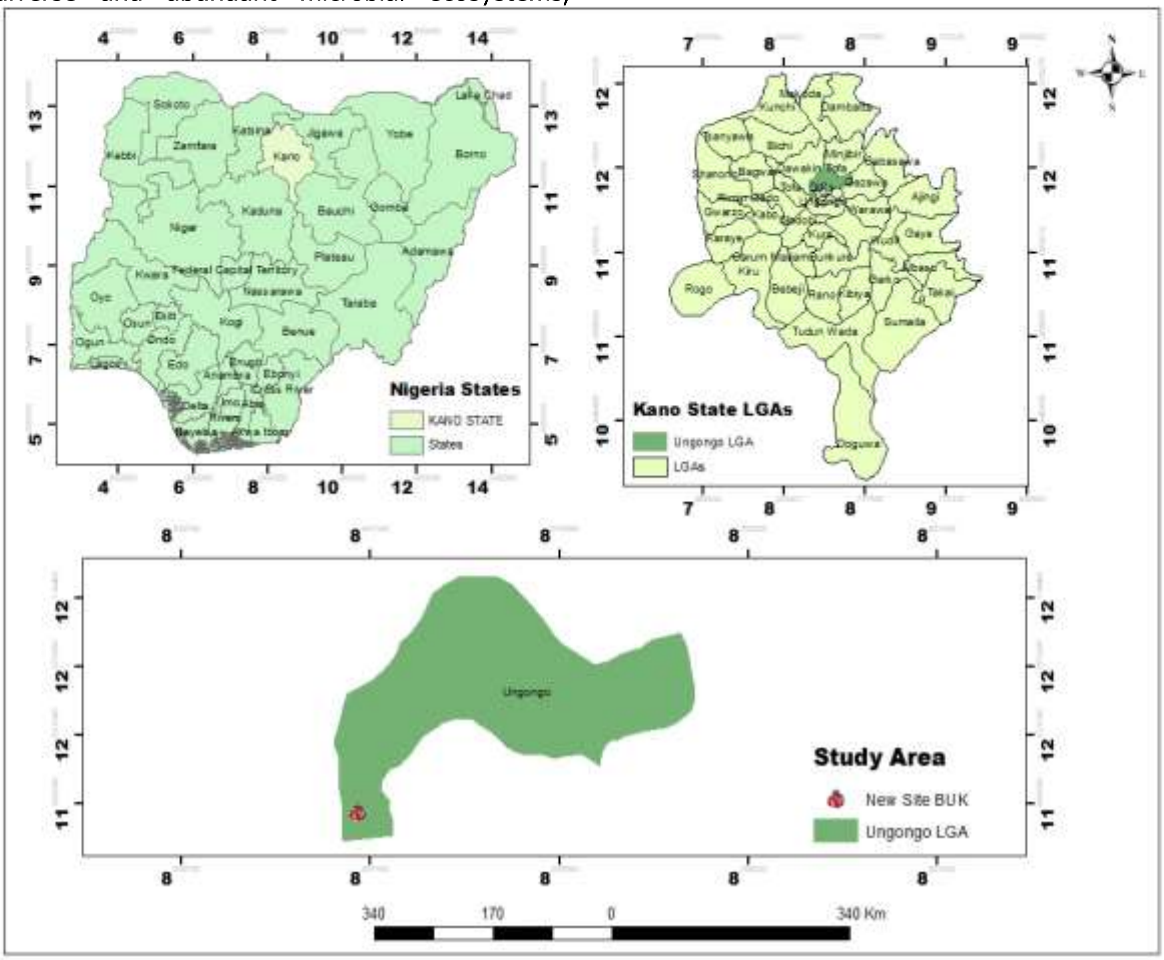

Figure 1: Map of Kano State Showing Study Area

Sampling Techniques

Stratified sampling techniques were used in this research. The entire study area was divided into four strata, which are: staff quarters, academic area, student's hostel/commercial area, and farmland. From each stratum, three sample plots of 100 m x 100 m in size were measured, from which all the indigenous drought-tolerant tree species in the sampled plot were counted and recorded. A purposive sampling method was used due to the higher abundance of tree species in the area to select the indigenous drought-tolerant tree species of economic importance to serve as the source of sample for laboratory tests and subsequently for analysis, The includes *Adansonia digitata* **(**Baobab)**,** *Parkia biglobosa* **(**Locust bean tree), and *Balanites aegyptiaca* **(**Desert date).

Sample Collection
The identification of the indigenous drought-tolerant tree species was done using plant identification application to make an approximate identification of unfamiliar species (Ochei and Kolhatkar, 2007). Soil samples were collected from underneath each of the sample trees at four different points opposite one another at depths of 0–30 cm and 30–60 cm using a soil auger. Soil samples from each of these depths were composited to give two composite samples per tree. All impurities were removed from the samples and were immediately enclosed in appropriately labeled bags and delivered to the Microbiology Research Laboratory of the Department of Microbiology, Bayero University, Kano, within 24 hours of collection for fungal enumeration, isolation and identification.

