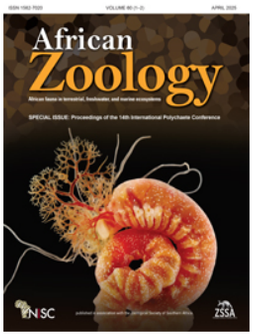

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Life-cycle of the European compost worm *Dendrobaena veneta* (Oligochaeta)

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The life-cycle of *Dendrobaena veneta* was studied to assess the potential of this species in vermiculture. The development, growth and reproduction were investigated by rearing worms at 25°C on urine-free cattle manure with a moisture content of 80% over a period of 200 days. It was found that cocoons are produced at a mean rate of 0,28 cocoons per worm per day and production can be sustained for at least 200 days. The mean incubation period of the cocoons is 42,1 days with a very low hatching success. The mean number of hatchlings per cocoon that hatched was 1,1. Sexual maturity may be attained within 20 to 35 days but some worms take up to 130 days. *Dendrobaena veneta* grew well on cattle manure. This species seems to be less suitable than some other epigeic species for vermiculture, at least in terms of its reproductive capacity in the experimental climatic conditions.

Die lewensloop van *Dendrobaena veneta* is bestudeer ten einde vas te stel wat die potensiaal van hierdie erdwurmspesie is vir sy benutting in vermikultuur. Die ontwikkeling, groei en voortplanting is ondersoek deur die wurms in 'n urienvrye beesmismedium met 'n voginhoud van 80%, by 25°C vir 200 dae te teel. Daar is gevind dat kokonne teen 'n gemiddelde koers van 0,28 per wurm per dag geproduseer word en dat hierdie produksie vir minstens 200 dae kan voortduur. Die gemiddelde inkubasieperiode van die kokonne is 42,1 dae met 'n baie swak uitbroeisukses. Die gemiddelde getal nakomelinge wat per kokon uitgebroei het, was 1,1. Volwassenheid word binne 20 tot 35 dae bereik maar sommige wurms het tot 130 dae geneem om volwasse te word. *Dendrobaena veneta* het goed gegroei op die beesmismedium. Indien die voortplantingspotensiaal van hierdie wurm met dié van ander oppervlakvoeders vergelyk word, lyk dit egter asof dit nie so 'n groot potensiaal het vir vermikompostering as die ander spesies onder dieselfde omgewingstoestande nie.

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With a rapidly expanding world population, and the growing use of intensive animal husbandry, the problem of waste disposal has escalated. According to Hartenstein & Bisesi (1989) it is important to manage animal wastes at minimal cost, on minimal land, with minimal damage to the environment and with the production of a commodity from the waste material. Earthworms are good candidates for fulfilling these requirements (Loehr, Martin, Neuhauser & Malecki 1984) and the use of earthworm biotechnology for the management of organic waste material is therefore receiving increased attention from biologists and agriculturalists (Graff 1974; Schulz & Graff 1977; Sabine 1983; Knieriemen 1985; Haimi & Huhta 1986).

To achieve the best results with vermicultural enterprises the correct species have to be selected. It is necessary to investigate several species of earthworms, as environmental conditions in different parts of the world vary. The optimal requirements of species and their ability to handle different wastes also vary (Knieriemen 1985; Loehr, Neuhauser & Malecki 1985).

Dendrobaena veneta, an earthworm species from the northern hemisphere, is one of the lesser known candidates for vermiculture. After comparing the growth and cocoon production of this species with that of four other candidates for vermiculture, Loehr *et al.* (1985) concluded that it does not have a very high potential in this regard. Their work was, however, done with a very small number of worms on a different type of substrate. Lofs-Holmin (1986) concluded that this species does have potential to combat organic waste problems. The complete life-cycle of *D. veneta* has not been documented yet. We therefore included this species in a comprehensive investigation of earthworm species with a potential for decomposing waste (Reinecke & Venter 1987; Venter & Reinecke 1988; Reinecke & Viljoen 1988; Reinecke & Hallatt 1989; Viljoen & Reinecke 1989a; Hallatt, Reinecke & Viljoen 1990).

