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Article in *Journal of Ecological Engineering* · January 2020

DOI: 10.12911/22998993/113410

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Life Cycle of the *Eisenia fetida* and *Dendrobaena veneta* Earthworms (Oligochaeta, Lumbricidae)

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ABSTRACT

Earthworms can be used in the vermicomposting process. The success of the process depends on many factors, including the choice of the appropriate earthworm species. *Eisenia fetida* and *Dendrobaena veneta* are treated as “compost earthworms”. They are characterized by a relatively short life cycle, relatively fast growth rate, efficient reproduction and a similar amount of organic matter processed, compared to species found in the natural environment. However, while analyzing their features in more detail, it can be seen that these two species differ. The aim of this study was to compare the selected features of the *Eisenia fetida* (Sav.) and *Dendrobaena veneta* (Rosa) earthworm populations in an annual cycle. The mature specimens of *E. fetida* or *D. veneta* were put in groups into plastic boxes with soil. Populations were checked regularly by manual sorting of the medium. The earthworms and cocoons were cleaned, counted and weighed individually. Afterwards, the mature individuals were placed in appropriate containers, while the cocoons were separated from the starting populations. The earthworms were fed *ad libitum* on kitchen wastes every four weeks. The experiment was carried out under constant laboratory conditions for 52 weeks. The analysis of the studied populations confirmed that the tested species of earthworms differ from each other. After 52 weeks of the experiment, the sum of earthworm biomass was higher for *D. veneta* compared to *E. fetida* species (18.568 ± 1.867 g and 7.263 ± 1.786 g; $p < 0.01$, respectively). This relationship was confirmed for the average body weight of earthworms (*D. veneta*: 0.912 ± 0.046 g; *E. fetida* 0.480 ± 0.006 g; $t = 15.95$, $p < 0.01$) and cocoons (*D. veneta*: 0.032 ± 0.003 g, *E. fetida* 0.014 ± 0.001 g; $t = 9.15$, $p < 0.01$).

Keywords: *Eisenia fetida* (Savigny 1826); *Dendrobaena veneta* (Rosa 1893); composting earthworm; annual cycle

INTRODUCTION

Earthworms have been used in vermicomposting for many years. This is an example of pro-environmental biotechnology enabling the processing of organic waste. It involves the decomposition of organic waste with the participation of a concentrated population of earthworms. This process can be controlled by people and its products are both vermicompost – a full-fledged fertilizer and the biomass of earthworm body (Kostecka, 2000; Sherman, 2003; Garg et al., 2005; Adi and Noor, 2009; Dominguez & Edwards, 2011b; Adhikary, 2012; Bożym, 2012; Kostecka et al., 2018). The success of the vermicomposting process depends on many factors. Due to the fact that

its effectiveness depends to a large extent, e.g. on the selection of the appropriate earthworm species, numerous studies are conducted around the world to compare and isolate the Lumbricidae species which are most suitable for this purpose (Bhattacharjee and Chaudhuri, 2002; Suthar, 2007; Dominguez and Edwards, 2011a; Adhikary, 2012; Lowe et al., 2014). The *Eisenia fetida* (Sav.) species is of particular interest, as it can be effectively used in the vermicomposting process due to the high reproduction rate and fast rate of organic waste processing. It is a species tested by many authors, both in terms of maintaining under laboratory conditions and in vermiculture. *Dendrobaena veneta* (Rosa) is a species relatively recently imported into anthropogenic environments,

which is why this earthworm species has been the subject of many subsequent studies for some time. Both species can be found in vermiculture under the conditions of the Polish climate. Both earthworms called “compost” (Reinecke and Viljoen, 1990; Viljoen et al., 1991) are characterized by a relatively short life cycle, relatively fast growth rate, efficient reproduction and a similar amount of organic matter processed compared to the species found in the natural environment. However, while analyzing their features in more detail, it can be seen that these species differ from each other (Lofs-Holmin, 1985; Kasprzak, 1986; Dominguez and Edwards, 2011a). The previous studies showed the differences in sensitivity to anesthetics and chemical stress (Podolak et al., 2019) and some features of the produced vermicompost (Kostecka et al., 2018).