Isolation of Fungi from the Soil Rhizosphere
According to the method of Zaved *et al.* (2008), one gram of soil from the sample was suspended in 9 mL of sterilized distilled water, mixed well for 15 minutes, and vortexed. The suspension was serially diluted from 10^{-1} to 10^{-4}. Pour plate technique was carried out to isolate the fungi from the soil sample. One (1) mL was pipetted onto a sterilized petri dish in duplicate, followed by the addition of molten potato dextrose agar and mixed three times clockwise and anti-clockwise. The set-up was incubated at room temperature for 5 days (Zaved *et al.*, 2008).

Enumeration of Fungi from the Soil Rhizosphere
Similarly, pour plate method was used to enumerate the fungal population from the soil rhizosphere. A serial dilution protocol was carefully followed to obtain a dilution up to 10^{-5} and One (1) mL was inoculated into a Petri dish in duplicate, and potato dextrose agar was added. The plates were incubated at room temperature (35°C) for 5 days. After incubation period, the fungal colonies were observed, counted, and recorded. The average of fungal colonies obtained were multiplied with the inverse of the dilution factor to obtain the number of fungal counts per gram of the soil sample (Ochei and Kolhatkar, 2007).

Identification of Fungi from the Soil Rhizosphere
After incubation, the fungi were identified using macroscopic and microscopic techniques (Naher *et al.,* 2013). Cultural and morphological appearance of fungi, including color pigmentation and spore formation, were observed for the identification of fungi. This was compared with the fungal identification chart.

RESULTS

Indigenous drought tolerant tree species
A total of 12 indigenous drought-tolerant trees were recorded in the study area, with a total of 81 individual tree species. A total of 8 families were encountered. The *Fabaceae* family had the highest individuals, with a total number of 33 (40.74%) stands. This is followed by *Mimosoideae* with 12 (14.81%) individuals. The least family obtained in this study is *Aracaceae* with 1 (1.24%) individual.

Abundance of fungi in the selected tree species at various depths
Table 2 shows the abundance of fungi at the depth of 0–30 cm. From the result, the highest fungal count obtained was 5.0 x 10^4 SFU/g from *Balanites aegyptiaca*, followed by *Adansonia digitata* with a fungal count of 4.5 x 10^4 SFU/g. The least fungal count obtained was from *Parkia biglobosa* with 3 x 10^4 SFU/g. However, at the depth of 30–60 cm, *Balanites aegyptiaca* was also found to have fungal count of 9.0 x 10^4 SFU/g, followed by *Parkia biglobosa* with 7.5 x 10^4 SFU/g. The least fungal count obtained at the depth of 30–60 cm was from *Adansonia digitata* with 5.5 x 10^4 SFU/g.

Table 1: Some indigenous drought tolerant tree species

Scientific Name	Family	Common Name	Local Name	Frequency	Percentage (%)
Acacia nilotica	*Fabaceae*	Gum arabic tree	Bagaruwa	10	12.35
Acacia sayel	*Fabaceae*	Thirty thorn	Farar kaya	12	14.81
Parkia biglobosa	*Fabaceae*	African locust bean	Dorawa	5	6.17
Piliostigma reticulatum	*Fabaceae*	Camal foot tree	Kargo	6	7.41
Adansonia digitata	*Bombacaceae*	Boaba	Kuka	10	12.35
Balanites aegyptiaca	*Balanitaceae*	Desert date	Aduwa	5	6.17
Borassus aethiopuim	*Aracaceae*	African palm	Giginya	1	1.23
Faidherbia albida	*Mimosoideae*	Apple ring acacia	Gawo	12	14.81
Lanneam acrocarpa	*Anacardiaceae*	African grapes	Taure	3	3.70
Selerocary abirrea	*Anacardiaceae*	Jelly plum	Danya	2	2.47
Terminalia mentally	*Combretaceae*	Umbrella tree	Itaciyar laima	10	12.35
Ziziphus-spinachristi	*Rhamnaceae*	Thorn jujube	Kurna	5	6.17
Total				**81**	**100**

Table 2: Abundance of fungi in the selected tree species at depth of 0-30cm and 30-60cm

Tree Species	0-30 (cm)	30-60 (cm)
	Mean TFC (SFU/g)	Mean TFC (SFU/g)
Adansonia digitata	4.5×10^4	5.5×10^4
Balanitesa egyptiaca	5.0×10^4	9.0×10^4
Parkia biglobosa	3.0×10^4	7.5×10^4
TOTAL	$\mathbf{12.5 \times 10^4}$	$\mathbf{22.0 \times 10^4}$

Microscopic observations were carried out through the use of a fungal identification chart. Several fungi were identified, including 2 genera of fungi and a total of 6 fungal isolates. The fungi isolated were identified as *Fusarium* and *Aspergillus*. The distribution of fungal species isolated at the different depths (0–30 and 30–60) includes *Aspergillus niger, Aspergillus fumigatus, Aspergillus flavus,* and *Fusarium solani.* At the depth of 0–30 cm, *Aspergillus niger* was the most abundant fungi isolated with 47.83% frequency of occurrence, followed by *Aspergillus fumigates* (28.26%). The least fungi isolated was *Fusarium solani* with frequency of occurrence of 4.35%. However, at the depth of 30–60 cm the most abundant fungal species was *Aspergillus niger* (36.16%), followed by *Aspergillus flavus* (30.43%). The least fungi isolated was also *Fusarium solani,* as presented in Table 3.