A fairly low mean temperature (~ 15°C) is characteristic of the natural habitat of *D. veneta*. To compare its potential with that of other vermicomposting species that we have already investigated and also because of the promising results obtained by Loehr *et al.* (1985) at 25°C, it was decided to study the life-cycle of *D. veneta* at the same temperature (25°C), and under the same conditions as were used for *Eisenia fetida* (Venter & Reinecke 1988), *Eudrilus eugeniae* (Viljoen & Reinecke 1989) and *Perionyx excavatus* (Hallatt, Reinecke & Viljoen 1990).

Materials and Methods

The specimens of *Dendrobaena veneta* used during the present study came from a stock maintained by Prof. O. Graff of Braunschweig, Germany. The experimental work was conducted in an environmental control chamber at a temperature of 25°C and a relative humidity of 80%.

A cattle manure medium, prepared from urine and straw-free cattle droppings, was used as a substrate. It was sun-dried, ground and sieved to a particle size of 500> <1000 µm and wetted with distilled water to a moisture content of 75–80%. This medium was left to stabilize for at least 48 h before the experimental animals were placed into it.

The worms (= 55) were reared in groups of five or ten in plastic containers with gauze lids. Fifty grams of the stabilized culture medium per worm was added when the experiment was started. After 20 days an additional 2,5 g of

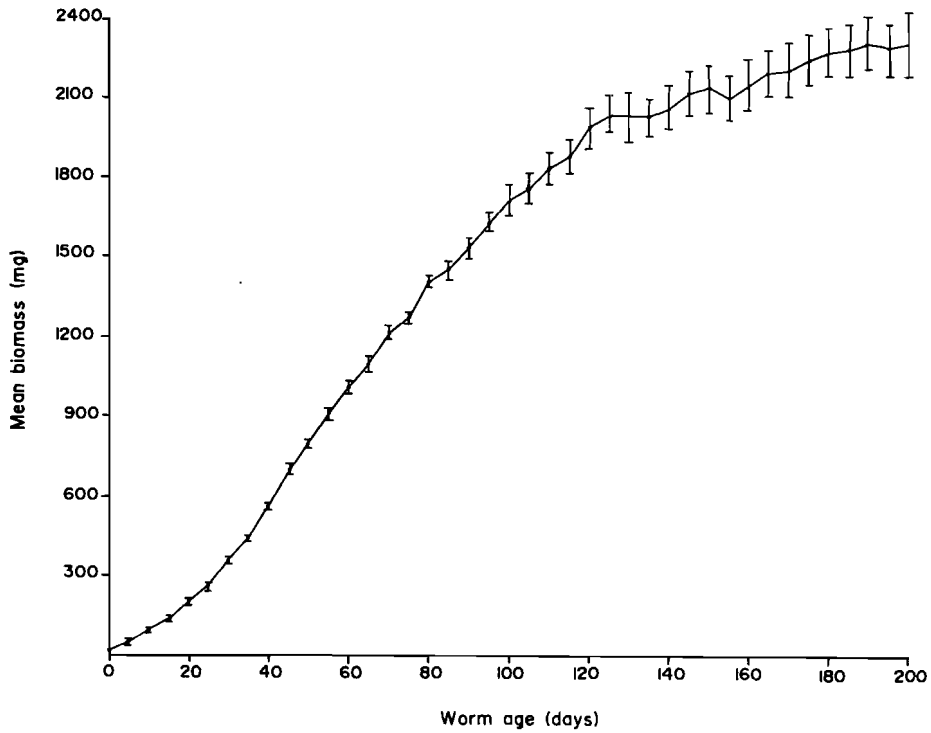

Figure 1 Change in biomass of specimens of *D. veneta* over a period of 200 days — vertical bars represent standard errors.

fresh cattle manure per worm was added; after 30 days a further 10 g of fresh manure per worm was added and this was repeated every 10 days until the end of the experimental period. Some of the older substrate was removed periodically to maintain the original volume of substrate in each container as closely as possible. This was deemed necessary to maintain a constant density–volume ratio and to minimize possible effects of changes in this factor.

