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Comparative palynology of *Macrotermes* sp. mounds and *Vespula vulgaris* nests on the University of Lagos campus, Akoka: preliminary study

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ABSTRACT. In order to assess the environmental indicator potential of wasp nests and termite mounds, the palynomorph content of three randomly selected *Macrotermes* sp. mounds (termitaria) and two *Vespula vulgaris* nests collected on the University of Lagos campus were examined. Palynological analysis showed the presence of 298 well-preserved palynomorphs showing characteristic morphological features. The recovered palynomorphs included pollen, pteridophyte spores and fungal spores, along with insect parts (106), diatoms (7) and a protist (1). The pollen assemblage of termite mounds comprised 78 pollen and pteridophyte spores, with Poaceae and Arecaceae pollen as dominants. In the wasp nest the pollen assemblage comprised 28 pollen and spore taxa, with Poaceae and Arecaceae pollen also dominant. Both mounds and nests had, besides diatoms, six pollen and spore taxa: Poaceae, Amaranthaceae, Pteridophyte spores, Arecaceae, *Raffia* sp. and *Rhizophora* sp. Vegetational grouping of the recovered pollen and spores indicated five phytoecological groups: secondary forest, mangrove swamp forest, freshwater, open vegetation and Poaceae. In statistical analyses, termite mounds had a higher species richness value (2.08 as compared to 1.99 from the wasp nests), while the wasp nests had a higher species diversity value (0.997 as compared to 0.845 from the termite mounds). Pollen analyses of the termite mounds and wasp nests suggest that both could be useful tools in environmental studies. This is the first attempt to evaluate the potential of termite mounds and wasps nest as natural pollen accumulators in Nigeria. The results suggest new possibilities for the use of the pollen records preserved in termite mounds and wasp nests for environmental studies.

KEYWORDS: Palynomorphs, termite mounds, wasp nests, environmental studies, Lagos

INTRODUCTION

Termites and wasps are social insects of vast economic, medicinal and ecological importance (Rozzanna et al. 2015). They can be found in the tropics and temperate regions. Both insects aid ecosystem engineering (Folgarait 1998). They are destructive and can be regarded as pests (Malaka 2016) but also serve nutritional purposes for humans (Alamu et al. 2013). Termites belong to the order Isoptera and live in woods or soils. Ten percent of all animal biomass in the tropics is from termites (Arnold 2017). There are about 3100 species of living and fossil species of termites (Krishna et al. 2013).

Africa has the highest termite diversity, with more than 1000 species (Arnold 2017). The

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vegetation type and land use of an area determine the impact of termites on soil processes (Bruno et al. 2001). This is because termites reengineer soil physical and chemical properties during feeding and mound construction. Termite mounds appear in areas with semi-deciduous vegetation (Oliveira et al. 2014). Kambhampati and Eggleton (2000) recognized seven families, but Krishna et al. (2013) has since updated information about this insect family. Nine families are now recognized: *Mastotermitidae*, *Kalotermitidae*, *Rhinotermitiae*, *Hodotermitidae*, *Termopsidae*, *Serritermitidae* (Noirot 1970), *Stolotermitidae*, *Stylotermitidae* and *Archotermopsidae*.

Generally, termites feed on detritus materials, although they can sometimes feed on plastics, paper and drywall. The difference in the shape and size of termite mounds is determined by the type of species responsible for the mound and by the surrounding environment (Lee & Wood 1971). During the process of constructing mounds and carrying out their daily tasks, termites intentionally or unintentionally collect pollen and spores, tissues and organic debris over the long range of the foraging area. The cellulosic materials are then transported to mounds and subjected to intensive degradation by the action of certain bacteria, protozoa or a few fungi, which live in the gut of the termite. In this way, pollen and spores are trapped inside the mounds (Arnold 2017). At the University of Lagos, two families (Rhinotermitidae, Termitidae), six subfamilies (Rhinotermitinae, Amitermitinae, Macrotermitinae, Nasutitermitinae, Termitinae, Microcerotermitinae) and seven genera are present, with members of the genus *Macrotermes* being the most dominant, constituting 40% of the total number of species on the Akoka campus (Kemabonta & Balogun 2014).

Wasp is a general term used to refer to a group of related insects of the order Hymenoptera (Peters et al. 2017). Certain wasps are solitary; that is, one nest is inhabited by one adult female wasp. As social insects, wasps are beneficial insects because they also pollinate plants, although much less than bees do (Hahn et al. 2015). Wasp nests are constructed mainly by foundress queens. Studies of the behaviour of two *Vespula* sp. with respect to their nest construction and foraging for plant fibre, prey, honey and water showed that queens concentrated on nest construction, foraging, ovipositing, sanitation and feeding of larvae. They carry out ovipositing as soon as the workers emerge (Akre et al. 1976). According to WaspBane (2014), wasps require a massive amount of energy on account of their anatomy and the pattern in which they fly. Hence, adult wasps feed on liquid foods such as nectar which are sugary.

