



## **Review on Termite Mound Soil Characteristics and Agricultural Importance**

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### **Authors' contributions**

*This work was carried out in collaboration between both authors. The first author SS wrote the first draft of the manuscript. The second author AMS corrected and outlined the manuscript. Both authors read and approved the final manuscript.*

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### **ABSTRACT**

Addition of soil with various amendments to boost up the nutrient content and moisture holding capacity is necessary for improving the crop productivity. Among the various amendments, compost prepared from the crop residues attracted much attention in recent years. The crop residues used as feedstock are added with different bulking materials such as rice husk and sewage sludge. In addition to these, termite mound soil which is available in plenty in tropical countries is found to be a suitable bulking material and is added with crop residues to obtain nutrient rich compost. In this paper we reviewed researches carried out on the characteristics, microbial diversity and organic matter degrading enzymes in termite mound soil. Further, the research carried out on the characteristics of compost amended with termite mound soil and its effect on crop productivity is also reviewed with the available literature. Majority of the investigations concluded that termite mound soil possessed more microbial population with a huge array of organic matter degrading enzymes. Few studies monitored the nutrient content of the soil and water holding capacity of the soil and crop yield when termite mound soil was used as a soil amendment. Limited studies were conducted using termite mound soil as a bulking material to compost crop residues. Based on the outcome of various studies, it is understood that the termite mound soil might be used as a soil amendment to increase growth and yield of crops.

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## 1. INTRODUCTION

Soil is made up of minerals, mixed with organic matter, air, water and other organisms and covering the earth's surface. Soil is formed mainly by weathering of rocks due to the physical factors in which disintegration of rocks take place and eventually formed in to sand, silt and clay particles [1]. In addition to weathering, abrasion of rocks by water, ice and wind are the important factor in determining soil formation processes. Further, soil formation is achieved by the chemical reactions such as hydration, hydrolysis, dissolution, and redox reactions [2]. The main functions of the soil are illustrated in Fig. 1.

The key indicators of soil fertility status are acidity in surface and subsurface soil layers,

organic matter content in surface soils and clay content in subsurface soils [4]. Soil is considered as an important habitat for a wide variety of living things [5]. Further, the decomposition of soil organic matter is achieved by the collective action of soil fauna and microorganisms [6]. So the important tool for monitoring nutrient status of the soil, agriculture sustainability and environmental health is the soil fauna [7]. The soil fauna is influencing the various processes in soil including retention, breakdown, and incorporation of plant remains, nutrient cycling which in turn affect the soil structure and porosity [8]. Further, the macro fauna such as earthworms, ants and termites play an important role in increasing the soil porosity, creating macro pores, and tunnels which enables movement of water into the soil profile [9,10].



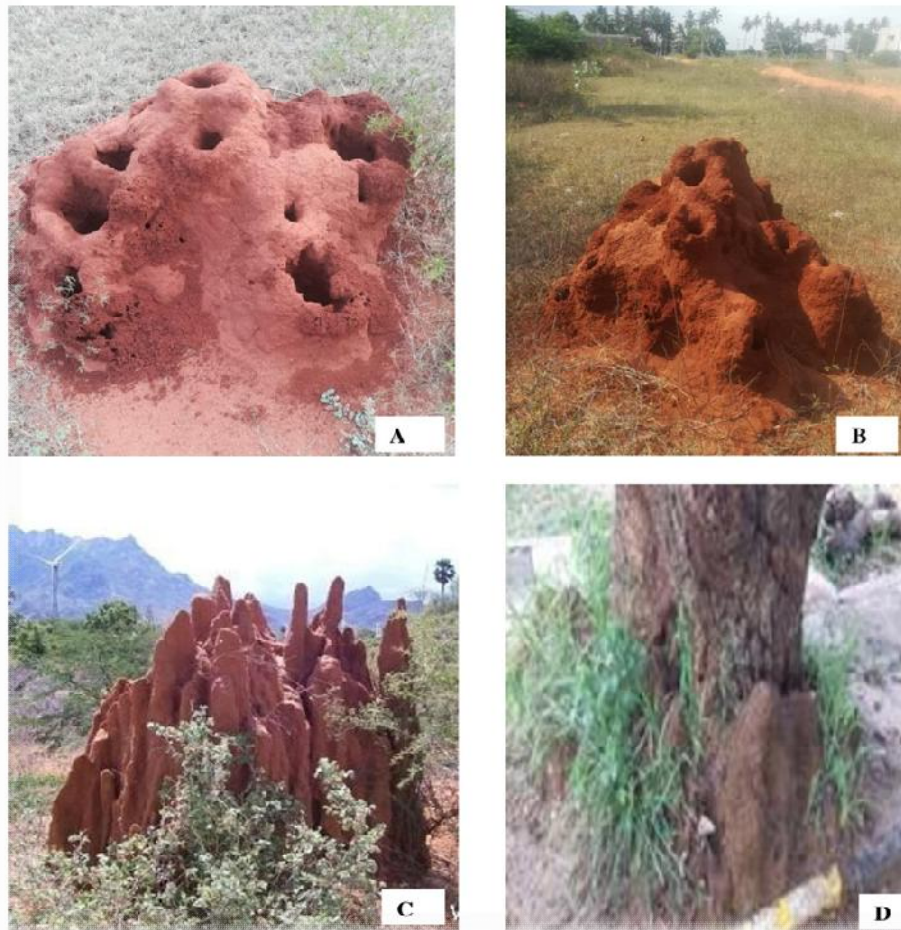
**Fig. 1. Illustration showing various functions of the soil [3]**