The study was started with day-old hatchlings. The biomass of each hatchling was determined before it was placed in the medium and thereafter every five days up to the age of 200 days, when the experiment was terminated. The biomass was determined by removing the worm from the substrate, washing off all particles of medium, removing all water from the surface of the worm with tissue paper and then weighing it in water in a weighing boat on a Sartorius analytical balance.

At each weighing, clitellum development was assessed as a measure of maturation. The containers were examined regularly to observe the process of copulation.

Once clitellums began to develop the medium was searched for cocoons every five days. Cocoons were counted and placed separately into multi-cell containers in the same medium. These cocoons were incubated at 25°C and observed daily for hatchling emergence. The viability and incubation period of the cocoons as well as the number of offspring were determined in this way.

Results

Growth

The growth rate of *D. veneta* over a period of 200 days is illustrated in Figure 1. The mean biomass of newly hatched worms was 23,9 mg for 55 worms. Most of the worms survived and grew well on the cattle manure substrate, but at least one worm in ten did not gain weight and remained much smaller than the rest during their whole life span. None of these smaller worms reached maturity and some did not survive the experimental period. The results obtained for these worms were not used in the final analysis.

The mean growth rate during the first 30 days was slow, about 7,6 mg per worm per day. Thereafter it increased steadily up to a worm age of about 100 days, with a mean growth rate of 19,4 mg per worm per day during this period. After this period of fast biomass increase, growth

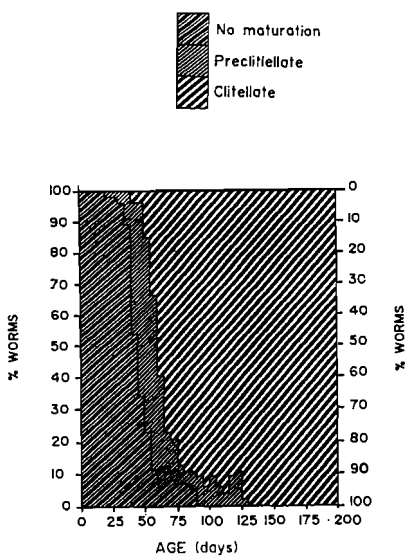

Figure 2 Maturation of specimens of *D. veneta*.

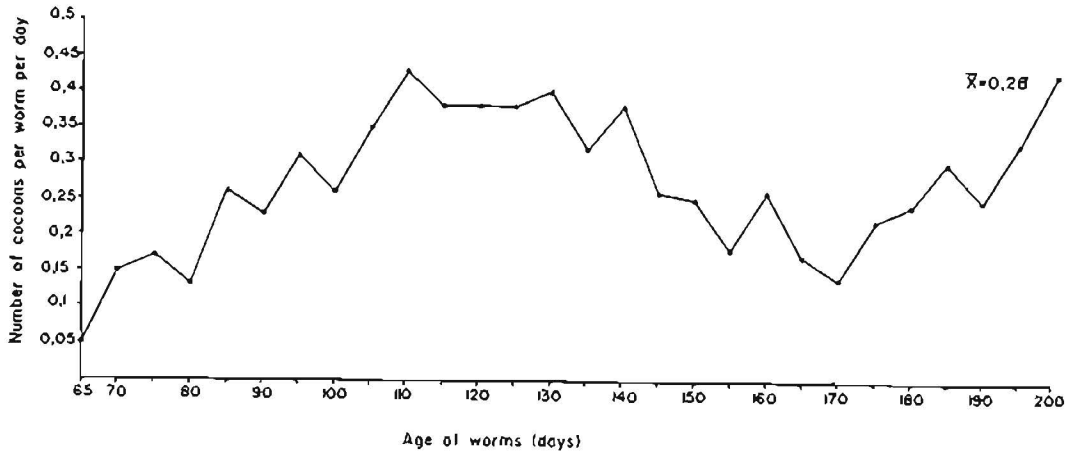

Figure 3 Cocoon production of *D. veneta* specimens over a period of 200 days.

slowed to 9 mg per worm per day between 100 and 140 days and then decreased still more, beginning to stabilize at a mean biomass of about 2200 mg per worm. The highest biomass attained by an individual worm was 3640 mg.

