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Assessments and Distribution of Parasitic Plants Species on Tree Species in Kano Cosmopolitan Green Areas, Nigeria

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ABSTRACT
This study offers a comprehensive assessment of mistletoe diversity, composition, and distribution on trees within Bayero University, Kano (BUK) campuses and the Kano Zoological Garden, Nigeria. Mistletoes, functioning as obligate hemiparasites, wield significant influence on forest ecosystems, shaping host tree physiology and biodiversity dynamics. Despite their ecological importance, a detailed examination of mistletoe species in these specific green zones remains scarce. This research addresses this gap by adopting a multidisciplinary approach, integrating field surveys and taxonomic analysis to furnish a holistic understanding of mistletoe prevalence and ecological interactions within these distinctive urban environments. The study reveals the presence of four mistletoe species namely: *Tapinanthus dodoneifolius*, *Tapinanthus oleifolius*, *Tapinanthus globiferus*, and *Agelanthus dodoneifolius*, parasitizing on various trees across the campuses and Kano Zoological garde, with *T. globiferus* emerging as the predominant species. The study identifies fifty-four tree species from sixteen families in the study area, among which ten—*Azadirachta indica*, *Adansonia digitata*, *Acacia nilotica*, *Delbajia sisso*, *Gmelina arborea*, *Khaya senegalensis*, *Mangifera indica*, *Parkia biglobosa*, *Terminalia catapa*, and *Zizupus spina-christi*—were found to be infected with mistletoe. Consequently, 372 out of the estimated 2,095 tree species within the BUK campuses were observed to be infected with four identified mistletoe species, with *Azadirachta indica* exhibiting the highest infestation rate and *T. globiferus* prevailing as the most abundant mistletoe species.

Keywords: Mistletoe; trees; Ecological interaction

INTRODUCTION
Tree species are known to provide diverse benefits from ecological (soil erosion control, watershed management, windbreaks and shelterbelts, desertification control, and climate change mitigation) to socio-economic advantage (source of income from the sale of fuel—wood, timber, edible fruits, and medicinal plants) (Seth, 2003; Elmendorf, 2008; Hadzigeorgiou *et al*., 2011). The causes of biodiversity loss are largely related to parasite infestation, as parasites are major causes of diseases in humans, livestock, crops, and plant species leading to poor yields, biodiversity loss, and great economic loss. Presence of parasite on trees could be very damaging and dangerous as they reduce the growth of host trees, and eventually causes death due to heavy infestations, this has pose a great tread to endangered or critically endangered species (Twyford, 2018). Nigeria is endowed with a rich biodiversity, with an estimated plant species of about 7,895 from 338 families and 2,215 genera (FGN, 2006). However, these tree species are disappearing at an alarming rate, owing largely to deforestation and other land use practices like road construction. About 146 species on the International Union for Conservation of Nature's (2012) list of threatened species are found in Nigeria, of which 18 fall under the category 'endangered' and 15 under the category 'critically endangered' (Borokini, 2014). When trees are destroyed, the natural ecosystem is undermined, leading to an environmental imbalance.

The International Union for the Conservation of Nature (IUCN, 2012) reported that over one-tenth of known tree species on earth are considered to be under threat. Furthermore, Whittaker (1975), Walter (1985), and UNDP (2004) noted that deforestation may primarily lead to the extinction of between 5 and 15 percent of the world's species between 1990 and 2020. Therefore, tree composition and management become very important in achieving sustainable development. The type of tree species growing in a specific location is related to factors such as climate, topography, geology, soil conditions, natural disturbances, and anthropogenic disturbances. Due to the importance of trees and their lineages with the environment and human activities, geographers have long been interested in the classification of trees, and this proves that trees structure vegetation over global, regional, and local spatial scales (Boisvenue and Running, 2006).

Parasitic plants, on the other hand, are plants that obtain all or part of their nutrition from another plant (the host) without contributing to the benefit of the host and, in some cases, causing extreme damage to the host (Westwood et al., 2010). The defining structural feature of a parasitic plant is the *haustorium*, a specialized organ that penetrates the host and forms a vascular union between the plants. Parasitic plants can be hemi-parasites (photosynthetic), or holo-parasites, which are completely devoid of chlorophyll and are thus obligatory and dependent on their host plants for their nutrition (Thorogood *et al*., 2009). Hemi-parasitic plants belong to a number of flowering plant families, including Balanophoraceae, Loranthaceae (Mistletoes), Orobanchaceae, Myzodendraceae, Olacaceae, Schoepfiaceae, Opiliaceae, Eremolepidaceae, Santalaceae, Viscaceae, Krameriacea, Lauraceae, and Convolvulaceae (Nickrent and Musselman, 2004). Their acquisition of host resources can exert strong effects on the host's growth, allometry, reproduction, and physiology, especially with heavy infestation (Press *et al*., 1999; Aukema, 2003). This reduces host productivity and/or reproductive effort and has been extensively documented for both root hemiparasites and shoot hemiparasites (Matthies and Egli, 1999). Effects on host physiology further impair host performance (Watling and Press, 2001). However, some groups of hemiparasites (especially mistletoes) are of great ecological importance as they may function as keystone resources in many ecosystems (Watson, 2001), and they positively affect diversity in forest habitats (Nickrent and Musselman, 2004).