In connection with the above, the aim of this study was to compare the selected features of *Eisenia fetida* (Sav.) and *Dendrobaena veneta* (Rosa) populations in an annual cycle.

MATERIAL AND METHODS

Earthworms

Composting earthworms, *Eisenia fetida* (Savigny, 1826) and *Dendrobaena veneta* (Rosa, 1893) (Annelida, Oligochaeta), derived from laboratory stocks at the Rzeszow University, were used for current experiment. The earthworm cultures were maintained under controlled laboratory conditions ($18 \pm 2^\circ\text{C}$, 24L) in plastic boxes filled with culture medium and protected against moisture loss. The stock of earthworms was regularly fed *ad libidum* with organic household waste (according to resource).

Culture medium – soil

Horticultural substrate (Kronen Universalerde – universal soil) was used for the experiment, with the manufacturer’s parameters of: pH (CaCl_2) 5.5–6.5; N 200–450 mg/l; P_2O_5 200–400 mg/l; K_2O 300–500 mg/l; ISO 9001 (2000).

Experimental scheme

Ten mature specimens (*clitellate*) of *E. fetida* (0.480 ± 0.007 g) or *D. veneta* (0.912 ± 0.046)

were put into plastic boxes (10 dm^3) with soil (8 dm^3) with proper humidity. Every four weeks, the populations were checked by manual segregation of the medium. The earthworms and cocoons selected from the soil were cleaned, counted and weighed individually. Afterwards, the mature individuals were placed in appropriate containers, while the cocoons were separated from the starting populations. The earthworms were fed *ad libidum* every four weeks (pomace from apples, carrot and beetroot, cooked potatoes + cellulose in a ratio of 4:1). The experiment was carried out under constant laboratory conditions ($18 \pm 2^\circ\text{C}$, 24L) for 52 weeks. Three replicates were used for each experimental group.

Statistical analyses

STATISTICA v. 10 (*StatSoft*) was used for statistical analyses. The results were expressed as mean and standard deviations ($\bar{X} \pm \text{SD}$). In order to determine the significant differences in the mean number, weight and reproduction of the observed populations in the following time intervals, a *one-way ANOVA* method of variance analysis and *multiple mean comparisons (NIR test)* were used. When comparing the average values for two independent groups, the *Student’s t-test* was used. $\alpha = 0.05$ was established as the level of significance. The *Spearman rank correlation coefficient* was calculated to show the strength of the relationship between the selected parameters (Meisner, 2011; Stanis, 2006; Łomnicki, 2007).

RESULTS AND DISCUSSION

Earthworm number/ cocoon number

The research showed that the population numbers of both earthworms species decreased during the 52 weeks of the experiment (Table 1). (*E. fetida*, $F=2.31$, $p<0.05$; *D. veneta*, $F=5.28$, $p<0.001$).

Other studies show that the average life expectancy of earthworms may depend on the species. Under favorable conditions, these animals can live up to 10 years (e.g. *Lumbricus terrestris*), although the average life expectancy is just over a year (Brzeski and Makulec, 1994). Rožen (2006) shows that the maximum life expectancy of the *D. octaedra* earthworms under laboratory conditions is 49 months. Edwards and Bohlen (1996)

Table 1. Changes in the number of individuals *E. fetida* and *D. veneta* earthworm populations in an annual cycle (individual·container⁻¹ ± SD)

Week	0	4	8	12	16	20	24	28	32	36	40	44	48	52
Earthworm numbers	<i>E. fetida</i>	10.0 ± 0.0	10.0 ± 0.0	9.7 ± 0.6	9.7 ± 0.6	9.7 ± 0.6	9.7 ± 0.6	9.3 ± 0.6	9.3 ± 0.6	9.3 ± 0.6	9.0 ± 0.6	8.7 ± 1.2	8.3 ± 1.2	8.3 ± 1.2
	<i>D. veneta</i>	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	9.7 ± 0.6	9.7 ± 0.6	9.7 ± 0.6	9.7 ± 0.6	9.3 ± 0.6	8.7 ± 0.6	8.7 ± 0.6

report that under laboratory conditions, *E. fetida* can survive 4.5 years. According to Lofs-Holmin (1985), mortality in the population of *E. fetida* under optimal conditions remains at 0–1% while for *D. veneta* it is 2%. The current research allowed comparing the life expectancy of mature specimens of the studied species. In both cases, animal mortality during the study was 17%, which may indicate their similar life expectancy under the conditions of the study. The mortality of individual earthworms during the experiment was accidental and did not depend on the species.