Funch (1985) remarked that termites do not recycle the material used in constructing their mounds. This remark informed the suggestion of Oliveira et al. (2014) that it should be possible to make paleoecological deductions from studying termite mounds over changing periods or seasons. The same suggestion was applied to wasp nests. Both social insects have played important roles in agriculture, medicine and ecology. New research has shown that termite mounds and wasp nests have the potential to serve as important sources of data for paleopalynological studies (Rozzanna et al. 2015). To further test this possibility we carried out a palynological study of three termite mounds and two wasp nests.

METHODS

The University of Lagos occupies 802 acres of land in the town of Akoka in the north-eastern region of Yaba, Lagos, and is surrounded by the Lagos Lagoon. It is located in the western part of Lagos State (20°50′N, 30°50′E). The total area occupied by the University of Lagos is ca 8194.93 m^2, ca 21% of which is estimated to represent conserved wetland (Nwankwo et al. 2003). The region experiences two rainy seasons (May to July, October to November) and dry seasons (December to March, August to September). The vegetation consists of humid, semi-deciduous wetland and lowland rainforest (Dibog et al. 1998), and is constantly being depleted as new structures are erected.

Examples of some common plants having different growth forms which inhabit different sub-vegetation zones within the Akoka campus of the University of Lagos are *Albizzia zygia* (DC.) J.F. Macbr., *Anthocleista vogelii* Planch., *Avicennia germinans* (L.) L., *Azadirachta indica* A. Juss., *Bombax buonopozense* P.Beauv., *Elaeis guineensis* Jacq., *Cassia fistula* L., *Senna alata* (L.) Roxb., *Terminalia catappa* L., *Tectona grandis* L.f., *Raphia hookeri* G. Mann & H. Wendl., *Bambusa vulgaris* Schrad., *Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg., *Rhizophora* sp., *Mussaenda poilta* Hiern, *Paspalum vaginatum* Sw. and *Delonix regia* (Hook.) Raf. (Nodza et al. 2014).

Termite mounds were collected randomly from three different locations along Indomie Bridge, and two wasp nests were collected from two points in the Botanical Garden of the University (Fig. 1, Tab. 1).

