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Physical, chemical and phosphatase activities characteristics in soil-feeding termite nests and tropical rainforest soils

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Abstract

Little is known about the relationship between soil biological function and the physical and chemical characteristics of soil-feeding termite nests in the Lopé tropical rainforest (Gabon). We compared nine soil-feeding termite nests of *Cubitermes* of different ages (fresh to mature to old) and six surrounding soils that originated from three forests differing with respect to age and vegetative cover according to 14 physical and chemical variables and acid (pH 4) and alkaline (pH 9) phosphatase activities. Physical and chemical variables of the studied samples were influenced by the three factors tested: (1) forest age, (2) termite activity (nest versus soil), (3) termite nest age. Soils from the gallery forest were strongly discriminated from all the other soils studied notably due to their high organic matter contents. All mature nests showed significant increases in K, P, clay and fine silt, pH, and cationic exchange capacity compared to soils. Some nests also had increased amounts of organic matter and larger water retention capacities. Moreover, we observed that with age the termite nests possessed decreased values of these variables from fresh to mature to old. Likewise, phosphatase activities also differed according to the three factors tested. Due to its high organic matter contents, the highest phosphatase activities were noted in the gallery forest. Within each forest, phosphatase activities decreased in mature nests compared to soils and tended to be higher in fresh nests compared to mature nests. These differences might be due to an inhibition by high inorganic P contents, as mature nests were enriched in this element and to the quality of organic matter as nests are built with termite faeces. Termite activity has an important role in influencing physical and chemical variables and phosphatase activities.

Keywords: Phosphatase activity; Termite nests; Soil-feeding termite; Tropical rainforest; Physical and chemical properties

1. Introduction

Tropical forests make important contributions to ecosystem processes such as biogeochemical cycling. Covering less than 7% of Earth's land surface, they provide habitats for more than half of the world's plant and animal species. They support the largest termite communities which are dominated by soil-feeding termites (Kambhampati and Eggleton, 2000). Furthermore, the feeding habit of these termites has major ecological effects—similar to those induced by endogeic earthworms.

Termites may be described as ecosystem engineers (Jones et al., 1994; Lavelle et al., 1997). Soil-feeding termites build their nests using their own faeces enriched in clay-organic complexes, formed during the passage through the gut by rearrangement of the ingested soil organic matter (Lee and Wood, 1971; Grassé, 1984). Thus, their nests, compared to the surrounding non-ingested soil, are usually enriched with organic matter, exchangeable bases and fine particles. Moreover, certain variables of structure such as aeration, porosity or aggregation are improved (Wood et al., 1983; Anderson and Wood, 1984; Lopez-Hernandez and Febres, 1984; Wood, 1988; Garnier-Sillam and Harry, 1995; Lobry de Bruyn and Conacher, 1995; Fall et al., 2001).

Our objective was to evaluate the effects of these termites using a soil biological function such as phosphatase activity and relating that function to the physical and chemical characteristics of the material studied. Soils enzyme

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activities are involved in the transformations and availability of nutrients to plants and can be used as biological indicators of soil health, i.e. the capacity of a soil to sustain plant and animal productivity and to maintain the quality of air and water environments (Alkorta et al., 2003). Acid and alkaline phosphatases are produced by bacteria, fungi and fauna (Nakas et al., 1987; Tarafdar and Claassen, 1988) whereas plants roots only produce acid phosphatases (Speir and Cowling, 1991). These enzymes play a major role in the hydrolysis of soil organic P, thereby releasing inorganic P for plant uptake. Moreover, plant species can have different effects on phosphatase activity (Grierson and Adams 2000).

We have compared nests of variable ages built by *Cubitermes* soil-feeding termites to the soils surrounding them. All of them originated from different biotopes of a Gabonese rainforest and we compared their phosphatase activity and a selection of physical and chemical properties. We attempted to clarify the origin of the observed variability of phosphatase activities by investigating the effects of three variables: forest biotope, presence of termite activity and termite nest age.

