1. Introduction

Termites are eusocial insects that are classified at the taxonomic rank of infraorder Isoptera,or as epifamily (Thorne, 1997; Lacy, 1980; Brady et al., 2006; Andersson, 1984; Vršanský, 2010; Garnier-Sillam and Harry, 1995). Termites were once classified in a separate order from cockroaches, but recent phylogenetic studies indicate that they evolved from close ancestors of cockroaches during the Jurassic or Triastic (Paul et al., 2012; McKittrick, 1965; Stingl et al., 2005; Bandi et al., 1995; Legendre et al., 2015; Malyshev, 1968). Approximately 3,106 species are currently described, with a few hundred more left to be described (Garnier-Sillam and Harry, 1995; Eggleton, 1999). Although these insects are often called white ants, but they are not real ants (Korb, 2008; Inward et al., 2007; Marais, 2009).

Division of labour exists in termite with distinct polymorphic features which includes sterile male, female workers and soldiers (Thorne, 1997; Lacy, 1980; Brady et al., 2006; Crosland et al., 1997; Smith et al., 2008; Crosland et al., 1998; Badertscher et al., 1983). The fertile females are called as the queens while fertile male known as kings (Korb et al., 2009; Atkinson and Adams, 1997; Bordereau and Han, 1986). Termites occupy in the subtropical and tropical regions (Black and Okwakol, 1997; Seiler et al., 1984), mostly detrivorous which feeds on dead plant materials and cellulose (Tian and Brussaard, 1993; Fujita et al., 2002; Mugerwa et al., 2011; de Souza and Brown, 1994; Haverty et al., 1974). Their economic importance lies on the effectiveness of recycling wood and plant materials (Holt, 1987; Ohkuma, 2003; Freymann et al., 2008; Noirot and Darlington, 2000).

Termites are among the most successful groups of insects on earth, colonising most landmasses (Ferrar, 1982; Murphy and Legge, 2007). Termite queens have the longest lifespan of any insect in the world, with some queens living up to 50 years (Carey, 2001; Thorne et al., 2002; Keller, 1998). Unlike ants, which undergo a complete metamorphosis, each individual termite goes through an incomplete metamorphosis that proceeds through egg, nymph and adult stages (Snyder, 1935; Lüscher, 1960; Lamberty et al., 2001).

Termites are a delicacy in the diet of many human cultures and are used in a variety of many traditional medicinal preparations (DeFoliart, 1990; Kinyuru et al., 2010; Kinyuru et al., 2013; Shockley and Dossey, 2014). The infraorder name is derived from the Greek word siso (equal) and ptera (winged), which refers to the nearly equal size of the fore-and hind-wings. The name “termite” derives from the Latin and Late Latin word termes (“woodworm, white ant”), altered by the influence of Latin terere (“to rub, wear, erode”) from the earlier word tarmes. Termite nest were commonly known as termitariumor termitaria. In early English, termites were known as wood ants or white ants. The modern term was first used in 1781.

Most termites use soil, together with saliva and faeces, to construct their nests (Noirot and Darlington, 2000; Emerson, 1938). Nest may be subterranean, epigeal (mounds) or within or attached to the outside of shrubs and trees (Noirot and Darlington, 2000). Some termite nests are simple constructions and their internal microclimate is not much different from that in the soil (Lüscher, 1961; Noirot and Darlington, 2000). Other nests are often complex structures where temperature and humidity are closely regulated to produce a favorable environment (Lüscher, 1961; Harris, 1956). Above-ground nests are continually being eroded and reconstructed, which redistributes soil over the surface (Harris, 1956). The resultant disturbance of soil profiles, changes in soil texture and changes in the nature and distribution of organic matter appear to be more significant than changes in the chemical properties (Holt and Lepage, 2000; Wood, 1988; Wambeke, 1992).

The size of the mounds, usually range up to 5 m high and 20 m broad; depends largely on the kind of soil and climatic conditions, while the proximity of the mounds to each other depends not only on the size but inter alia on the soil type and depth of soil (Holt and Lepage, 2000; Wood, 1988; Noirot and Darlington, 2000; Emerson, 1938). It is not uncommon for the number of mounds to average one and a half per acre (3.7 per hectare) and in any one area the mounds usually, but not necessarily, are the work of one species of termite. Each species of termite builds its mound in a slightly different way, but as the shape of a mound depends upon the nature of subsoil and climate, if the conditions are not suitable their particular shape of mound, a species will build accordingly (Moe et al., 2009; Asawalam et al., 1999; Hesse, 1995).

