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DIVERSITY AND DENSITY OF TERMITE MOUNDS IN BHADRACHALAM FOREST REGION, ANDHRA PRADESH

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ABSTRACT
To determine and quantify the diversity and density of mound-building termites, we were observed Bhadrachalam forest region located at Khammam district, Andhra Pradesh, India. In the present study we observed that the termite fauna was enriched with 7 species, belonging to 2 genera of family Termitidae. We investigated chemical and physical properties of termite mound at forest region. Their effects on the development of native plant species. Carbon, Phosphorus, Potassium levels in the termite mounds were significantly elevated by 1.16 pap, 12.63 kg/acre and 15.63 kg/acre respectively. While termites mound significant differences more in Manganese, Iron, Copper, Zinc, Sulphur and pH concentration was observed. Average density of termite mounds of different study areas was studied.

INTRODUCTION

Termites are social insects of the order Isoptera with about 3,000 known species, of which 75% are classified as soil-feeding termites. The diet of soil-feeding termites consists of no-cellular organic material mixed with clay minerals. Their gut is formed by five compartments that present rising gradients of pH, up to 12.5, and different status of oxygen and hydrogen (Brune *et al.,* 1995; Brune and Kuhl, 1996; Donovan *et al.,* 2001; Eggleton and Tayasu, 2001). These characteristics are certainly important and may effectively contribute to mound soil chemical and physical characteristics. Termites are recognized as "ecosystem engineers" (Dangerfield et *al.,* 1998) because they promote soil transformations by disturbance processes. They collect particles from different soil depths and deposit them in mounds, so that contents of organic C, clay and nutrients, pH and microbial population increase higher in termite mounds in relation to adjacent soils (Lal, 1988; Black and Okwakol, 1997; Holt, 1998; Ohkuma, 2003). The accumulated material is later redistributed by erosion causing changes in soil microstructure and fertility (Lee and Wood, 1971; Black and Okwakol, 1997; Dangerfield *et al.,* 1998; Jungerius *et al.,* 1999; Shaefer, 2001). Termites also build a vast network of galleries that increase soil porosity and water infiltration (Mando and Stroosnijder, 1999; Leónard and Rajot, 2001) and these galleries may be filled up with topsoil after rainfalls, contributing to the process of formation of latosols (Shaefer, 2001). Clay content in termite mounds is usually 20% higher than in nearby soils, but it is not known whether termites select particles or soil undergoes a physical fractioning through the gut, or 2:1 clay minerals are modified to more expansible forms (Lee and Wood, 1971; Donovan *et al.,* 2001; Jouquet *et al.,* 2002a; 2002b). It is possible that clay minerals are altered as soil particles are carried in their mouths or in their gut.

MATERIALS AND METHODS

The study was carried out in the Bhadrachalam forest region, Khammam. The climate is semi – arid tropical with three well marked seasons such as summer, rain and winter season per year. The summer between Februarys to middle of June, followed by monsoon extending from middle of June to September. The winter season extend from middle of the November to middle of the February. Quantitative survey of the termites in Bhadrachalam forest region was conducted in all season from 2008–2010. Due to the variability in size and location of the termite colonies a quadrate method was used to quantify the abundance of subterranean termite colonies in forest areas.

Termite mound soil sampling

The *O. obesus* mounds were cut opened by digging the mound soil sampling was carryout at different ranging from top of the mound to the bottom and mixed it as single sample. The adjacent surrounding surface soil that was unaffected by termite activity was also sampled within 2 mts. from the base of the mound.

Termite earthen foraging sheet sampling

The *O. obesus* earthen foraging sheet covered on the trunk of different trees such as *Terminelia tomentosa, Bridelia retusa, Maduca indica, Morinde pubscens, Anacardium occidentale* and *Tectona grandis* were collected. In order to assess the nutrient content of the earthen foraging sheet on trees in relation to that of the mound soil and adjacent of the *O.obesus* mounds.

Analysis of the soil samples

All the collected termite related soil samples *i.e.* mound soil of different parts of the mound of *O.obesus,* adjacent soil and the earthen sheet on the trunk of different trees soil were air dried and passed through a 2mm sieve for particle size analysis and through 0.5 and 2.0 mm sieve for physical and chemical analysis. The analysis was carried out at the soil chemistry laboratory of the Acharya N.G. Ranga Agricultural Research Station, Warangal following standard methods (Jackson, 1976).