Some hemi-parasitic plants provide food in the form of fruit, seed, nectar, and medicine for various animals. According to Watson and Herring (2012), mistletoe exhibits a highly irregular distribution across sites, being entirely absent from some sites and occurring in remaining sites. In this regard, hemi-parasitic plants could also be of conservation interest in their own right. Canopy infestation by hemiparasites is influenced by the presence of mother parasitic plant species and other players or agents that hasten pollination. The aim of this research work was to conduct a comprehensive assessment of parasitic plant species (mistletoes) diversity, composition, and distribution across various tree species within the cosmopolitan green areas of Kano.

MATERIALS AND METHODS

Study Area

The study was conducted at two campuses of Bayero University, Kano and Kano Zoological Garden. Kano state is situated between latitude 12°40' and 10°30'N and longitude 7°40' and 9°30'E. The climate is classified into dry and wet seasons. The dry season typically spans from November to March, while the rainy season extends from May to September.

The mean annual rainfall is approximately 690 mm, and the mean annual temperature ranges between a maximum of 33.0°C and a minimum of 19.0°C. The vegetation predominantly consists of savanna, categorized climatically into Northern Guinea Savanna and Sudan Savanna. The Northern Guinea Savanna is characterized by open woodland or brush with shorter grasses, while the Southern Guinea Savanna has taller grasses.

Sampling

The study was conducted from November 2021 to October 2022, encompassing both dry and wet seasons. Stratified sampling techniques were employed to capture the variability of the land cover, dividing the land into two strata, namely residential areas and open areas for sample collection. Sampling were performed using quadrat and transect methods, as described by Kawo et al. (2006). Measuring tape and ranging poles were utilized for measuring and pegging the quadrats.

Determination of parasitic plant distribution and rate of infestation on tree species

Parasitic plant species were identified using an identification guide, and representative samples were taken to the herbarium for identification. The distribution and rate of infestation by parasitic plants were calculated by counting the number of parasitic plants on tree species and the trees infected with parasitic plants. Infestation intensity (%) was calculated following Ram et al. (2006) as

$$\frac{\text{the number of infested branches on a tree}}{\text{total number of branches on a tree}} \times 100,$$

using Shannon-Weiner indices, Evenness, and Dominance

Data analysis

Descriptive statistics were applied to compare the means of species diversity indices and parasitic plants among different sites using SPSS software (version 18, 2010). To assess the diversity, composition, and distribution of parasitic plants and tree species in the areas, Shannon diversity indices ($H=\sum Pi*\ln Pi$) and Sorenson's diversity indices (S=3C) were used.

Species diversity was calculated using the Shannon-Weiner diversity index (1949).

$H = - \sum Pi \ln Pi$

Where: Pi is the proportion index of species i, $Pi = n/N$,

n = number of individual of a particular species,

N = total number of individual of all species and ln = the natural log of the number.

Species Distribution: The distribution was calculated using the Dominance and Evenness (Pielou, 1966)

$$E = H/\ln S$$

Where: H = Shannon-Weiner diversity index,

S = Total number of species in the sample and

ln = the natural log of the number.

RESULTS AND DISCUSSION

Determination of mistletoe species distribution and rate of infestation on the host tree species

Tables 1 to 3 showed the distribution of mistletoe on tree species. The results revealed that all four identified mistletoe species were present in approximately 36% of the tree species in the study areas. *Agelanthus dodoneifolius*, *Tapinanthus oleifolius*, *Tapinanthus dodoneifolius*, and *Tapinanthus globiferus* were identified on tree species in the BUK campuses, while *Tapinanthus globiferus*, *Tapinanthus dodoneifolius*, and *Agelanthus dodoneifolius* were identified in Kano Zoo. In the BUK Old Campus, *Azadirachta indica* had the highest rate of infestation (54.6%), followed by *Terminalia catapa* (16.4%), while *Adansonia digitata* had the least rate of infestation. In BUK New Campus, the highest rate of infestation was observed in *Azadirachta indica*, followed by *Terminalia catapa* (13.3%) and *Tamarindus indica* (10.0%)