Maturation and copulation

The first indications of clitellum development appeared between Days 20 and 35. The worms were deemed sexually mature when they had fully developed and swollen clitellums. This was reached at Day 30 by some worms. One hundred per cent maturation was attained after 130 days (Figure 2).

Copulation was observed a number of times. In most cases it occurred with the copulating worms lying on the surface of the substrate. A typical mucous band keeps the two worms together during this process.

Cocoon production

The first cocoons were observed on Day 65 (Figure 3). In the period between the first observation of maturation (i.e. at about 30 days) and the beginning of cocoon production, copulation was observed, but it can not be accurately stated how long after copulation cocoon production commenced. During the experimental period the rate of cocoon production varied and cocoon production continued through to the end of the experimental period of 200 days.

A peak cocoon production period occurred between Days 110 and 130, with a mean production rate of 0,4 cocoons per worm per day. Thereafter the production rate fluctuated with the lowest production rate at 170 days, followed by an increase to 0,43 cocoons per worm per day on Day 200. Over the whole study period the mean production rate was 0,28 cocoons per worm per day.

It was noted that all the cocoons of *D. veneta* occur within clumps of substrate (Figure 4a), and often more than one cocoon can be found in the same clump. Ramisch & Graff (1985) made extensive observations of the phenomenon in Lumbricidae and concluded that the principal importance lies in protection against loss of water. The cocoons are smooth and oval in shape with one end sharply pointed and the other more blunt. The colour of the cocoons changed markedly with ageing, the freshly formed cocoons

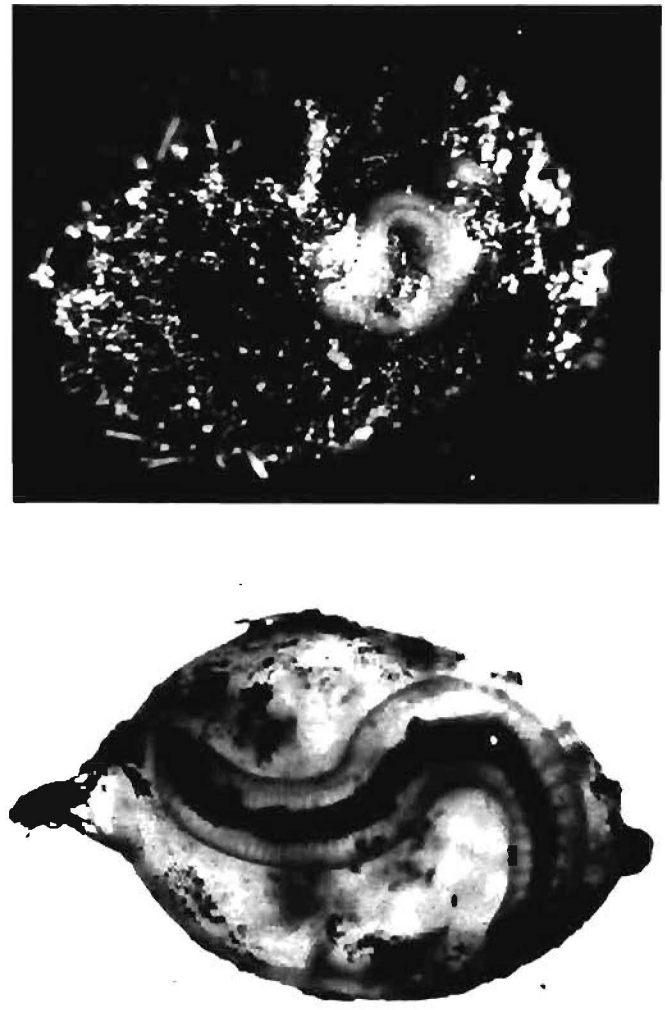

Figure 4 4.1 Cocoon of *D. veneta* in a lump of substrate.
4.2 Micrograph of a cocoon of *D. veneta*.

having a light greenish yellow colour, changing to light brown, reddish brown, dark brown and black, with age. Cocoons in which embryos did not develop retained their light colouring.