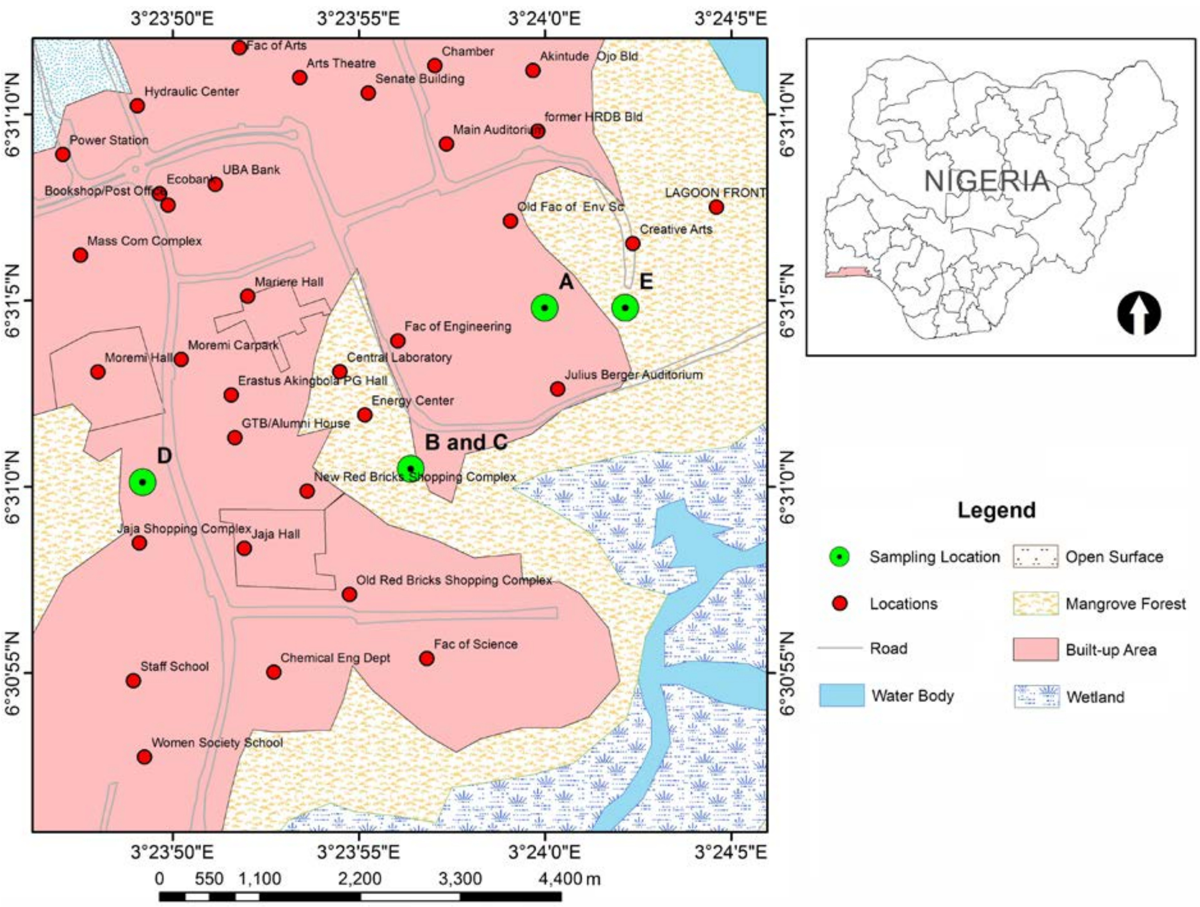

Fig. 1. Map showing points of sample collection

The nests and the mounds were in roof spaces along the Indomie bridge and under sheds in the Botanical Garden. These were then scrapped and bagged in preparation for analysis. Sub-samples from the mounds and nests were collected and subjected to standard palynological procedures described by Erdtman (1960). The resulting residue was stored in 0.2 ml glycerine. With a 10 µl micropipette, 10 µl of each residue was mounted on microslides and covered with a coverslip. Nail polish was used to seal the coverslip edges. The material was observed with an Olympus CH-2 binocular microscope. Slides were duplicated in order to ensure maximum recovery of pollen diversity.

Palynomorphs were identified using published atlases (Sowunmi 1973, 1995, Roubik & Moreno 1991, Gosling et al. 2013, Adeonipekun et al. 2015) and reference slides from the Palaeobotany/Palynology Laboratory of the Department of Botany, University of Lagos. Wasp and termite species were identified in the Department of Zoology, University of Lagos.

STATISTICAL ANALYSIS

Species richness and diversity values of palynomorphs and diatoms within *Macrotermes* sp. mounds and *Vespula vulgaris* nests were calculated. The Shannon-Wiener index (H') was used in calculating species richness. Diversity was calculated using the Simpson index (D'). The Shannon-Wiener index was calculated using the formula:

$$H = -\Sigma\ (Pi\ In\ Pi)$$

where P is the proportion of individuals found in the ith species, and In is the natural logarithm.

The Simpson Index was calculated using the formula:

$$D = 1 - \frac{\Sigma n\ (n-1)}{N(N-1)}$$

where n is the number of individuals of each species, and N is the total number of entities in the dataset (Kemabonta & Aderemi 2014).

Table 1. Sampling locations of termite mounds and wasp nests collected at the University of Lagos

Samples	Location	Geo-Coordinates	Insect/Materials	Colour
A	Botanical Garden 1	06°31.08′N; 03°24.04′E	Wasp/Soil	Grey
B	Indomie Bridge 1	06°31.01′N; 03°23.95′E	Termite/Wood	Whitish brown
C	Indomie Bridge 2	06°31.01′N; 03°23.95′E	Termite/Wood	Brown
D	Indomie Bridge 3	06°31.00′N; 03°23.83′E	Termite/Wood	Deep brown
E	Botanical Garden 2	06°31.08′N; 03°24.04′E	Wasp/Soil	Yellow

RESULTS

TOTAL PALYNOMORPHS RECOVERED

Pollen, spores and other palynomorphs were found in the studied mounds and nests. A total of 298 palynomorphs were recovered. The pollen and spores were well preserved and showed characteristic morphological features. Eight of the 98 recovered pollen types were unidentified. Seventeen spore types were recovered. In terms of diversity, nine types of pollen, three types of pteridophyte spores and three diatom species were recovered. Fungal spores were the most abundant palynomorphs, followed by pollen grains and then insect parts. Other palynomorphs including pteridophyte spores were less abundant (Fig. 2).

VEGETATION DIVERSITY OF RECOVERED PALYNOMORPHS

We categorized the palynomorphs into phytoecological groups. Of the recovered palynomorphs, all grass pollen was grouped together as Poaceae. Poaceae and Amaranthaceae families represent the open vegetation group (Fig. 4). Pollen of Arecaceae, Cyperaceae, *Raffia* sp. and *Nymphaea lotus*, and spores of *Nephrolepis biserrata*, Monolete and Trilete spore types represent the freshwater and freshwater swamp forest vegetation group. *Rhizophora* sp. was the only mangrove pollen recovered. Pollen of *Cleistopholis patens*, *Senna* sp. and Euphorbiaceae represent the secondary lowland rainforest group.