Ziziphus mauritiana, *Khaya senegalensis*, *Mangifera indica*, and *Syzygium guineense* had the least rate of infestation, ranging from 0.4% to 0.8% (Table 2). The results from Kano Zoological Garden as presented, have indicated that *Azadirachta indica* had the highest rate of infestation (39.6%), and followed by *Delbajia sisso* (19.6%) and *Terminalia catapa* (14.5%). *Acacia seyal* and *Psidium guajava* had the least rate of infestation at 0.2%.

Table 1: Mistletoe species rate of infestation on the tree species

Host tree species	Rate of infestation	*Agelanthus dodoneifolius*	*Tapinanthus dodoneifolius*	*Tapinanthus globiferus*	*Tapinanthus oleifolius*
		Bayero University Old Campus			
Acacia seyal	3. 6	0	1	15	0
Azadirachta indica	54.6	40	23	167	13
Adansonia digitata	3.1	2	0	9	3
Balanite aegyptiaca	3.8	3	2	11	1
Mangifera indica	4.5	2	0	18	0
Tamarindus indica	3.4	5	3	7	0
Terminalia catapa	19.7	23	17	42	6
Terminalia mentalis	6.9	0	4	27	0
Vitex doniana	3.4	0	1	14	0
Zizipus spina-christi	3.4	0	4	11	0
Total	100	75	55	292	23
		Bayero University New Campus			
Azadirachta indica	64. 5	27	6	124	3
Adansonia digitata	6.8	7	1	9	0
Khaya senegalensis	0.8	2	0	0	0
Mangifera indica	0.4	0	1	0	0
Tamarindus indica	10.0	17	0	8	0
Terminalia catapa	13.3	9	0	24	0
Terminalia mentalis	2.8	2	0	5	0
Syzygium guinensis	0.4	1	0	0	0
Zizupus Mauritania	0.8	0	0	2	0
Total	99.8	65	8	172	3
		Kano Zoological Garden			
Azadirachta indica	39.6	34	11	129	0
Acacia seyal	0.2	0	0	1	0
Adansonia digitata	4.7	3	1	17	0
Delbajia sisso	19.1	27	4	53	0
Gmelina arborea	1. 1	0	0	5	0
Khaya senegalensis	2.2	2	0	8	0
Mangifera indica	0.6	0	0	3	0
Parkia biglobosa	2. 7	6	0	6	0
Psidium guajava	0.2	0	0	1	0
Syzygium guineense	9.7	14	0	29	0
Tamarindus indica	2.9	0	0	13	0
Terminalia catappa	14. 5	22	5	37	0
Zizupus spina-christi	3.8	0	9	8	0
Total	101.2	108	21	310	0

Percentage Level of Mistletoe infestation on tree species

Tapinanthus globiferus exhibited the highest level of infestation (73%) among all mistletoes in the study sites (Figure 1). Subsequently, *Agelanthus dodoneifolius* showed infestation rates of 36% in BUK Old Campus, 15% in BUK New Campus, and 6% in Kano Zoological Garden. *Tapinanthus dodoneifolius* exhibited infestation rates of 23% in BUK Old Campus, 8% in BUK New Campus, and 18% in Kano Zoological Garden. Meanwhile, *Tapinanthus oleifolius* was only found in BUK Old Campus and BUK New Campus, with the lowest percentage level of infestation.

