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## Ingestion of charcoal by the Amazonian earthworm *Pontoscolex corethrurus*: a potential for tropical soil fertility

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1 **Abstract**

2

3 It is now attested that a large part of the Amazonian rain forest has been cultivated  
4 during Pre-Colombian times, using charcoal as an amendment. The incorporation of charcoal  
5 to the soil is a starting point for the formation of fertile Amazonian Dark Earths, still selected  
6 by Indian people for shifting cultivation. We showed that finely separated charcoal was  
7 commonly incorporated in the topsoil by *Pontoscolex corethrurus*, a tropical earthworm  
8 which thrives after burning and clearing of the rain forest, and that this natural process could  
9 be used to improve tropical soil fertility. Our paper is a contribution to the present debate  
10 about (i) the origin of black carbon in fertile Dark Earths, (ii) the detrimental vs favourable  
11 role of *Pontoscolex corethrurus* in tropical agriculture, (iii) natural processes which might be  
12 used to increase tropical soil fertility

13

14 *Keywords:* Tropical earthworms, Tropical soil fertility, Slash-and-burn agriculture, Charcoal

15

16 *Pontoscolex corethrurus* (Annelida: Oligocheata: Glossoscolecidae) is a small  
17 terrestrial earthworm which commonly inhabits rain forest soils over the whole Amazonian  
18 basin (Römbke et al., 1999). Its important burrowing activity through the topsoil, associated  
19 with its efficient digestive system (Zhang et al., 1993; Barros et al., 2001), allows it to thrive  
20 in soils poor in organic matter, such as those found in areas now deforested for the need of  
21 agriculture. In the absence of organic input to the soil, excessive casting activity of this  
22 species may cause damage to permanent pastures through the coalescence of earthworm casts,  
23 leading to appearance of a thick compact surface crust (Chauvel et al., 1999). However, the  
24 detrimental influence of this species may be questioned when the agricultural use of the land  
25 is only temporary, as in slash-and-burn shifting agriculture, or when available carbon is

1 regularly added to the soil. We hypothesized that *P. corethrurus* could be responsible for the  
2 observed increase in soil fertility which has been reported to occur in Amazonian Dark Earths  
3 formed during Pre-Colombian times (Myers et al., 2003; Steiner et al., 2004).

4  
5 Using a quantitative optical method (Topoliantz et al., 2000), we investigated the  
6 distribution of humus components in soils under shifting cultivation, still practised by  
7 Wayana and Aluku people settled along the Maroni river, French Guiana (Topoliantz et al.,  
8 2005b). This method allowed us to estimate the relative volume of components of the soil  
9 matrix, including plant tissues at varying stages of decomposition, mineral particles of  
10 varying size and nature, aggregates of varying colour, size and shape.

11  
12 The untouched old forest exhibited low contents of both charcoal and charred material,  
13 representing 2% and 7% of the volume of the soil matrix, respectively. We showed that six  
14 months after burning of the same forest for cultivation, the contents of charcoal and charred  
15 material increased to 10% and 20% of the soil matrix, respectively, in the top 3 cm. After  
16 three years of cultivation these amounts decreased to 6% and 15%, respectively. During the  
17 cultivation period the amount of dark humus (mixture of charcoal and mineral soil in varying  
18 proportion) increased steadily. The examination of dark humus revealed that it was mainly  
19 comprised of faecal pellets of *P. corethrurus*, which contained a multitude of small charcoal  
20 fragments of 10-100  $\mu\text{m}$  admixed in a mineral paste.

21  
22 Charcoal, ingested together with soil particles, is mixed with mucus secreted in the  
23 oesophagus then finely ground in the muscular gizzard of earthworms. It is excreted as a  
24 muddy paste which is further stabilized by Van der Waals forces after drying, thus forming  
25 dark humus (Hayes, 1983). We also showed by laboratory experiments that *P. corethrurus* did

1 not ingest charcoal alone but rather added it to mineral soil. A mixture of charcoal and soil  
2 was preferred to either pure charcoal or pure soil (Topoliantz and Ponge, 2003, 2005a). This  
3 points to a positive feed-back which improves the habitat of *P. corethrurus* by increasing the  
4 carbon content of the soil.

5

6 It has been demonstrated that finely divided charcoal (also called black carbon) was a  
7 source of stable humus (Tryon, 1948; Chan et al., 1999). Slow oxidation and hydroxylation  
8 increase donor/acceptor charges, giving the soil strong exchangeable properties. The positive  
9 impact of charcoal in ameliorating the physical and chemical properties of tropical soils has  
10 been reported in various situations (Glaser et al., 2002). To the light of our results we expect  
11 the peregrine earthworm *P. corethrurus* to be the main agent for the incorporation of charcoal  
12 to the topsoil in the form of fine particles of silt size, which favoured the formation of stable  
13 humus in Amazonian Dark Earths or 'Terra Preta' during Pre-Colombian times (Glaser et al.,  
14 2000).

15

16 The natural development of *P. corethrurus*, able to feed and reproduce in tropical soils  
17 poor in organic matter, opens avenues for new agricultural practices better adapted to  
18 permanent settlements, using charcoal in mixture with nutrient-rich amendment (Steiner et al.,  
19 2004). In situ experiments were conducted with the help of a local agriculturist at Maripasoula  
20 (French Guiana), using waste products of slash-and-burn agriculture (charcoal and manioc  
21 peels) as an amendment. We demonstrated that the addition of charcoal together with manioc  
22 peels, known to be rich in phosphorus (a limiting nutrient in tropical soils), increased yard-  
23 long bean production at the natural population size of *P. corethrurus*, thus allowing  
24 diversification of family agriculture without any additional cost (Topoliantz et al., 2002;;  
25 Topoliantz et al., 2005).

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