While analyzing the average number of cocoons found in experimental containers, it was found that this number fluctuated in subsequent weeks of the experiment (*E. fetida*, $F = 7.62$, $p < 0.001$; *D. veneta*, $F = 4.47$, $p < 0.001$). It was observed that the earthworms of both species began to reproduce at the same time. Moreover, they deposited on average two cocoons per week per individual (Table 2). Other studies showed that juveniles appear faster in the earthworm population of *E. fetida* compared to *D. veneta* (Podolak et al., 2019).

Other studies reported that the time necessary to start reproduction can be different even for the individuals of the same species, because it may depend, e.g. on the conditions in the culture. According to Górny (1975), the earthworm species found in litter and in surface soil layers are more exposed to temperature and humidity fluctuations, which is why they make more cocoons than the earthworms penetrating deeper soil layers. Brzeski and Makulec (1994), indicate

that earthworms produce about 40–100 cocoons per year. Larger species behave differently; living in deeper layers of soil, they produce about 5–27 cocoons per year. According to Lofs-Holmin (1985), the *E. fetida* earthworms reach maturity after about 30 days and begin laying cocoons. In the case of the *D. veneta* earthworms, the maturation process is usually longer, so that the first cocoons appear in populations after about 40 days. Dominguez and Edwards (2011a) report that this time for *E. fetida* is about 28–30 days, but for *D. veneta*, it is longer and extended to 65 days. In the present research, the mature specimens were introduced into the experiment, and therefore began to form their cocoons at about the same time.

During the conducted research, it was found that both earthworm species deposited on average about 2 cocoons per week per individual. Other authors (Brzeski and Makulec 1994) report that at the same time as presented in the study, these earthworms can lay up to five cocoons. Similar results are presented by Lofs-Holmin (1985) claiming that *E. fetida* produce on average 6 cocoons per week, whereas in *D. veneta* it is about 5 cocoons. On the basis of the obtained data, it cannot be clearly stated which population produced more cocoons, because relatively large values of standard deviations made it impossible to compare the average number of cocoons deposited by both tested species (Table 2). The number of cocoons may also depend on the type of food supplied. Kostecka (2000) shows that the *E. fetida* earthworms deposited an average of 1.7 ± 1.4 cocoons per week, but the addition of cellulose to

Table 2. Changes in the number of cocoons laid by *E. fetida* or *D. veneta* individual (cocoon·mature individual⁻¹ ± SD) in an annual cycle

Week		0	4	8	12	16	20	24	28	32	36	40	44	48	52	Mean
Cocoon numbers	<i>E. fetida</i>	0	7	6	9	9	10	8	11	9	12	9	7	8	8	8.6 a
		±	±	±	±	±	±	±	±	±	±	±	±	±	±	±
		0	0	1	1	1	1	1	1	2	1	2	2	1	1	2.0
	<i>D. veneta</i>	0	6	7	7	7	10	8	9	7	8	12	10	8	8	8.2 a
		±	±	±	±	±	±	±	±	±	±	±	±	±	±	±
		0	0	0	1	1	1	1	0	1	1	2	2	1	0	1.8

the culture medium increased both their number and weight. In the present research, a similar set of waste was used as food and results similar to those presented by the author were obtained.

According to Górny (1975), the earthworm species found in litter and in surface soil layers are more exposed to temperature and humidity fluctuations, which is why they make more cocoons than the earthworms penetrating deeper soil layers. According to Brzeski and Makulec (1994), the former lay about 40–100 cocoons per year. Larger species behave differently; living in deeper soil layers, they produce about 5–27 cocoons per year. Dominguez and Edwards (2004) report that *E. fetida* can produce 0.35–1.3 cocoons per day, and *D. veneta* 0.28 cocoons during the day, on average.

