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A Note on Experimental Gigantic *Eisenia* and *Dendrobaena* Earthworms

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Abstract

Earthworms are iteroparous organisms with indeterminate growth, i.e. they continue to increase in size throughout their life and after completion of sexual development. Terrestrial oligochaetes vary greatly in size. Depending on the species, adult earthworms can reach between 10 mm and 3 m in length and between <1 mm and >25 mm in width, with most being of length 5-15 cm. Among the more than 7000 species described to date, very few (~20) reach lengths greater than 1 m. The longest earthworm on record is *Amynthas mekongianus*, which is found in the mud banks of the Mekong River in Southeast Asia and which reaches almost 3 m in length. It is about the same size as *Megascolides australis*, the 'Giant Gippsland Earthworm'. These atypically giant earthworm species remain a scientific curiosity in terms of their biology, but they cannot be considered cases of gigantism. Gigantism occurs when organisms are much larger than normal or exhibit excessive growth. The biology, life cycle and growth and reproduction rates of *Eisenia fetida* (Savigny 1826) and *Eisenia andrei* (Bouché 1972), the earthworm species most commonly used in vermicomposting and vermiculture, have been widely reported. Here we present details of the enormous growth of individual specimens of *Eisenia andrei* and *Dendrobaena hortensis* reared under particular culture conditions and fed a special diet. Individuals almost 20 times the average weight of individuals of the species have been obtained. Possible explanations for this interesting phenomenon are discussed.

Keywords: Gigantism; Earthworm Growth; *Eisenia*

Introduction

Earthworms are iteroparous organisms with indeterminate growth, i.e. they continue to increase in size throughout their life and after completion of sexual development. Terrestrial *oligochaetes* vary greatly in size. Depending on the species, adult earthworms can reach between 10 mm and 3 m in length and between <1 mm and >25 mm in width, with most being of length 5-15 cm. Among the more than 7000 species described to date, very few (~20) reach lengths greater than 1 m. The longest earthworm on record is *Amynthas mekongianus*, which found in the mud banks of the Mekong River in Southeast Asia. This species reaches almost 3 m in length and is about the same size as *Megascolides australis*, the "Giant Gippsland Earthworm". Most giant earthworms, which are found in particular locations in the Southern Hemisphere, reach up to 3 m in length and up to 500-600 g in weight, although much of this weight is due to soil contained in the gut. There is no standardized size classification for earthworms. Nonetheless, in European fauna, small earthworms are generally less than 5 cm long and weigh less than 0.5 g, medium-sized earthworms range from 5-10 cm in length and 0.5-5 g in weight, large-sized earthworms range from 10-30 cm in

length and 5-20 g in weight, and giant earthworms exceed these sizes (reaching up to 1 m long and 100 g in weight) [1].

These atypically giant earthworm species remain a scientific curiosity regarding their biology, but they cannot be considered cases of gigantism. Gigantism occurs when organisms belonging to the same species are much larger than normal or exhibit excessive growth.

Earthworms obtain energy from the organic matter on which they feed, and their growth mainly depends on the quality of the resource and on the species, as well as on food availability, environmental factors (which can directly or indirectly affect growth by modifying food availability) and other biotic factors such as competition [2]. This is particularly evident because of the indeterminate growth and large species-dependent variations in size observed in earthworms.

Here we present details of the extraordinary growth of individual specimens of *Eisenia andrei* and *Dendrobaena hortensis* reared under particular culture conditions and fed a special diet. Individuals almost 20 times the average weight of individuals of the species were obtained. Some possible explanations for this interesting phenomenon are discussed.

Material and Methods

Experimental trials were conducted in the laboratory and greenhouse facilities of the Animal Ecology Group at the University of Vigo (Spain) and in the laboratory and vermicomposting facilities of the Minhobox company, in Juiz de Fora, Minas Gerais, Brazil. Earthworms (*Eisenia andrei* and *Dendrobaena hortensis*) were collected by hand sorting of pilot vermicomposting reactors housed in the aforementioned facilities.

In the trials in which the gigantic earthworms were obtained, newly mature individuals (n=5) of *Eisenia andrei*, *Eisenia fetida* and *Dendrobaena hortensis* were placed in 1700 cm^3 plastic dishes (n=5). These earthworms were supplied with 1500 cm^3 of pretreated (aeration for 35 days) ox ruminal content. The plastic dishes holding the earthworms were placed in growth chambers in complete darkness and at a constant temperature of 11ºC. Earthworms were not supplied with any additional food during the trial, which ended when the earthworms began to lose weight (42 months). Similar trials were conducted with *D. hortensis*, which were held at room temperature. Unfortunately, and because Minhobox is a commercial company and not a research institute, the earthworm growth was not recorded regularly, and the findings are somewhat observational.