Pollen of freshwater taxa was the most abundant palynomorph recovered from all samples analysed (Fig. 4). Poaceae and Arecaceae (*Raffia*) families dominated in high proportions.

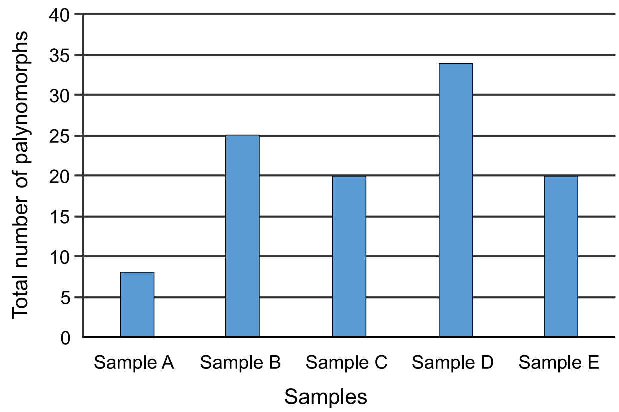

Fig. 3. Total number of pollen and spores, including diatoms, recovered from each sample

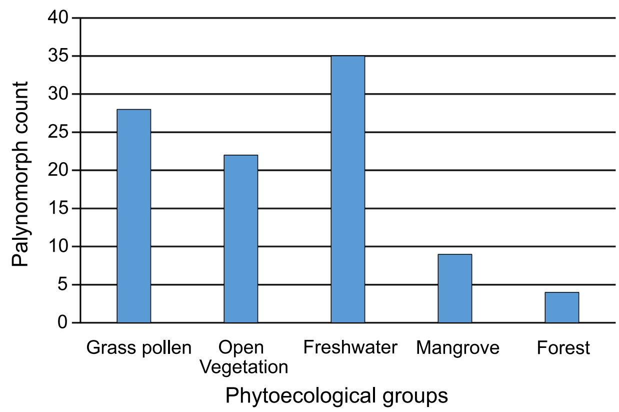

Fig. 4. Proportions of phytoecological groups of recovered palynomorphs

TERMITE MOUNDS VERSUS WASP NESTS

Total palynomorph content

Termite mounds contained higher numbers of palynomorphs (Fig. 5). Sixty-four percent of the total palynomorphs recovered came from termite mounds, and 36% came from the wasp nests.

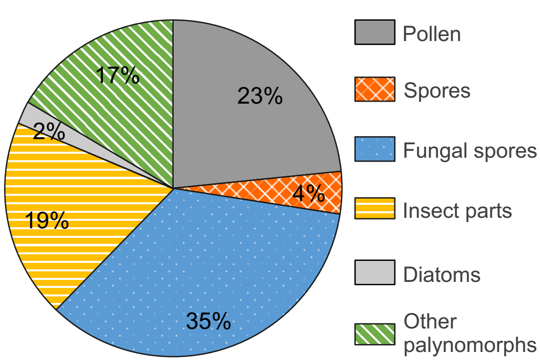

Fig. 2. Diversity of total palynomorphs and diatom frustules recovered

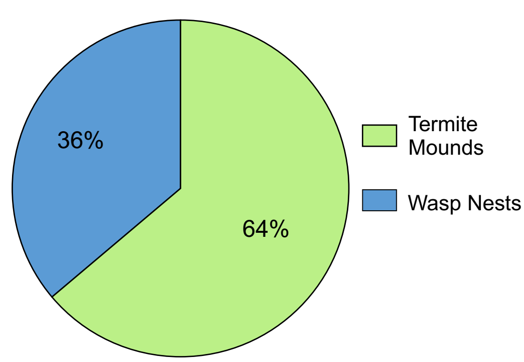

Fig. 5. Comparison between total palynomorphs recovered from termite mounds and wasp nests

Phytoecological groups found in termite mounds versus wasp nests

Five major phytoecological groups were represented in both types of sample, with freshwater and grass pollen dominating (Figs 6, 7).

Species composition

Seven types of palynomorphs were present exclusively in the termite mounds, one type was present only in the wasp nests, and seven types were common to both mounds and nests (Fig. 8).

Fungal spore content

Seventy-nine percent of the 145 fungal spores recovered were from *Macrotermes* sp. mounds, and 21% came from *Vespula vulgaris* nests (Fig. 9).