Body weight/ cocoon weight

The obtained data show a regular increase in the biomass of both populations till 32 weeks of the experiment. The total biomass of the population of *E. fetida* earthworms was lower than the average total biomass of the *D. veneta* earthworm population after 52 weeks (7.263 ± 1.786 g and 18.568 ± 1.867 g, respectively) ($t = 7.58$, $p < 0.01$). The average body weight of mature *E. fetida* after 52 weeks reached more than half of the average body weight of *D. veneta* (0.480 ± 0.006 g and 0.912 ± 0.046 g, respectively) ($t = 15.95$, $p < 0.01$) (Fig. 1).

According to the available publications, the compared species are similar to each other, but *E. fetida* is an earthworm with smaller body sizes; therefore, it achieves a lower average individual

weight than *D. veneta* (Lofs-Holmin 1985). Mature body weights correlate with the data obtained by Dominguez and Edwards (2011a) where the average weight of mature individual *E. fetida* was 0.55 g, and *D. veneta* was 0.92 g.

The body weight of earthworms, as well as the reproduction rate largely depend on the type of food supplied (Sangwan et al., 2008). For example, in the experiment of Garg et al., (2005) the highest mass was reached for the *E. fetida* earthworms processing the sheep manure, and the lowest for the individuals feeding on the horse manure. In other studies (Kostecka, 2000), it was shown that after a year breeding, the body weight of mature *E. fetida* earthworms reached 0.764 ± 0.447 g. In the conducted research, earthworms regularly received the kitchen waste containing boiled potatoes. Additionally, a large living space and lack of density (caused by the removal of cocoons) of animals influenced the value of the obtained body mass.

The earthworms of different species lay cocoons of different shape and size (Kasprzak, 1986, Edwards and Bohlen, 1996, Dominguez and Edwards, 2011a). The current research has confirmed that this is a characteristic feature of each species. The *E. fetida* cocoons were smaller compared to the *D. veneta* cocoons (Fig. 2).

While analyzing the average masses of cocoons from *E. fetida* and *D. veneta* populations, they were found irregular in subsequent weeks of the experiment (Fig. 3) (*E. fetida*, $F = 1.78$, $p > 0.05$, *D. veneta*, $F = 5.88$, $p < 0.01$). Nevertheless, the cocoons laid by *E. fetida* earthworm were lighter compared to the cocoons laid by *D. veneta*

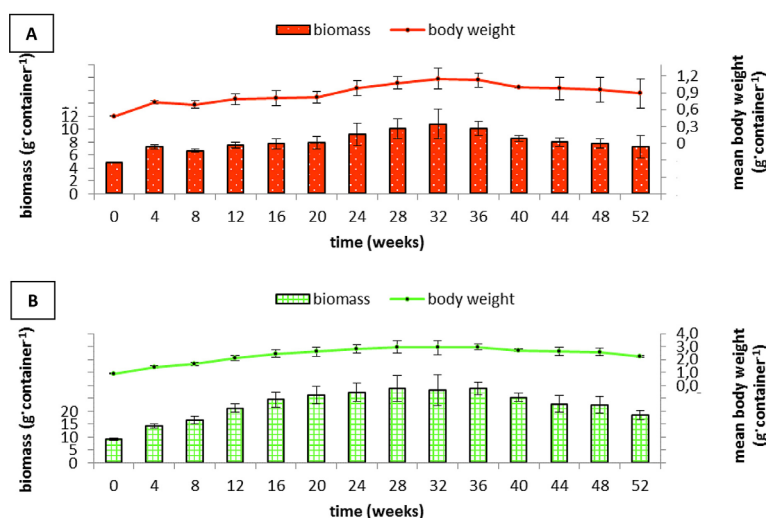


Fig. 1. Changes in biomass of population ($\text{g} \cdot \text{container}^{-1} \pm \text{SD}$) and mean body weight ($\text{g} \cdot \text{individual}^{-1} \pm \text{SD}$) of mature individuals: A) *E. fetida*, B) *D. veneta* earthworm in an annual cycle