Results

In *Eisenia andrei* the mean mature weight of individuals was much greater in those fed on sewage sludge (2.51 g) than in those fed on spent coffee grounds (0.34 g); some very large individuals (3.5 g) were obtained from the reactor supplied with sewage sludge (Figure 1).

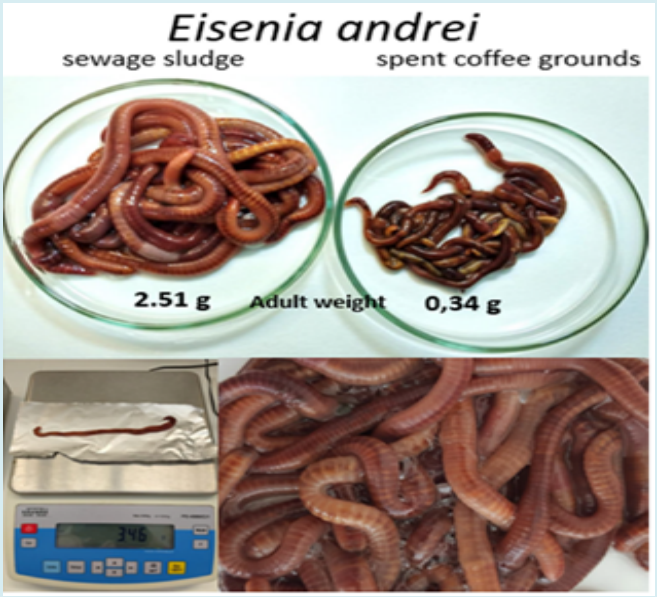

Figure 1: Variation in size and weight of mature individuals of *Eisenia andrei* fed fresh sewage sludge (2.51 g) (top left) or spent coffee grounds (0.34 g) (top right). Photographs showing a large specimen of *Eisenia andrei* (3.46 g) (bottom left) and individual specimens of *Eisenia andrei* collected from the vermireactor supplied with sewage sludge (bottom right).

Gigantic individuals of *Eisenia andrei* (9. 1 g) and *Eisenia fetida* (7 g) were obtained after being held for 42 weeks at 11ºC and fed ox ruminal content (Figure 2). These were the heaviest weights obtained, but 20% of the individuals reached weights of between 5.5 and 6 g. These gigantic specimens displayed notable modifications in their external morphology, including great dilation of the body that began in the segments posterior to the clitellum, with the typical red coloration of this species being maintained only in the segments anterior to the clitellum, with those posteriors to the clitellum being a lighter salmon colour (Figure 2).

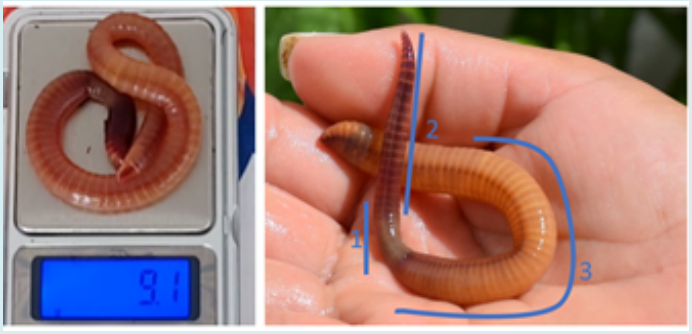

Figure 2: Gigantic individuals of *Eisenia andrei* (9.1 g) held at 11ºC and fed ox ruminal content (left). Modifications in their body are indicated, including (1) great dilatation of the body that begins in the segments posterior to the clitellum, [2] the typical red coloration of this species is maintained only in the segments anterior to the clitellum, and [3] the area posterior to the clitellum in these gigantic earthworms is a lighter salmon colour.

The gigantic specimens of *E. andrei* and *E. fetida* did not excrete casts, did not produce cocoons and their guts apparently remained empty.

The earthworm species *Dendrobaena hortensis* also reached an extraordinary weight (7.8 g) when held at room temperature and fed ox ruminal content (Figure 3). This species also reached large body weights when fed on fresh sewage sludge, although lower than those fed the ox ruminal content (Figure 3). In both substrates, *D. hortensis* produced numerous viable cocoons.