The results for BUK Old Campus tree species infested by mistletoe at the study sites indicated that 86% were alive, 11% were dying, and none were dead. Similarly, the results for BUK New Campus tree species infested by mistletoe revealed that 92% were alive, 8% were dying, and none were dead. In Kano Zoological Garden, the results showed that 80% were alive, 12% were dying, and 8% were dead (Figure 2)
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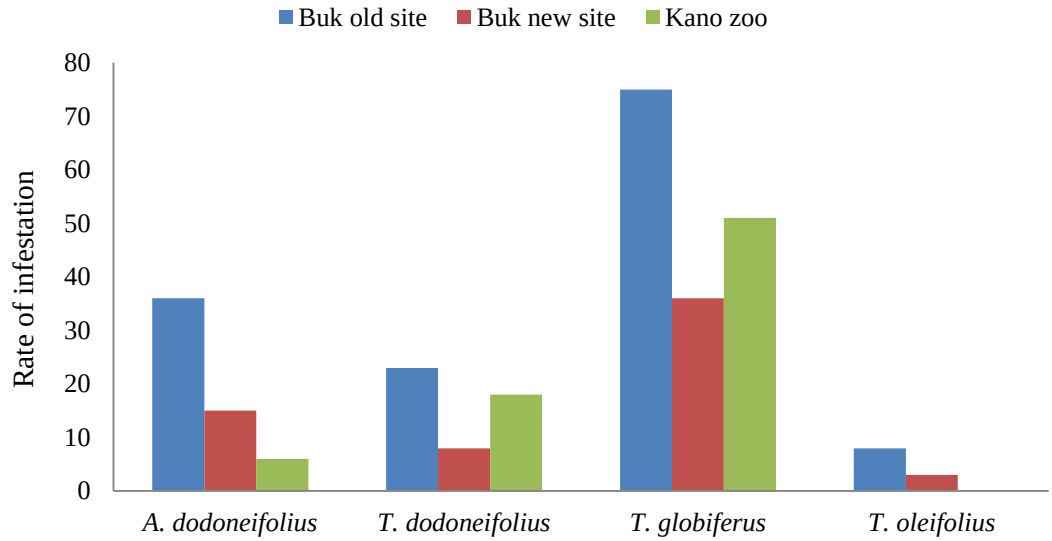

Figure 1: Percentage rate of infestation by mistletoe species on trees of Bayero University campuses and Kano Zoological Garden

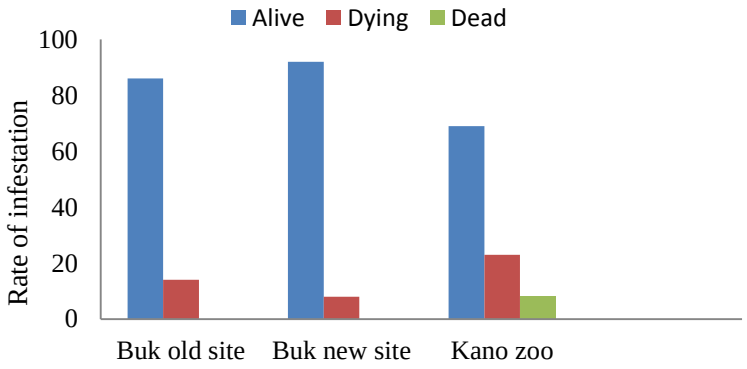

Figure 2: Infection of tree species by mistletoe in Bayero University campuses and Kano Zoological Garden

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Diversity indices of Mistletoe species and their abundance in the study areas

The diversity indices of mistletoe species in BUK Old Campus are presented in Table 2. The Shannon diversity, dominance index, and evenness of mistletoe were 0.988, 0.524, and 0.711, respectively. Similarly, the diversity indices of mistletoe species in BUK New Campus are shown in Table 3, with the Shannon diversity, dominance index, and evenness of mistletoe calculated as 0.769, 0.408, and 0.554. Additionally, the diversity indices of mistletoe species in Kano Zoo are provided in Table 4, indicating a Shannon diversity of 0.736, a dominance index of 0.438, and an evenness of 0.670.

Table 2: Diversity indices of mistletoe and their abundance on host species in BUK Old Campus

Mistletoe Species	Total no of individual species	Pi (n/N)	H(Pi In Pi)	D	E(H/InS)	Abundance class
Agelanthus dodoneifolius	65	0.2621	0.3509	0.0069	0.253	Abundant
Tapinanthus dodoneifolius	8	0.0323	0.1109	0.1043	0.079	Occasional
Tapinanthus globiferus	172	0.6935	0.2538	0.4809	0.183	Very Abundant
Tapinanthus oleifolius	3	0.0121	0.0534	0.0002	0.039	Rare
Total	248		0.769	0.592 D=1-D =1-0.592 D=0.408	0.554	

Table 3: Diversity indices of mistletoe and their abundance on host species in BUK New Campus

Mistletoe Species	Total no of individual species	Pi (n/N)	H(Pi In Pi)	D	E(H/InS)	Abundance class
Agelanthus dodoneifolius	75	0.1685	0.3001	0.0283	0.216	Abundant
Tapinanthus dodoneifolius	55	0.1236	0.2584	0.0153	0.186	Abundant
Tapinanthus globiferus	292	0.6562	0.2765	0.4306	0.199	Very Abundant
Tapinanthus oleifolius	23	0.0517	0.1532	0.0027	0.110	Frequent
Total	445		=0.988	=0.4761 D=1-D =1-0.4761 D=0.5237	=0.711	