Species richness and diversity of palynomorphs in termite mounds and wasp nests

Seventy-seven palynomorphs were recovered from termite mounds as compared to 30

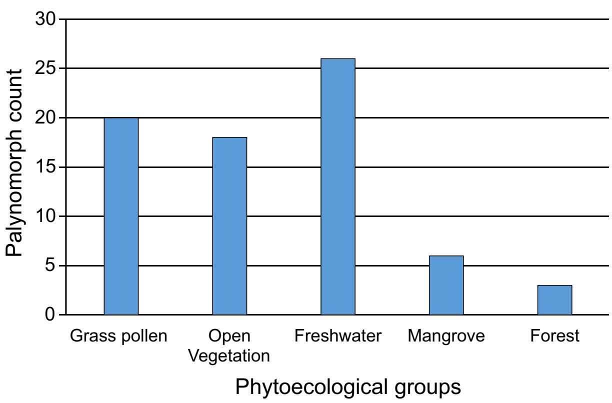

Fig. 6. Phytoecological groups of recovered palynomorphs from *Vespula vulgaris* nests

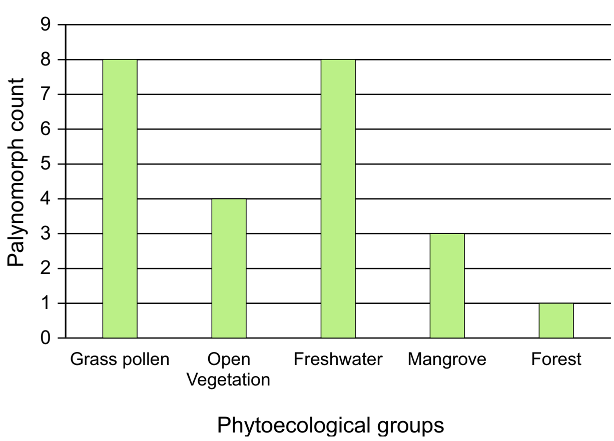

Fig. 7. Phytoecological groups of recovered palynomorphs from *Macrotermes* sp. mounds

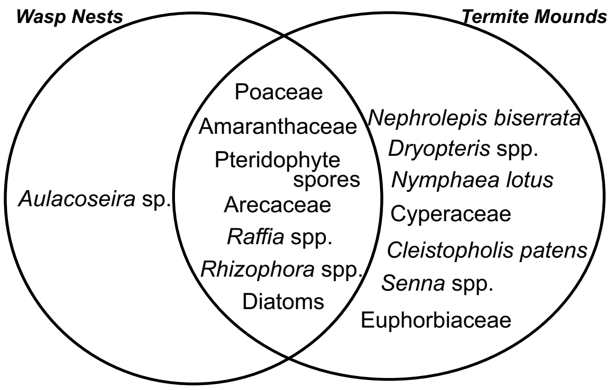

Fig. 8. Pollen types present in termite mounds and wasp nests from the University of Lagos, Nigeria. * Intersection – pollen types shared by both samples. Modified after (Oliveira et al. 2014)

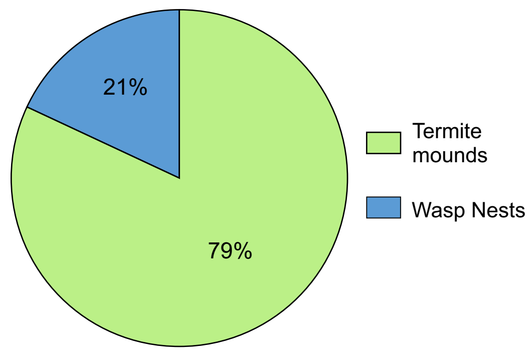

Fig. 9. Fungal spores contents in termite mound and wasp nest

recovered from wasp nests. Species diversity analysis of the wasp nests gave a D' value of 0.8533; for termite mounds the D' value was lower at 0.8339. Species richness (at 95% confidence interval) was also lower in the termite mounds (H'= 2.08) as compared to the wasp nests (H'= 2.10). Poaceae and Arecaceae pollen were the most abundant and most widely distributed palynomorphs, while spores of *Nephrolepis biserrata* and *Dryopteris* sp. (including pollen of *Cleistopholis patens*) were poorly represented.

Analysis of the soil materials used in construction of the two wasp nests showed conspicuous differences in content of heavy metals and non-metals in the nests. The phosphate (PO_4^{3-}), magnesium (Mg), potassium (K), iron (Fe) and calcium (Ca) content of both nest samples was high. Soil material of the nest from sampling point E had greater K, Ca, Mg, and PO_4^{3-} content, while that from the other nest had higher Fe content (Tab. 4). The termite mounds were not analysed in this regard, since the building material was wood, which is cellulosic, rather than soil.