The epigeics (decomposes organic matter on or near the soil surface), endogeics (live in the mineral soil and feed on humus) and anecics (transfer materials between the soil and litter) are the three groups of fauna present in the soil [11]. So the termite mound soil is a niche for many microorganisms and fauna. Many reviews summarized the ecology and microbiology of termite mound soil. But the researches on utilization of termite mound soil as soil amendment to improve the nutrient content of the soil and enhance crop growth has not been reviewed yet. Hence, in this article the microorganisms and the enzymes present in termite mound soil, its role in improving crop growth and yield and utilization of termite mound soil as a bulking material for composting is reviewed.

## 2. DISTRIBUTION AND CHARACTERISTICS OF TERMITE

Termites are considered as eusocial insects and the most successful groups of insects and ubiquitous in nature [12,13]. Termites do not survive in cold regions due to their soft cuticles [14]. Hence, except Antarctica they are found everywhere and the size of their colonies range from a few hundred individuals to enormous societies with several million individuals. Their distribution is found in tropical and sub-tropical regions from 50°N to 45°S [15,16]. The termite mounds found in various parts of Tamil Nadu, India is shown in Fig. 2.

They live in soil or wood preferably the dry condition [17], undergo incomplete



**Fig. 2. Photographs showing termite mounds found in different districts of Tamil Nadu, India. (A) Pattukottai (Thanjavur District); (B) Coimbatore (Coimbatore District); (C) Aralvaimozhi (Kanyakumari District); (D) Anna University campus (Chennai District)**

metamorphosis and pass through the stages such as egg, nymph, and adult in their lifecycle. Because of their self-regulating nature within the colony itself, they are considered as super organisms [18,19].

They are detritivores and capable of decomposing the wastes such as deadwood, feces and dry plants in the environment and helping to recycle [20,21]. The microbial symbionts present in the gut of the termites decompose or dissimilate the cellulose and hemicellulose components of the organic materials they ingest [22]. The cellulose is decomposed by the symbiotic protozoa and other protists present in the gut and enabling the absorption of the end products by the termites [23-25]. Globally, there are about 2600 species of termites [26,27]. As they feed on lignocellulose, they are considered as a big problem to agricultural sector in tropical and sub-tropical regions [28,29]. But, because of maintaining soil fertility in agroecosystem, they are considered as important organisms [27, 30]. While constructing the mounds, termites improve the soil physical and chemical characteristics by excavating and breaking down organic materials [31,32]. In addition, termites play an important role in regulating soil moisture by facilitating upward movement of water and controlling transpiration with their sheeting. Through this, the upward flow of nutrients is achieved by mass transfer [33]. Further, they could mitigate the effects of drought in tropical rain forests through enhanced nutrient availability which was attributed to the increasing water holding capacity of the soil by the increasing termite population [34].