Table 4: Diversity indices of mistletoe and their abundance on host species in Kano Zoological garden

Mistletoe Species	Total no of individual species	Pi (n/N)	H(Pi In Pi)	D	E(H/InS)	Abundance class
Agelanthus dodoneifolius	108	0.2460	0.3449	0.0605	0.314	Very Abundant
Tapinanthus dodoneifolius	21	0.0478	0.1453	0.0023	0.132	Frequent
Tapinanthus globiferus	310	0.7062	0.2457	0.4987	0.224	Very Abundant
Tapinanthus oleifolius	0	0	0	0	0	Nil
Total	=439		=0.736	=0.5615 D=1-D =1-0.5615 D=0.4385	0.670	

DISCUSSION

Tapinanthus sp. was identified as the most abundant and widespread species in this study, consistent with the findings of Boussim *et al*. (1993). The prevalence of *Tapinanthus globiferous* may be attributed to various factors, including the response of birds to mistletoe fruit abundance, resulting in variations in the transmission on the campus (Konsala *et al*., 2022). Additionally, the ability of mistletoe seeds to germinate and establish successfully (Ramírez and Omelas, 2012), and mistletoe-host compatibility, which is influenced by the host's susceptibility to infection and mistletoe infectivity (Reid and Yan, 2000), may contribute to its dominance.

A positive relationship was observed between mistletoe infestation and tree diameter, with larger trees hosting more mistletoes. This could be explained by the fact that large trees provide better perches for birds that disseminate mistletoe seeds (Overton, 1994). Reid and Yan (2000) noted that mistletoes have a greater impact on trees following water stress or drought. The results indicated that *Tapinanthus globiferus* had the highest number of infestations (292 in BUK Old Campus, 172 in BUK New Campus, and 310 in Kano Zoological Garden). It was followed by *Agelanthus dodoneifolius* (75 in BUK Old Campus, 65 in BUK New Campus, and 108 in Kano Zoo) and *Tapinanthus dodoneifolius* (55 in BUK Old Campus, 8 in BUK New Campus, and 21 in Kano Zoological Garden). The infestation rates were 54.6% in *Azadirachta indica* and 16.4% in *Terminalia catapa*, while other identified tree species had lower infestation rates.

The Shannon diversity index, typically ranging from 1.5 to 3.5, rarely reaching 4.5 (Ifo *et al*., 2016), was calculated. BUK Old Campus had the highest value (0.988), followed by BUK New Campus (0.769), with Kano Zoological Garden having the least value (0.736). In terms of evenness, BUK Old Campus scored the highest (0.711), followed by Kano Zoo (0.670), and BUK New Campus had the lowest evenness. In this study, 6% of mistletoe-infested tree species were dying at BUK Old Campus, 14% at BUK New Campus, and 23% at Kano Zoological Garden. Rigling *et al*. (2010) suggested that mistletoe infestation makes trees more vulnerable to drought stress in xeric campuses.

This is because, during drought conditions, when trees reduce transpiration rates, mistletoes continue to transpire, increasing water loss and drought stress on host trees (Fischer, 1983; Zweifel *et al*., 2012). Severe mistletoe damage was observed on shea trees under drought stress conditions, leading to deaths (Boussim *et al*., 2004). Moreover, 8% of tree species were recorded as dead in Kano Zoological Garden, while none were found dead at the two study campuses. However, mistletoe-infested trees at the study campuses were also infested with stem borers. This observation may be attributed to mistletoe infection increasing the susceptibility of trees to fungal diseases and bark beetles (Hawksworth and Weins, 1996).

CONCLUSION

The mistletoe species, namely *Agelanthus dodoneifolius*, *Tapinanthus oleifolius*, *T. dodoneifolius*, and *T. globiferus*, were found parasitizing on various tree species such as *Azadirachta indica*, *Parkia biglobosa*, *Tamarindus indica*, *Terminalia catapa*, *Terminalia mantally*, *Delbajia sisso*, *Adansonia digitata*, *Syzygium guinensis*, *Khaya sengalensis*, *Azadirachta indica*, *Gmelina arborea*, *Albizia lebbeck*, and *Araucaria columnaris* in the study green zones. 372 out of the estimated 2,095 tree species within the BUK campuses were observed to be infected with four identified mistletoe species, with *Azadirachta indica* exhibiting the highest infestation rate and *T. globiferus* prevailing as the most abundant mistletoe species. *Azadirachta indica* recorded the highest percentage of trees infestation, with *Tapinanthus globiferus* identified as the predominant mistletoe species.

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