DISCUSSION

From the termite mounds and wasp nests we recovered 298 palynomorphs (Tab. 3). The recovered palynomorphs included pollen grains, pteridophyte spores, fungal spores and accessory palynomorphs (Fig. 2). The recovered pollen and spores were present in fairly sufficient quantities and most of their morphological features were visible by light microscopy. Oliveira et al. (2014) recorded low pollen recovery from analysed sediments and moss polsters of termite mounds in the Chapada Diamantina region of Bahia State, Brazil. He attributed this to exposure of the pollen and spores to oxidation. Poaceae and Arecaceae (*Raffia*) pollen gave the highest occurrence values in our study, in line with the findings of Oliveira et al. (2014).

Among the samples analysed, sample D (mound) gave the highest pollen and spore recovery, while sample A (nest) had the lowest shares of pollen and spores (Fig. 3). This may be explained by the location of the sample D mound close to a dead log in the vicinity, coupled with the availability of material in the surrounding lush vegetation.

Of the five phytoecological groups, the groups most represented were freshwater in the mounds and Poaceae in the nests (Figs 6, 7). The termite mounds yielded more palynomorphs than the wasp nests did.

Sixty-four percent of the total palynomorphs recovered were from the mounds, and 36% were from the nests (Fig. 5). This implies that the wood-constructed mounds may be a more efficient source of data for environmental studies. The work of Oliveira et al. (2014) also supports the suggestion that termite mounds generally have the potential to serve as pollen collectors. Horowitz (1992) remarked that oxidative processes damage pollen and spores in soil; hence the poor yield of palynomorphs from the *Vespula vulgaris* nests. Other environmental factors such as pH (Dimbleby 1957, 1961), redox potential (Eh) (Tschudy & Scott 1969), varying climatic conditions (Andersen 1986) and clast-pollen collisions (Catto 1985, Fall 1987) can also lead to pollen and spore degradation during transport and eventual sedimentation of the soil used in building nests (Oliveira et al. 2014).

Table 2. Species richness and diversity of palynomorphs in termite mounds and wasp nests

Species	Termite Mounds	Wasp Nests
Poaceae	20	8
Amaranthaceae	18	4
Pteridophyte spores	4	1
Nephrolepis biserrata	1	2
Dryopteris spp.	1	0
Diatom	3	2
Nymphaea lotus	2	0
Aulacoseira spp.	0	2
Arecaceae	4	5
Raffia spp.	13	2
Cyperaceae	2	0
Rhizophora spp.	6	3
Cleistopholis patens	1	0
Senna sp.	2	0
Euphorbiaceae	0	1
Total	**77**	**30**
Species Richness (H')	**0.8339**	**0.8533**
Species Diversity (D')	**2.077**	**2.099**

Nephrolepis biserrata and *Dryopteris* spores and *Nymphaea lotus*, Cyperaceae, *Cleistopholis patens*, *Senna* sp. and Euphorbiaceae pollen were recovered solely from the mounds, while *Aulacoseira* sp. was the only form present exclusively in the nests. Besides diatoms, six pollen and spore types were present in both types of sample: Poaceae, Amaranthaceae, Pteridophyte spores, Arecaceae, *Raffia* sp., and *Rhizophora* spp. (Fig. 8). WaspBane (2014) reported that social wasps feed on fallen fruits, nectar, and carrion such as dead insects. This information can help in drawing inferences about the relationship between the pollen and spores recovered from the nests and about the wasps' feeding habits. The inferred relationship from this study suggests that *Vespula vulgaris* likely fed more on Arecaceae (palm) plant parts than on Poaceae and other pollen or their parts.

The recovery of *Aulacoseira* sp. from the wasp nests shows that *Vespula vulgaris* probably obtained its food from the freshwater ecosystem; this diatom would have become incorporated into the soil that the wasps used to construct their nests. We also observed a relationship between the pollen and spores recovered from mounds and the species of wood or trees from which *Macrotermes* sp. derived cellulose, supported by the recovery of pollen of woody species such as *Senna* sp. *Rhizophora* sp., Arecaceae, *Cleistopholis patens*, and *Raffia* sp. from the mounds (Fig. 8).