2. Materials and methods

2.1. Site and sample description

The study was carried out in the Lopé rainforest, Gabon (from 0°03′ to 1°10′ N, 11°17′ to 11°50′ E). The climate of the area is equatorial with an annual average precipitation of 1500 mm and an annual average temperature of 26 °C (White and Abernethy, 1997). Natural vegetation is made up of a wide range of forests of different age. Sample description is summarized in Table 1.

Nine termite nests and six surrounding topsoils were collected from three different biotopes corresponding to three forests of variable age: 'Okoume', 'Rocher', 'Doda'. The Okoume forest, where *Aucoumea klaineana* is the dominant plant species, is a relatively young forest (50–200 years old) that represents a recolonization of the savanna by the forest. The Rocher forest is a 800 years old mature forest dominated by Marantaceae. The Doda forest, the oldest forest explored, is a gallery forest (at least 2500 years old).

All the termite nests studied were built by soil-feeding species of the genus *Cubitermes* (Termitidae, Termitinae). The termite nests in the different biotopes varied in age from fresh (F), which is a black freshly-made construction, to mature (M) which is a typical nest construction to old (O). Four termite nests, ON1 (M) to ON4 (O) and two surrounding soils, OS1 and OS2 were sampled from the Okoume forest, three termite nests, RN1 (F) to RN3 (M) and two surrounding soils RS1 and RS2 were sampled from the Rocher forest and two termite nests DN1 (M) and DN2 (M) and two surrounding soils DS1 and DS2 were collected from the Doda forest. We considered a nest left by the *Cubitermes* builder termite species and reinvaded by inquiline termites as an old nest. Inquiline termites live in nests they do not build themselves and which were left by the building termites (Grassé, 1984). An example is given by ON4 (O) that was reinvaded by *Apilitermes*. Surrounding soils are defined as soils without noticeable termite activity. Surrounding soil samples are composites of five pooled topsoil (0–5 cm) subsamples. All samples were air-dried, crushed and sieved (1 mm) and thoroughly mixed.

Table 1
Samples description

	Type	Name	Age	Builder termite
OKOUME	N	ON1	Mature	*Cubitermes* sp 1
(*Aucoumea* forest)		ON2	Mature	*Cubitermes* sp 2
50–200 years old		ON3	Fresh	*Cubitermes* sp 2
		ON4	Old	*Cubitermes* sp 2
	S	OS1		
		OS2		
ROCHER	N	RN1	Fresh	*Cubitermes* sp 1
(Marantaceae forest)		RN2	Mature	*Cubitermes* sp 1
800 years old		RN3	Mature	*Cubitermes* sp 1
	S	RS1		
		RS2		
DODA	N	DN1	Mature	*Cubitermes* sp 1
(gallery forest)		DN2	Mature	*Cubitermes* sp 1
2500 years old	S	DS1		
		DS2		

For the sample names, the first letter refers to the biotope type (O, Okoume forest; R, Rocher forest; D, Doda forest), the second letter to the nature of the sample (N, termite nest; S, soil), and the number to the sample number given.

2.2. Physical and chemical soil characteristics

Samples were analyzed for particle size distribution (AFNOR 31–107, AFNOR, 2004), cationic exchange capacity (CEC) and contents of Ca, Mg, K and Na (AFNOR 31–130, AFNOR, 2004), organic matter (Nelson and Sommers, 1982) and inorganic P (Joret and Hebert, 1955). Water retention capacity was determined on a 10 g sample by the procedure of Feodoroff and Betremieux (1964).

2.3. Enzyme assays

Acid and alkaline phosphatase activities of termite nests and soils were measured by the method of Tabatabai (1982). The phosphatases assays only differed in the choice of the pH-value of the buffer (4 and 9), adapted for tropical soils. The unit of phosphatase activity (U) was expressed in μg phenol min^{-1} and referred to the mass of dry material. After adjusting samples to their field water capacity to stimulate micro-organisms, phosphatase activities were immediately measured and then measurements repeated every 24 h from 0 up to 96 h. Samples were incubated at 30 °C in the dark until assayed. Three replicates were analyzed for each enzyme activity.