### 3. CHARACTERISTICS OF TERMITE MOUND SOIL

In India so far 337 species of termites have been reported including *Coptotermes gestroi*, *Coptotermes heimi*, *Heterotermes indicola*, *Schedorhinotermes spp.*, *Ondontotermes spp.*, *Psammotermes rajathanicus*, *Macrotermes gilvus*, *Microcerotermes spp.*, *Nasutitermes sp.* [35]. The *Ondontotermes spp.* is possessing mound building nature [36]. Further, in the tropics termites are considered as an important ecosystem engineers [37].

The accumulation of soil nutrients in termite mound soil plays an important role in ecosystem services [31]. Termite mound soils have high concentration of total nitrogen (N), Higher cation

exchange capacity (CEC), and more mineral nutrients such as calcium ( $\text{Ca}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ), and potassium ( $\text{K}^+$ ) than the surrounding soils [38-40]. Another study reported that in addition to high pH, and CEC termite mound soils have higher clay and aluminium ( $\text{Al}^{3+}$ ) contents. Further, the soils in the base of the termite mounds have higher total organic carbon and particulate organic content and humic substances [41]. In addition, it has been reported that the  $\text{Ca}^{2+}$  content at the mound base was higher than that of mound top [41]. Also the carbon content was found to be higher at the mound base which depends on both the termite species and nesting material. Normally the core of the nest or mound has a carton material, made up of organic matter, soil and saliva which are covered by a dark substance secreted by the termites [42]. The P content also varies between different segments of the mound [43], which is related with the clay content of the mound soil. However, the P uptake by the plants is increasing with higher clay content [44].

### 4. MICROBIAL DIVERSITY AND ORGANIC MATTER DEGRADING ENZYMES IN TERMITE MOUND SOIL

The termite mound constructed by *Captotermes acinaciformis* was found to have approximately six times more microbial biomass when compared to the surrounding soil. Since, prior to the ingestion by the termites, the food materials are decomposed by microorganisms and thus the decomposed products are rich in N content [45]. A shotgun metagenomics study revealed that the termite mound soil harbored archaeal, eucaryotes and bacteria. The predominant genera were *Sphingommas*, *Streptomyces*, *Sphingopyxis* and *Mycobacterium* [46].

Termite mound soil is colonized with various microbial communities belonging to the phyla *Bacteroidetes*, *Firmicutes*, *Spirochaetes*, *Chloroflexi*, *Nitrospirae*, *Planctomycetes*, *Proteobacteria*, *Tenericutes*, *Actinobacteria*, *Deinococcus-Thermus*, *Verrucomicrobia*, *Fibrobacteres*, *Elusimicrobia*, *Acidobacteria*, *Synergistetes*, *Cyanobacteria*, *Chlamydiae* and *Gemmatimonadetes* [47-50]. However, the microbial population depends on the soil pH and C:N ratio of the soil and *Bacteroidetes* are predominant in soil with pH > 6.5 and C : N ratio < 12.5 [51]. Further, from termite mound soil, the beneficial microorganisms such as *Citrobacter freundii*, *Paenibacillus sp.*, *Enterobacter sp.*, and

*Lactobacillus* sp., have been successfully isolated [52].

Studies have been conducted and reported that the microorganisms colonized in termite mound possessed more beneficial enzymes [53]. The cellulose degrading enzyme carboxy methyl cellulase was isolated from the bacterium *Bacillus thermoalcaliphilus* present in the termite mound [54]. This was further confirmed that cellulose degraders are predominant in termite mound soil collected from semi-arid zones of Delhi, India [55]. The termite mound is colonized with gut inhabitants (*Staphylococcus* sp., *Micrococcus luteus*, *Micrococcus roseus*) and soil inhabitants (*Bacillus thermoalcaliphilus*, *Cellulomonas* sp., *M. luteus*, *M. roseus*), producing both endogenous and exogenous enzymes to degrade different types of cellulose [56].

## 5. TERMITE MOUND SOIL IN NUTRIENT CYCLING

The important elements determining soil nutrient status through nutrient cycling (nitrogen, sulfur and phosphorus) are soil bacteria [57]. The termite mound soil is harboring a vast array of microorganisms involving in various processes such as nitrogen fixation, inhibition of pathogens and mobilization of key elements in soil [58,59]. Moreover, the important bacterial species namely *Staphylococcus saprophyticus* and *Bacillus methylotrophicus* isolated from termite mound soil possessed antifungal activity and inhibited the growth of *Fusarium oxysporum*, *Alternaria brassicae*, *Rhizoctonia solani*, *Sclerotium rolfsii*, and *Colletotrichum truncatum* [58].