Table 3: Distribution of fungal species and their abundance at rhizosphere (depth 0-30cm and 30-60cm)

Fungal Species	0-30 (cm)		30-60 (cm)	
	No. of Isolates	Percentage (%)	No. of Isolates	Percentage (%)
Aspergillus fumigatus	13	28.26	9	19.57
Aspergillus niger	22	47.83	17	36.96
Aspergillus flavus	9	19.57	14	30.43
Fusarium solani	2	4.35	6	13.04
Total	**46**	**100**	**46**	**100**

DISCUSSION

The findings from this study revealed the presence of indigenous drought-tolerant tree species in the study area with abundance of fungi in the rhizosphere soil. The findings revealed that *Acacia sayel, Faidherbia albida, Acacia nilotica, Adansonia digitata,* and *Terminalia* were the most abundant tree species in the study. The finding of this study is in contrast to the findings of Wakawa *et al*. (2016) who reported 80% of the total trees in their study area to be *Azadirachta indica* and *Eucalyptus camaldulensis. Azadirachta indica* and *Eucalyptus camaldulensis* have become some of the choice species for planting in the northern part of Nigeria since their introduction in Nigeria because of their easy establishment, fast growth, and easily adapt to the region (Wakawa *et al*., 2016). Indigenous drought-tolerant tree species also help in promoting sustainable development within our communities and green infrastructure which provide several social, communal, psychological, economic, and environmental benefits (Roy *et al.,* 2019). Drought-tolerant characteristics of trees allow them to maintain healthy growth and ecosystem services even during droughts (Roy *et al.,* 2019) Drought-tolerant trees act as natural filters, removing pollutants and dust particles from the air, and drought-tolerant species continue to provide this benefit even during dry periods when water-stressed trees may lose some filtering capacity (Escobedo *et al.,* 2018).

The abundance of fungal colonies was observed to be higher at the depth of 30–60 cm with 22.0×10^4 SFU/g. This is in line with Ateh *et al.* (2019) who reported that the microbial load of fungi was higher than that of bacteria, with a value of 4.49×10^5SFU/g and 34.3×10^5SFU/g for bacteria and fungi respectively at the soil profile (0–15 cm) in the Girei site of Adamawa State. This finding is in contrast with the work of Liu *et al.* (2018), who revealed that fungi are concentrated in the upper layer of the rhizosphere because plant roots tend to be more concentrated in the upper soil layers, leading to a higher influx of root exudates that fuel microbial growth. The difference between the findings may result from differences in the geographical locations of the study area. The variations in fungal community structure across the rhizosphere of different tree species are likely driven by root exudate composition (Song *et al.,* 2017). Microbial activity, including respiration, consumes oxygen (Yao *et al.,* 2018), and the shallow zone of the rhizosphere generally has better aeration due to diffusion from the atmosphere. The rhizosphere environment is not uniform; as we move deeper, factors like oxygen availability and nutrient concentrations decline. This creates a selective pressure that favors fungi species adapted to thrive in these conditions (Brune *et al*., 2016). Four dominant fungal species were identified in the rhizosphere soil samples, which include *Aspergillus fumigatus, Aspergillus niger, Aspergillus flavus,* and *Fusarium solani*. This finding is consistent with several studies that reported a higher prevalence of *Aspergillus* species in the rhizosphere of various tree species in arid and semi-arid regions. In a study conducted by Mahmoud *et al.* (2021) they reported that the diverse fungal community found in their studies is *Aspergillus* species in the rhizosphere of medicinal plants growing in the Egyptian deserts.

CONCLUSION

This study revealed that there is an abundance of some indigenous drought-tolerant tree species, in Sudan Savannah ecological zone (BUK new site) with *Fabaceae* as the highest family of indigenous drought-tolerant trees in the study area. *Balanites aegyptiaca* had the highest fungal abundance, with a fungal count of 5.0×10^4SFU/g and 9.0×10^4SFU/g at the depths of 0–30 cm and 30–60 cm, respectively. The fungal abundance showed that *Aspergillus niger* had 22 (47.83%) and 17 (36.96%) at the depths of 0–30 cm and 30–60 cm, respectively. In order to save the drought tolerant tree species from going extinct, afforestation initiatives should be implemented in the Sudan savannah ecozone, with a focus on indigenous drought-tolerant tree species that can withstand drought.

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