The standardized transect sampling method

To determine the density of mounds, three different forest sites were selected viz., Bhadrachalam, Dummagudem, Mulkalapally. Five transects used to sample vegetation and mounds. Each transect was approximately one hectare. The mounds were directly counted from each transect (Pomeroy 1977, 1978) and the samples of termite workers and soldiers were collected from each mound and infested trees for identification.

RESULTS

Various termite species were collected from different trees, mounds, the fallen tree pieces of logs, dead tree stumps, twigs of more than 2cm in diameter (woody debris) on the forest floor in the Bhadrachalam forest area. They are belonging to two families viz., Termitidae and Rhinotermitidae. In Termitidae *Odontotermes boveni* (Thakur), *Odontotermes brunneus* (Hagen), *Odontotermes feae* (Wasmann), *Odontotermes guptai* (Roonwal and Bose), *Odontotermes indicus* (Thakur), *Odontotermes obesus* (Rambar), *Odontotermes redemanni* (Wasmann), *Odontotermes wallonensis* (Wasmann), *Macrotermes convulsionaries* (Konig), M*icrocerетermes beesoni* (snyder) and *Microtermes obesi* (Wasmann) and in Rhinotermitidae, *Coptotermes hemi* (Wasmann) *and Heterotermes indicola* (Wasmann), (Table 1).

Distribution of termite mounds in study area

Termite mound survey: In order to study termite mounds five transects were surveyed in Bhadrachalam forest area and identified the following termite species.

***Odontotermes brunneus* (Hagen)**

Its mounds are distributed throughout the study areas. The mounds are low, dome shaped, broad – based (diameter upto 5m) earthen mounds and 1m height, surface, rather rugose with several large external holes leading to tunnels which join the underground galleries crises – cross. Dome shaped mounds are 1m high, surface highly rugose and with small, blind, papillate projections (5 – 8cm high) and small holes (2 – 3cm) in diameters leading to blind tunnels .These two types of mounds occur within the forest regions were observed.

Table 1: Diversity of termite species recorded in the Bhadrachalam forest region.

Family	Sub family	Name of the Species
Termitidae	Macrotermitinae	*Odontotermes brunneus* (Hagen) *Odontotermes feae* (Wasmann) *Odontotermes guptai* (Roonwal and Bose) *Odontotermes obesus* (Rambur) *Odontotermes redemanni* (Wasmann) *Odontotermes wallonensis* (Wasmann) *Macrotermes convulsionaries* (Konig)

***Odontotermes feae* (Wasmann)**

O. feae have massive subterranean nests, up to 2.5 meter in diameter, which go down about a meter underground. They are irregularly dome shaped earthen mounds. It has several mound holes open at surface and lead into vaults for the lodgment of fungus-combs, the royal chamber lies centrally just below ground level.

Odontotermes obesus

(Rambur) the most common mound building termite of Bhadrachalam forest region which shows a most remarkable range of variations in mature mound structure, from the tall. Two types of mounds have been found in the Bhadrachalam forest. Type -1: Tall, buttressed unilocular, containing a large fungus comb and few small ones. Type –II Low broad-based non-buttressed dome shaped or irregular – shaped with a few holes which may be closed (Figs. 1 to 6) and different size of *O. obesus* mounds are sporadically distributed in the forest.

Odontotermes redemanni

(Wasmann): It is a common mound building termite of Bhadrachalam forest region. The mounds are large, dome-shaped to conical in shape and next extend underground also to depth of about 3m massive structure, reaching to a height of about 1/2m above the ground. There are many openings on surface of the mound and these lead in to chimney like shaft to the main nest. The nest inside consists of a number of chambers which contain the fungus combs. The royal cell is about 7-12 cm in length and is situated near a large central chamber.

Normally only a single royal pair is found in the royal cell but sometimes more than one queens and more than one king have been recorded.

Odontotermes wallonensis

(Wasmann): This species is common in Bhadrachalam forest region the mound of *O. wallonensis* are dome shaped, broad-based (diameter up to 4 m) earthen mounds a showed sub conical 50 cm high, with smooth outs surface without papillae, projections, irregularly shaped structure of earth having a number of opening chimneys leading deep in to mound internally the mounds have chambers with fungus combs. The fungus combs are above arranged in tiers one over the other. *O. wallonensis* make massive subterranean nests up to 2-5m in diameter which go down above a meter underground (Roonwal, 1970) the royal chamber lies much below the ground level and may have more than one queen. The fungus combs are round or large, folksy.