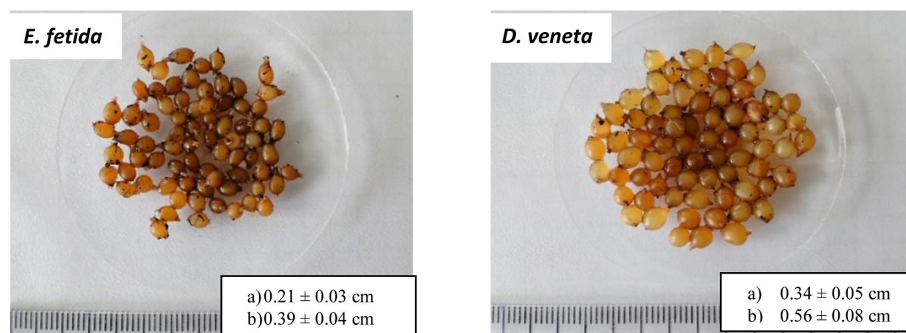


Fig. 2. Cocoons of *E. fetida* and *D. veneta* earthworms (a – width, b – length; $\bar{x} \pm SD$, $n = 50$)

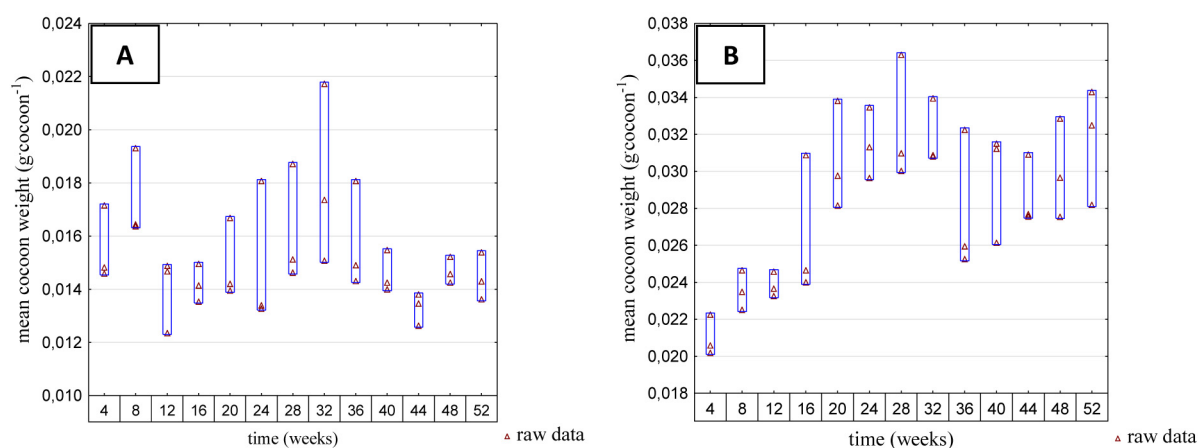


Fig. 3. Change of mean cocoon weight ($\text{g} \cdot \text{cocoon}^{-1}$) of A) *E. fetida* or B) *D. veneta* earthworms in an annual cycle

(0.014 ± 0.001 g; 0.032 ± 0.003 g, respectively $t = 9.15$, $p < 0.01$).

While analyzing the relationship between the average body weight of breeding individuals and the average mass of laid cocoons in the *E. fetida* populations, no such relationship was found ($r_s = 0.209$, $p > 0.05$). Positive moderate correlations of average body weight of mature individuals and the average cocoon weight were found in the population of *D. veneta* earthworms ($r_s = 0.659$, $p < 0.05$). This means that with the growth of the body weight of mature individuals, the mass of a single cocoon increases as well.

CONCLUSIONS

While analyzing the selected features of the studied populations, it was confirmed that the tested species of earthworms differ from each other. After 52 weeks of the experiment, the sum of earthworm biomass was higher for *D. veneta* compared to the *E. fetida* species (18.568 ± 1.867 g, 7.263 ± 1.786 g; $p < 0.01$, respectively). This relationship was confirmed for the average

body weight characteristic of both species of earthworms (*D. veneta*: 0.912 ± 0.046 g; *E. fetida* 0.480 ± 0.006 g; $t = 15.95$, $p < 0.01$). The *D. veneta* earthworm cocoons were larger, which also confirms the interspecies differences (*D. veneta*: 0.032 ± 0.003 g, *E. fetida* 0.014 ± 0.001 g; $t = 9.15$, $p < 0.01$).

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