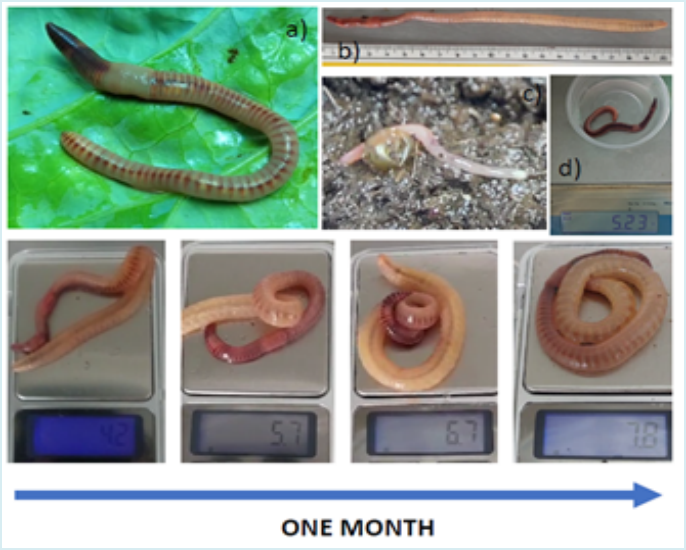

Figure 3: Weight and growth variation of individuals of the earthworm species *Dendrobaena hortensis* held at room temperature and fed ox ruminal content. Top line: A) External morphology of *D. hortensis*; B) Size (length) of the gigantic individuals of *D. hortensis*; C) Newly hatched individual of *D. hortensis*; D) Specimen of *D. hortensis* fed on sewage sludge at room temperature. Bottom line: Variation in body weight of *D. hortensis* during one month: the weight of the earthworms increased by 1 g per week until reaching a final weight of 7.8 g.

Discussion

The findings of this observational study can be summarized as follows: 1) Specimens of the earthworm species *Eisenia andrei* and *E. fetida* reached extraordinary weights of respectively 9.1 g and 6 g when fed ox ruminal content, and 2) specimens of *Dendrobaena hortensis* reached extraordinary weights of 7.8 g, when fed ox ruminal content, and of 5.3 g, when fed fresh sewage sludge. These are exceptional records and the weights are much higher than reported to date in any scientific study.

The magnificent, comprehensive EGrowth database, constructed by soil ecologist Jerome Mathieu, includes data regarding the growth of more than 50 earthworm species [3]. Mathieu searched for earthworm growth data in scientific articles and PhD theses since 1900, analyzing more than 400 publications and finally using 162 of these to build the database. The EGrowth database includes 1073 earthworm growth curves, constructed with more than 16000 biomass measurements [3]. The best documented earthworm species were found to be *E. fetida* (n=244), *Lumbricus terrestris* (n=131), *E. andrei* (n=87), *Aporrectodea caliginosa* (n=74) and *Lumbricus rubellus* (n=70) [3]. The maximum weights recorded were 3008 mg for *E. andrei* and 2471 mg for *E. fetida*. These are the earthworm species most frequently used in vermicomposting, with *E. andrei* being the predominant species used in vermicomposting facilities worldwide [4]. Although most specialists now consider *E. andrei* and *E. fetida* different species, older studies and even much of the current literature refer to both species as *E. fetida* or *E. foetida*, the latter of which is an incorrect and invalid version of the original *E. fetida* [5]. The two species are almost identical, only differing in the body pigmentation pattern, and with few differences in ecological or biological parameters. However, growth and reproduction rates are somewhat higher in *E. andrei* than in *E. fetida* [6]. The biology and ecology of *E. fetida* and *E. andrei* are well known, and their life cycles and population biology have been investigated by several authors [2,6]. The fact that these are by far the best documented species regarding growth makes the observation of these gigantic individuals of *E. andrei*, with a body weight that triples the previous record, even more striking.

Interestingly, in our vermireactors fed with fresh sewage sludge, we also obtained specimens of both species that also exceed the records obtained to date, although the sizes are much smaller than those of the gigantic *E. andrei* and *E. fetida* obtained in Brazil.

The Egrowth database does not include any information on *Dendrobaena hortensis*, although it does include data on its close relative *D. veneta*. The maximum weight of *D. veneta* previously recorded is 3.34 g, which is also much less than the weights obtained in the trials in Brazil and Vigo and reported here. The epigeic earthworms *D. veneta* and *D. hortensis* are also commonly used in vermicomposting and vermiculture. They are often considered the same species because their morphology is similar, except for the body colour. The dorsal side of *D. hortensis* has red-violet stripes and the ventral side is pale red, whereas *D. veneta* is uniformly red and is not striped. However, the species are phylogenetically different [4,7] and their life cycle parameters are unknown, mainly due to this taxonomic confusion.

The most plausible explanation for these extreme cases of gigantism in earthworms seems to be the diet based on the ox ruminal content and more specifically the microbial content of this substrate, as the physical and chemical characteristics are not very different from those of other substrates commonly used in vermicomposting. In addition, specific genes must also be involved as the extreme gigantism appeared in ca. 20% of the individuals of the studied populations. Further work is required to determine the mechanisms that explain these interesting findings.

Acknowledgements

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