Macrotermes convulsionaries

Small termite mounds constructed by *Macrotermes convulsionaries*. These termites have evolved a construction technique which extends the thermo-regulatory these structures respond and adapt to constantly changing internal conditions and external weather influences to maintain

Figure 1: Photograph showing mound of *Odontotermes wallonensis*

Figure 2: Photograph showing mound of *Odontotermes feae*

Figure 3: Photograph showing mound of *Odontotermes obesus*

Figure 4: Photograph showing mound of *Odontotermes redemanni*.

Figure 5: Photograph showing mounds of *Macrotermes convulsionaries*.

Figure 6: Photograph showing mound of *Odontotermes brunneus*

equilibrium in the colony. *Macrotermes convulsionaries* mound is a typical unclosed mound.

Different termite species mounds density was presented in Table 2. The average density of *Odontotermes obesus* mounds was (0.31/ha) followed by *O. brunneus* (0.21/ha) *Macrotermes convulsionaries* (0.18/ha), *O. redemanni* (0.12/ha), *O. wallonensis* (0.10/ha), *O. feae* (0.04/ha) and lowest density was recorded *O. guptai* (0.02/ha) in Bhadrachalam north forest region. However, their distribution was not consistent. In case of Dummugudem forest region *O. obesus* (0.26/ha), followed by *Macrotermes convulsionaries* (0.20/ha), *O. brunneus* (0.18/ha), *O. redemanni* (0.14/ha), *O. wallonensis* (0.12/ha), *O. feae* (0.06/ha) *O.guptai* (0.04/ha). The density of mounds distribution in Mulakalapally forest region presented in Table 2. The *O. obesus* (0.28/ha), followed by *O. brunneus* (0.19/ha) *Macrotermes convulsionaries* (0.17/ha) *O. redemanni* (0.12 /ha) *O. wallonensis* (0.11/ha), *O. feae* (0.06/ha) and lowest density was represented by *O. guptai* (0.04/h) the density and distribution of termite mounds associated with soil texture.

Table 2: Estimated density of mounds different termites in three study areas

Species	Density of mounds per ha(Bcm)	Density of mounds per ha(Dgm)	Density of mo undsper ha (M. pally)
O. obesus	0.31	0.26	0.28
O. brunneus	0.21	0.18	0.19
O. redemanni	0.12	0.14	0.12
O. wallonensis	0.10	0.12	0.11
O. feae	0.04	0.06	0.06
O. guptai	0.02	0.04	0.04
M.convulsionaries	0.18	0.20	0.17
Total	**0.98**	**1.00**	**0.97**

Bcm- Bhadrachalam; Dgm-Dummugudem; M.pally-Mulakalapally

Chemical properties of *O. obesus* mound soil, soil surrounding of the mound and earthen sheet soil on trees are presented in Table 3 in Bhadrachalam north forest region.

Zinc: The mounds soils of the *O. obesus* contained more Zn (0.53 ± 0.41), over that of soil surrounding of the mound (0.36 ± 0.12) and earthen sheet soil of trees (0.28 ± 0.10).The results are shown that zinc content was more in the mound soil than that of the soil of surrounding of the mound and earthen sheet soil.

Iron: The mounds soil of *O. obesus* contained more Iron (427.13 ± 17.60), than that of soil surrounding of mound (38.51 ± 4.75) and earthen foraging sheet soil on the trunk was (0.87 ± 0.11) the results have showed and that Iron was found more in mound soil than the other two samples.

Manganese: The mean value of Mn in the mound soil was (37.43 ± 4.42), soil surrounding of mound (38.22 ± 7.83) and

Table 3: Chemical composition of *O. obesus* mound soil surrounding of mound soil and earthen sheet soil analysis in Bhadrachalam north forest region

Elements	Mound soil	Surrounding soil	Earthen sheet soil
Zinc (ppm)	0.53 ± 0.41	0.36 ± 0.12	0.28 ± 0.10
Iron (ppm)	427.13 ± 317.60	38.51 ± 4.75	0.87 ± 0.11
Mn (ppm)	37.43 ± 4.42	38.22 ± 7.83	34.92 ± 11.66
Cu (ppm)	5.40 ± 14.15	3.55 ± 8.57	6.08 ± 14.61
C (%)	1.16 ± 0.113	0.59 ± 0.017	0.78 ± 0.045
P (Kg/acre)	12.63 ± 2.383	9.75 ± 1.980	20.75 ± 1.410
S (ppm)	5.68 ± 0.785	5.68 ± 0.760	7.70 ± 0.841
K (Kg/acre)	151.63 ± 22.195	194.25 ± 25.162	212.88 ± 16.828
pH (ppm)	7.43 ± 0.067	6.67 ± 0.201	7.39 ± 0.130

earthen foraging sheet soil on the trunk (34.92 ± 11.6), the content of Mn was highest in soil surrounding of the mound compared to that of the mound soil and earthen sheet soil.