The building process is as follows: a worker termite fills its mouth with clay which there becomes mixed with saliva, and selects a grain of sand which it carries in its mandibles. Placing the sand grain in position the termite squirts the wet clay round it and kneads its head and mandibles. Contrary to the statements made by Marrais (1938) and Grasse (1950) that termites dig down as far as the water-table in order to obtain moisture, it has been suggested by Harris that they produce all the water they need metabolically (Hesse, 1995).

In the view of the wide distribution of the mounds and the part they can play in agriculture it was considered that a comprehensive study from the chemical and physical accepts would be of considerable scientific and practical interest. Evidence in the literature and from native agricultural practices shows that termite mound excreta considerable influence upon the growth of certain crops (Hesse, 1955; Holt and Lepage, 2000; Wood, 1988; Noirot and Darlington, 2000; Emerson, 1938).

Termites are vital to the functioning of natural ecosystems, particularly in Australia's tropical north, where they recycle nutrients in a range of ecological niches. Scientists believe that manipulating termite density and activity may help to restore degraded areas faster, or make ecosystems more resilient to disturbance. Termites inhabit moist environments teeming with potential bacterial and fungal pathogens, parasites such as nematode worms, and predatory arthropods such as ants, beetles, scorpions and centipedes (O'Neill, 2002).

Some species of termite soldiers produce some sticky, irritating exudates from their snouts to repel predators such as ants (Rosengaus et al., 1998a; Rosengaus et al., 1998b; Blum et al., 1992). Being glue-like, these exudates also shows antibiotic activity (Rosengaus et al., 1998a; Rosengaus et al., 1998b; Thomas, 1987). Given the lack of qualitative and quantitative data on termite mounds and their soil properties, the purpose of this research work is to compare the mound morphology, antimicrobial activity and associated microorganisms.

1.2 Hypothesis

The current research work is based on the following hypothesis: (1) morphological differences exist among various termite mounds in Kerala; (2) antimicrobial activity differs across various mounds; and (3) associated microorganisms also vary across these mounds.

2. Materials and Methods

2.1 Study area

Kerala state covers an area of 38,863 km^2 with a population density of 859 per km^2 and spread across 14 districts. The climate is characterized by tropical wet and dry with average annual rainfall amounts to 2,817 ± 406 mm and mean annual temperature is 26.8°C (averages from 1871-2005; Krishnakumar et al., 2009).

2.2 Sample collection

Samples of different termite mounds were collected based on a survey and personal observation. A total of 9 termite mounds were spotted from different regions across Kerala during December 2015 to February 2016. These mounds were observed in different cash crop plantations and uncultivated vacant lands. The samples were collected without disturbing their natural habitat and ecosystem. Small portions of the mounds were excavated and opened to observe the internal structure using standard procedures (Darlington, 1982). Nine different mounds were selected for morphological comparison and soil chemical characterization while four mounds were randomly selected for antimicrobial activity study and associated microbial isolation. Locations of the sample collection areas were recorded using a Trimble Geoexplorer II (Trimble Navigation Ltd, Sunnyvale, California) and data were transferred using GPS Pathfinder Office software (Trimble Navigation Ltd, Sunnyvale, California).

2.3 Morphological characterization

Morphological characterizations of termite mounds were studied according to Darlington (1982) and Watson, (1962). The instruments used to collect data were, measuring scale (30 cm), tape (160 cm), weighing machine, camera, field book and shovel. Parameters taken were mound height, color, soil texture, substrate used and number of partitions.

Table 1. Geographic details of Termite mounds (M1 to M9) during December 2015 to February 2016 in Kerala.

Samples	Location	Feature	GPS position		Altitude (m)
			Latitude	Longitude	
M1	Poonjar	Rural	9˚40’19.80” N	76˚50’13.83” E	173
M2	Koottickal	Rural	9˚35’13.89”N	76˚53’06.24’’ E	111
M3	Poonjar	Rural	9˚41’21.87’’N	76˚51’09.76’’E	100
M4	Peringulam	Rural	9˚40’28.10’’N	76˚50’46.80’’E	77
M5	Athirumkal	Rural	9˚9’38.01” N	76˚52’24.73” E	97
M6	Erumeli	Semi-urban	9˚28’51.80’’N	76˚50’42.18’’E	49
M7	Thodupuzha	Urban	9˚47’58.09’’N	76˚39’48.94’’E	46
M8	Konni	Semi-urban	9˚13’36.14’’N	76˚50’58.84’’E	33
M9	Pala	Urban	9˚42’49.51” N	76˚40’58.54” E	23

M1: mound 1; M2: mound 2; M3: mound 3; M4: mound 4; M5: mound 5; M6: mound 6; M7: mound 7; M8: mound 8; M9: mound 9.