Soil binding enzymes have been extracted from the termite mound soils [60]. Among the oxidoreductases class of enzymes, dehydrogenase is the key enzyme indicating the overall microbial activity of the soil [61]. Further, the organic matter decomposition in soil is achieved by these enzymes [62]. The dehydrogenase enzyme activity of the fertile soil was found to be > 30 mg TPF/g/h [63]. Most recently a plant cell wall degrading enzyme has been reported in gut micro biomes of Neotropical termite species [64].

## 6. TERMITE MOUND SOIL APPLICATION AND CROP GROWTH

Studies have been conducted to evaluate the effect of termite mound soil on crop growth. As termite mound soil contains essential nutrients

such as nitrogen, calcium, phosphorus and sulfur the mound soil is incorporated into soil to improve the crop growth. The termite mound soils are enriched with organic carbon, total nitrogen and available P [65]. So it could be used as soil amendment by the local farmers [66]. Furthermore, the mound soils are having very high level of exchangeable K and clay, thereby improving the soil nutrient – holding capacity and water retention [67]. Moreover, the application of termite mound soils to improve the growth, yield and nutrient contents of crops such as okra, rice, bean, tomato, sorghum and maize was studied by many researchers. The effect of termite mound soil and termite mound soil compost on growth of crop species is illustrated in Fig. 3.

The studies conducted on the effect of termite mound soil on the crop growth are summarized in Table 1.

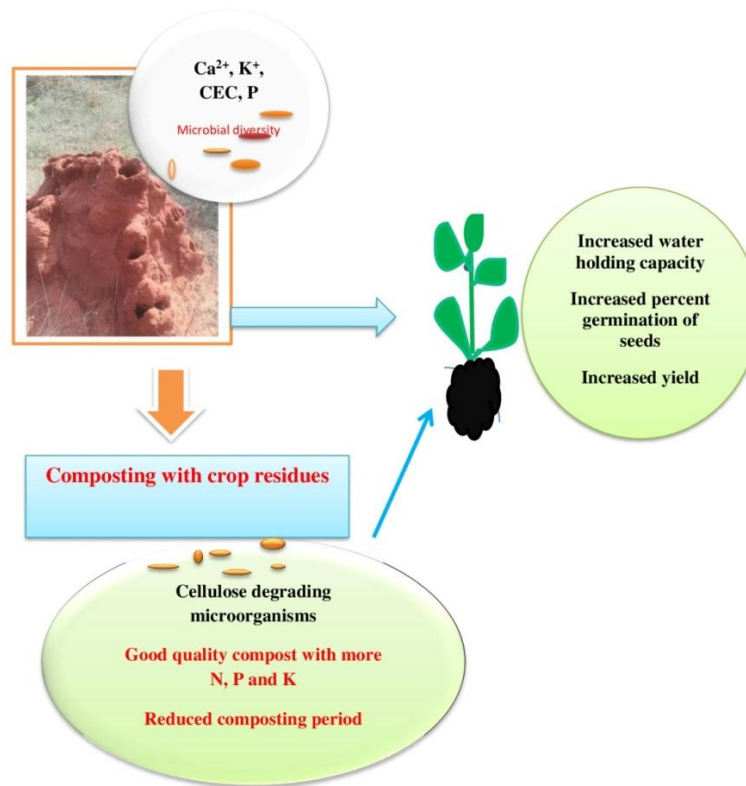
## 7. TERMITE MOUND SOIL AS A BULKING MATERIAL IN COMPOSTING

Bulking agents or materials are carbon based materials used currently in composting processes [79]. Studies were conducted with different bulking materials such as agricultural residues (sugarcane trash, rice straw) and sewage sludge [80]. It is demonstrated that bulking agents speed up the degradation process at the initial stage of composting and reduce the duration of composting [81]. The addition of bulking materials helps to achieve the thermophilic phase and lower the period of mesophilic phase [81,82]. The efficiency of composting process depends on Bulk Density, CEC and moisture holding capacity of the bulking material added. Due to the higher Cation Capacity, organic carbon and nitrogen content, water holding capacity and clay content [83,84], termite mound soil is a good option to use as a bulking material in composting process. Few studies have been conducted to explore the possibility of utilizing termite mound soil in composting to get compost with good quality and enriched with nutrients. The rapid degradation of organic matter when amended with termite mound soil is due to the abundance of biomass degrading bacteria, fungi, actinomycetes and yeasts in it [85]. The cellulose degrading bacterium, *Cellulomonas* sp., present in the termite mound soil [86] produces cellulose degrading enzyme capable of degrading cellulosic materials during composting process. The literatures available on the use of termite mound soil as a bulking material for composting are summarized in Table 2.