Copper: The earthen sheet soil contained more Copper (6.08 ± 4.61) that of mound soil (5.4 ± 14.15) and soil surrounding of the mound (3.55 ± 8.57). The results have shown that the content of Copper was found more in earthen sheet soil than the soil of surrounding of mound and the mound soil.

Carbon: The mound soil of *O. obesus* contained and more Carbon (1.16 ± 0.113), than that of soil surrounding of mound (0.59 ± 0.017) and earthen sheet soil (0.78 ± 0.45). The results indicating that the amount of C content was more in mound soil compared to that of other two soil samples.

Phosphorus: The mound soil sample of *O. obesus* contained less (12.63 ± 2.383) over that of soil earthen sheet soil (20.75 ± 1.41) and more that of adjacent soil (9.75 ± 1.980). The results have shown that the content was more in earthen sheet soil compared to that of the mound soil and soil surrounding of the mound of *O.obesus*.

Sulphur: The mean value of Sulphur in the mound soil was (5.68 ± 0.785) and soil surrounding of the mound (5.68 ± 0.760) and earthen sheet soil (7.92 ± 0.636) .The results showed higher Sulphar in the mound soil compared to that of soil surrounding of the mound and earthen sheet soil of *O. obesus*

Potassium: The mound soil of *O. obesus* contained less K (151.63 ± 22.19 Kg/ha) than the soil surrounding of the mound (194.25 ± 25.16) and earthen sheet soil (212.88 ± 16.8). The results shown that earthen sheet foraging soil contain more potassium content compared to that of mound soil and soil surrounding of the mound of *O. obesus*.

pH: The mound soil samples constructed by *O. obesus* contained higher pH values (7.43 ± 0.07) over that of normal soils (6.67 ± 2.01) and earthen sheet soil (7.39 ± 1.30)

Physical properties of soil

Mechanical composition was determined by the international pipettee method (Piper, 1950) and the percentage of coarse gravel, fine gravel, coarse sand; fine sand, silt and clay were calculated.

Texture properties: The texture analysis of all the samples were carried out and the percentage of sand both coarse and fine, clay and silt in the samples were determined.

Colour: Colour of the mound soil differed from those of near by soils. Mound soil was found darker than the surrounding soil and earthen sheet soil.

Particle size distribution

Coarse and particles: The percentage of coarse and fine sand was less in termite soil than surrounding soil.

Fine sand particles: The mound soil of *O. obesus* contained less fine sand compared to that of adjacent soil.

Clay: Mounds constructed by *O. obesus* contained more clay compared to that of the surrounding soil.

Silt: The mound soil of *O. obesus* contained equal percentage of silt to that of normal soil.

Chemical properties

Chemical properties of mound soil, soil surrounding of mound soil and earthen sheet soil on trees are presented in (Table 3) in Bhadrachalam forest region

Zinc: The mean value of Zn in the mound soil was (0.31 ± 0.13); soil surrounding of the mound (0.04 ± 0.14) and earthen sheet soil of trees (0.39 ± 0.06). The results shown that zinc was found more in surrounding soil than the other two soil samples.

Iron: The mean value of Iron in the mounds soil (378.5 ± 196.7), soil surrounding of mound (36.41 ± 4.75) and earthen sheet soil (16.55 ± 5.57). The result shown that iron was found maximum in mound soil than the other two soil samples

Manganese: The mean value of Mn in mound soil (43.36 ± 6.29), soil surrounding of the mound (37.28 ± 7.37) and earthen sheet soil (38.21 ± 8.15) The Mn content was more in mound soil than the surrounding soil and earthen sheet soil.

Copper: The copper mean value in the mound soil (0.43 ± 0.31), soil surrounding of the mound (0.81 ± 0.50) and earthen sheet soil (0.58 ± 0.42) .The results indicate that the content of copper was found more in earthen sheet soil than the other two samples.

Carbon: The mean value of C in the mound soil found (0.76 ± 0.109), soil surrounding of the mound (0.81 ± 0.155) and earthen sheet soil (0.86 ± 0.042) .The results shown that the content of C is more in earthen sheet soil than the other two soil samples.

Phosphorus: The mean value of P in the mound soil (17.38 ± 1.580), soil surrounding of the mound (18.63 ± 0.084) and earthen sheet soil (23.25 ± 0.700).The content was more in earthen sheet soil than the mound soil and soil surrounding of the mound.