However, it is still difficult to conclude that the pollen grains and spores from the *Vespula vulgaris* nests definitely reflect the feeding

Table 3. Phytoecological grouping, diatoms and accessory palynomorphs recovered from each sampling points

Palynomorphs	Sample					Total
	A	B	C	D	E	
Grass pollen						
Poaceae	3	3	6	11	5	**28**
Open vegetation						
Amaranthaceae	–	9	5	4	4	**22**
Freshwater						
Pteridophyte spores	–	3	1	1	1	**6**
Nephrolepis biserrata	–	1	–	–	–	**1**
cf. *Dryopteris* spp.	–	–	–	1	–	**1**
Arecaceae	2	3	1	1	3	**10**
Raffia spp.	–	2	3	8	2	**15**
Cyperaceae	–	–	2	–	–	**2**
Mangrove vegetation						
Rhizophora spp.	1	1	1	4	2	**9**
Lowland rainforest vegetation						
cf. *Cleistopholis patens*	–	1	–	–	–	**1**
Senna sp.	–	1	–	1	–	**2**
cf. *Euphorbiaceae*	1	–	–	–	–	**1**
Others						
Indeterminate pollen	–	2	3	2	–	**7**
Broken pollen	–	–	–	–	1	**1**
Aulacoseira spp.	–	–	–	–	2	**2**
Diatom	1	–	–	3	1	**5**
Nymphaea lotus	–	1	1	–	–	**2**
Fungal spores	15	42	38	34	16	**145**
Cf. *Alternaria* sp.	–	–	–	–	1	**1**
Fungal hyphae	11	2	–	13	17	**43**
Chitinous palynomorph	–	–	–	–	1	**1**
Insect parts	12	10	10	26	22	**80**
Insect eggs	–	–	–	–	26	**26**
Cf. Protist	1	–	–	–	–	**1**
Total	**47**	**84**	**77**	**108**	**103**	

habits of the wasp species, because there are other ways through which pollen and spores could have been deposited in the nests. Wind could have deposited pollen and spores in the nests through dispersal from surrounding vegetation. Other possible pathways include incorporation within soil particles used for building the nests (Oliveira et al. 2014) and passive transport of pollen and spores by attachment to hairs. Palynological analysis of the guts of these two social insects will help ascertain any positive correlation between the palynomorphs found in the dwellings of *Vespula vulgaris* and *Macrotermes* sp. and their feeding habits.

The recovery of *Rhizophora* sp., monolete spores, trilete spores, *Nephrolepis biserrata*, *Dryopteris* sp., *Nymphaea lotus*, and *Aulacosera* sp. and other diatom species confirms that the wasp nests and termite mounds can be used to characterize the vegetation of a particular environment (Tab. 3). The University of Lagos is located along the Lagos Lagoon axis, covering more than one kilometre, with mangrove swamp forest vegetation (Onadeko et al. 2013). The representative palynomorphs encountered in both types of sample reflect this. The pollen and spores from the termite mounds and wasp nests exemplify the pollen rain of the locality, and can be used to study changes in the vegetation of the environment over time (Figs 6, 7).

Nobre and Aanen (2012) described a mutualistic relationship between termites and fungi: termite workers assimilate lignocellulolytic enzymes from feeding on the asexual fruiting bodies of fungi. These enzymes are mixed with their own enzymes and in some cases with bacteria, and then used in digesting foraged plant materials. This explains why there were more fungal spores in termite mounds than in wasp nests (Fig. 9). Another important reason is that termites live on dead plant material

Table 4. Metal and non-metal concentrations (mgkg^{-1}) of soil used in building wasp nests

Parameter	Soil from sampling point A	Soil from sampling point E	FEPA (1991)
Phosphorus as PO_4^{3-}	22.5	31.5	NA
Magnesium (Mg)	351.03	385.54	NA
Potassium (K)	434.23	382.78	NA
Iron (Fe)	2770.46	2625.53	19.393 ± 6.649 or (0.300 mg/l)
Calcium (Ca)	425.4	620. 5	NA
Chromium (Cr)	NT	NT	0.618 ± 0.193
Nickel (Ni)	NT	NT	0.867 ± 0.075
Copper (Cu)	NT	NT	0.600 ± 0.272
Manganese (Mn)	NT	NT	2.040 ± 1.049
Lead (Pb)	NT	NT	0.450 ± 0.598
Arsenic (As)	NT	NT	0.083 ± 0.035
Cadmium (Cd)	NT	NT	1.150 ± 0.090
Zinc (Zn)	NT	NT	0.730 ± 0.337

which hosts fungi that disperse spores into the immediate surroundings. Wasps, on the other hand, feed on living organic matter.

Wasp nests showed greater palynomorph species diversity than the termite mounds (Tab. 2). Wasps fly and pollinate a wide range of plant species, while termites do not feed on living plants or nectar but obtain their food from dead plant material (WaspBane 2014). The pollen in the mounds would have come from the surrounding vegetation and also would have been present in the peaty degraded plant material used by the termites, explaining the greater palynomorph species richness of the termite mounds.