**Table 1. Summary of literatures available on the effect of addition of termite mound soil on crop growth**

Crop species	Effect	References
Lettuce ( <i>Lactuca sativa</i> )	Enhanced plant growth	[68]
Okra ( <i>Abelmoschus esculentus</i> )	Enhanced plant growth	[69]
Upland rice( <i>Oryza sativa</i> L. cv. <i>Maravilha</i> )	Improved soil texture and chemical properties, Reduced Al content, Increased K content	[70]
Common bean( <i>Phaseolus vulgaris</i> L. cv. <i>Perola</i> )	Increased Grain yield	[70]
Tomato( <i>Solanum lycopersicum</i> )	Water retention at field capacity, permanent wilting point, increased yield	[71]
Fodder sorghum( <i>Sorghum bicolor</i> )	Enhanced plant growth	[72]
Sorghum ( <i>Sorghum</i> sp.)	Significant increase in plant height	[73]
Rattle pod( <i>Crotalaria ochroleuca</i> )		
Sudangrass( <i>Sorghum sudanense</i> )	Improved water holding capacity of the soil	[74]
Silky wattle ( <i>Acacia holosericea</i> )	<i>Pseudomonas montelli</i> present in termite mound soil enhanced the growth of ectomycorrhiza	[75, 76]
Maize ( <i>Zea mays</i> )	Increased growth and yield	[77]
Paddy ( <i>Oryza sativa</i> L.) and Common bean ( <i>Phaseolus vulgaris</i> L.)	Improves the growth	[78]
Eggplant( <i>Solanum melongena</i> )	Yield has been increased	[69]



**Fig. 3. Illustration showing the effect of termite mound soil and termite mound soil compost on crop growth**

**Table 2. Studies conducted with termite mound soil as a bulking material in composting**

Raw materials used for composting	Outcome	References
Crop residues and termite mound soil as a bulking material	Good quality compost enriched with nutrients Germination Index (GI) of Cashew nut ( <i>Anacardium occidentale</i> ) and Soybean( <i>Glycine max</i> ) seeds increased	[87]
The mixture consisting of crop residues (ground nut stover 361.65 kg, soybean 54.59 kg, potato 379.19 kg), termite mound soil (50 kg), cowdung(84.90 kg) was composted	Good quality compost with N (20.19 g/kg), P (3.79 g/kg) and K (32.77 kg) has been obtained. Reduction of composting time (within 70 days matured compost). When applied to the field, the nutrient release from the compost was in a controlled manner and plant growth was enhanced	[88]

For the conversion and stabilization of organic matter microorganisms are considered as important factor [89]. The microorganisms act on lignocellulose and release soluble organic intermediates, which cause partial solubilization of soluble fraction of the polymeric matrix and further transform into humic substances by microbial or chemical reactions [89]. However, when different raw materials with different physico-chemical characteristics are used for composting, they provide different growth conditions to the microbial community during the process of composting. In order to regulate microbial community, relevant environmental conditions should be adjusted to complete the process [90]. Filamentous bacteria are predominantly available in the termite mound soil [91] and the bacterial community is influenced by pH and organic matter content of the environment [62,92,93]. The highest organic matter content, enzymes and microbial population in the termite mound soil would speed up the composting process [94–97].

## 8. CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

It is concluded that naturally available termite mound soil could be used as a bulking material in the composting process. It is found to have more enzymes capable of degrading lignocellulose materials. Only limited studies have been conducted with termite mound soil used as a bulking material in composting process. More studies are required on the feed stock selection and optimization of parameters to improve the quality of compost and reduce the composting duration while termite mound soil is incorporated. Thorough study is needed to explore, isolate and characterize the enzymes present in the termite mound soils. Further research is required to

study the microbial diversity and nutrient content of the termite mound soil distributed in different regions.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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