Sulphur: The mean value of sulphar in the mound soil (6.23 ± 0.756) and soil surrounding of the mound (6.68 ± 0.502) and earthen sheet soil (7.88 ± 0.512). The results shown that sulphar content was more in earthen sheet soil than the mound soil and soil surrounding of the mound.

Potassium: The mean value of K in the mound soil (176.25 ± 10.00) soil surrounding of the mound (178.75 ± 14.47) and earthen sheet soil (229.50 ± 11.23). The results shown that earthen sheet soil contain more potassium content then the mound soil and soil surrounding of mound. Physical properties and chemical properties of the mound soil and adjacent soil and earthen sheet soil compared in three different forest sites not showed much differences.

DISCUSSION

Seven termite species were collected from Bhadrachalam forest had known mound building termites. The ground mounds constructed by *Odontotermes* sp and *Macrotermes* and all were subterranean in Bhadrachalam forest.

Termite mounds create islands of fertility for grasses, trees and animals (Holt and Lepage 2001, Diehl *et al.,* 2005, Scott *et al*., 2006). Hence increased biodiversity within termite mounds especially important for litter inhabiting macro fauna such as

spiders and arthropods, mounds provided an environment with sufficient moisture content for soil macro fauna to survive.

Termites play a significant role in nutrient cycling. Their mounds, earthen foraging sheets and runways are modified forms and are enriched with Zn, Iron, Carbon. The darker colour of the mound suggested the presence of organic matter of the mound. (Arshad, 1981).

Overall Carbon percentage was found maximum in mound soil compared to surrounding soils and earthen sheet soil (Table 3) Harries (1949) stated that the termite consume large quantities of organic matter of woody nature for their food. Apparently they carry the digestion process to enrich the soil in organic carbon. In the present study also Carbon content was less in soil samples of surrounding soils, and earthen sheet soil. Watson (1967) reported higher values of organic carbon in the mound soil than the surrounding soil. In the present study it was found that the amount of Carbon present in termite mound soil is higher compare to that of adjacent soil earthen sheet foraging soil on trunk.

In the present investigation Phosphorus content in termite mound soil had little low than in earthen sheet soil (Table 3). Lobry, de Bruyn and Conacher (1990) findings are near with present findings. According to them in general, mound soil and earthen sheet soil containing a higher amount of P than the adjacent soil. In the present study Phosphorus content mound soil and earthen sheet soil higher than the surrounding soils.

Potassium content is less in mound soil and surrounding soil compared to that of the earthen sheet soil. Lee and Wood (1971a) stated that K content were in general of little higher in termite mound soil compared to that of adjacent soil samples. However, these present findings disagree with the Lee and Wood (1971) findings. Amount of Potassium was found significantly higher in earthen sheet soil compared to mound soil and adjacent soil.

Present study revealed that pH of (the mound soil, adjacent soil and earthen sheet soil presented in (Table 3). pH of the surrounding soil of mound was lower compared to that of mound soil but it was similar to earthen sheet soil. According to Lee and Wood (1971a) generally, the pH of soil in mounds is lower than that of the surrounding soils but the difference are small. In the present study, mound soil and earthen sheet soil had similar, but less in surrounding soils. The results indicate that mound soil and earthen sheet soil was neutral.

Zinc, Iron, Mn were found maximum in mound compared to that of surrounding soil and earthen sheet soil on trunks.

However, there is a little information in the literature to compare with these findings on nutrient contents of the earthen sheet. The findings of the present study clearly revealed the role of subterranean termites in plant nutrient cycling in the ecosystem. This is first of its kind in forest ecosystem.

Termites distribution of various castes in different parts of the mounds in this semi – arid zone of peninsular India population density of various castes in different parts of the mound of the termites *Odonototermes wallonensis* studied by Vasant kumar and Vijay kumar (2010).

The mounds are features built from subsoil taken from as much as depth of 3 meters including the composition of mound soils to be closely related to the nature of the adjacent subsoil. Termites as major bio-turbators created biogenic structures (galleries, nests, mounds, fungus mit, and chambers) that strongly influenced the physical and chemical properties of soil (Kaschu *et al.,* 2006; Jouquet *et al.,* 2007). Comparative studies of termites mound and the adjacent soils had been carried out in previous research. Kaschu *et al.* (2006), Iise *et al.* (2007) in the study of the impact of mound building termites on surface soil properties in secondary forest reported termite activities in a landscape by regulation.

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