The mineral profile of the two wasp nests showed high concentrations of iron (Fe), calcium (Ca), magnesium (Mg), potassium (K), and phosphate (PO_4^{3-}) (Tab. 4). The acceptable average concentrations of some heavy metals according to the Nigerian Federal Environmental Protection Agency (FEPA 1991 Act) were published by Ezejiofor et al. (2013). The Fe content of soil from both nests was very high (2770.46 mg/kg in sample A; 2625.53 mg/kg in sample B) and clearly above the FEPA limit for Fe in sediments (19.393 ± 6.649 mg/kg). This shows that the environments from which the wasps got the soils for building their nests were highly polluted. The high Fe concentrations in the soil samples are at least partly responsible for the poor yields of palynomorphs from the nests, due to more intense oxidative processes which degraded the pollen grains and spores (Fig. 5). The nest with higher Fe content had lower pollen and pteridophyte spore recovery (8) than the nest with lower Fe content (ca 20 pollen and pteridophyte spores). This difference is not great but the higher recovery (Fig. 2) shows that slight variation of Fe content affects the preservation of pollen and spores.

The soil from the nest at sampling point A had calcium (Ca) content of 425.4 mg/kg, while that from sampling point E had Ca content of 620.5 mg/kg. This appreciable difference (Tab. 3) was accompanied by a higher share of insect parts in the nest from sampling point E. Calcium is a vital component of the insect exoskeleton, occurring as calcium carbonate and providing mechanical strength (Harrington et al. 1998). The relatively high Ca concentrations may be due to the higher number of insect parts (including wings, appendages, eggs and antennae of dead insects) in both of those samples. Another possible reason could be the peculiar climatic conditions of the tropics. Aubert and Pinta (1977) suggested that the climatic conditions in tropical zones can raise the Ca content of soil due to the interaction of climate factors with ferralitic soil.

There is not much information about the average concentrations of Mg, K, and PO_4^{3-} in Nigerian soils but some are available from the World Health Organization and the Nigerian Federal Environmental Protection Agency (Ezejiofor et al. 2013). In soils from densely populated and industrialized areas in Aba, Ezejiofor et al. (2013) recorded maximum concentrations of Fe at 853 mg/kg, Mg at 108.63 mg/kg and K at 88.66 mg/kg. Anyakora et al. (2013) reported a maximum Fe concentration of 2216 mg/kg in soils from heavily industrialized areas of Lagos State. These levels and those in other research are below the levels we recorded in the soil samples from the nests, which reflect high contamination of the environment from which the wasps obtained the soils to build their nests. We cannot say for certain whether other processes were responsible for the high levels of Mg, K and PO_4^{3-}, aside from fact that these elements occur naturally in the earth's crust. Severe contamination due to metallurgical activity and other anthropogenic factors within the University may also have led to the increased concentrations of these metals and non-metals. We were unable to find a basis for correlating the increased concentrations of Mg, K, and PO_4^{3-} with the palynomorph or insect part yields. Only Fe is known to be directly involved in oxidative degradation of palynomorphs. Further research will be carried out to examine this correlation. The method of sample preparation did not affect the palynomorphs (Oliveira et al. 2014), as they were visible and retained most of their morphological features. The observed differences between the pollen assemblages from soil sediments of the *Vespula vulgaris* nests and from the *Macrotermes* sp. wood-built mounds may be linked to the high Fe concentration in the soils (Tab. 4) which resulted in poor pollen preservation in the nests. To some extent this limits their potential use as a tool for environmental studies.

In a study of palynomorphs recovered from termite mounds made of soil, McGlone and Wilmshurst (2005) found palynomorphs in low quantities and poorly preserved. Social insect nests and mounds made of soil are not generally good for preserving palynomorphs, due to rapid oxidative processes resulting from high Fe content (Traverse 2008). Our work bears this out (Figs 1–9). On the other hand, termite mounds made from wood, abundant in cellulose, provide an oxidation-free environment for pollen and spore preservation.

CONCLUSION

Our comparative analysis of palynomorphs recovered from *Vespula vulgaris* nests made from soil and from *Macrotermes* sp. mounds made from wood showed that the latter contained more palynomorphs and are a better source of palynomorphs, though both nests and mounds could be useful tools in environmental studies. This is the first attempt to assess the potential of termite mounds and wasp nests as natural pollen accumulators in Nigeria. The results suggest new possibilities for the use of the pollen records preserved in termite mounds and wasp nests for environmental research. They should prove useful in the study of pollen rain, the character of vegetation, climatic phases and possibly the paleoecology of an area. Social insect mounds and nests constructed of soil poorly preserve palynomorphs, due to exposure to oxidative conditions. Fungal elements recovered from samples may be a good source of information on the diet or digestive processes of these social insects.

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