The cocoons are extremely fragile, making them difficult

to handle. The walls of the cocoons are thin, making it possible to observe the development of the embryos and young worms inside the cocoon, using a stereo microscope (Figure 4b). Because of the fragility of the cocoons, weighing and measuring was not attempted and these parameters were not used during the study.

Hatching success, incubation period and number of offspring

Of the 643 cocoons incubated, a hatching success of only 19,6% was obtained at the constant temperature of 25°C. The incubation period varied from 15 to 80 days with a mean of 42,1 ± 1,03 days (Figure 5).

The number of hatchlings produced by all the cocoons that hatched was 1,1 ± 0,05 hatchlings per cocoon. The largest number of hatchlings to emerge from a single cocoon was two (8%). Ninety-two per cent of the cocoons produced only one hatchling (Figure 6). Upon emergence of the hatchlings from the cocoon they had a pink colour and the segments were well differentiated.

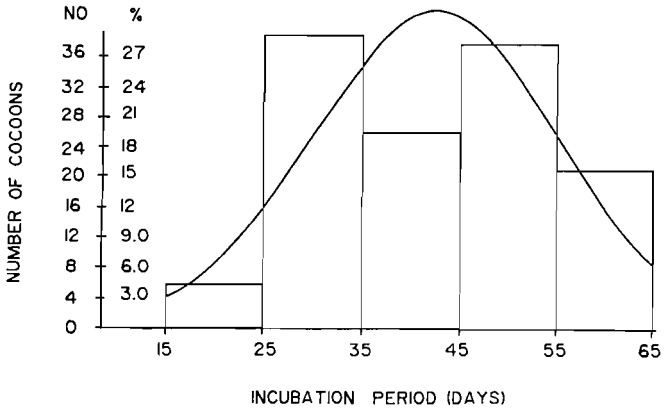

Figure 5 Incubation period of cocoons of *D. veneta*. Mean = 42,1 ± 1,03 days; n = 643.

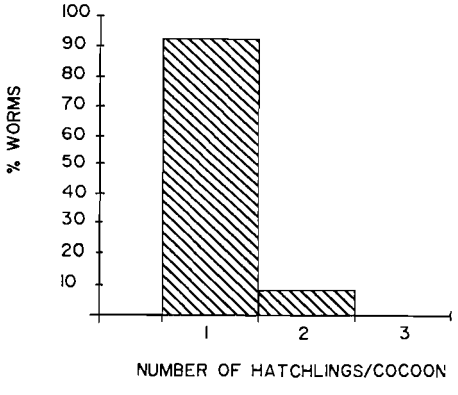

Figure 6 Percentage occurrence of number of offspring of *D. veneta* per cocoon. Mean number of hatchlings per cocoon = 1,1 ± 0,05; n = 138.

Discussion

Growth

The population of *D. veneta* studied exhibited a typical sigmoid growth pattern (Figure 1), indicating that the environmental conditions were close to optimum and that the duration of the study period was not too short for this particular species. This growth pattern compares well with that found by Loehr *et al.* (1985) but the growth rate was higher in the latter case, with maximum biomass being attained after 120 days, while the highest mean biomass during our study was recorded on Day 200.

Loehr *et al.* (1985) however, used sludge as substrate and they did not mention other environmental factors, except for the temperature at which the growth study was conducted. Earthworms grow differently on different substrates (Neuhauser, Kaplan, Malecki & Hartenstein 1980) and this might explain the differences between the results of the two studies. Although the influence of moisture on the growth of *D. veneta* has not yet been studied, similar studies on other earthworm species show that moisture availability has a major influence on growth rate (Reinecke & Venter 1985; Viljoen & Reinecke 1989b; Viljoen & Reinecke 1990). Moisture availability during our experiment was probably different from that in the study by Loehr *et al.* (1985) and this could explain the differences in the results of the two studies. It has been suggested that moisture could affect food utilization by earthworms (Reinecke & Venter 1987) and therefore influence growth.

The growth rate of *D. veneta* during the present study compared favourably with that of the other vermicomposting species *E. fetida* (Venter & Reinecke 1988) and *P. excavatus* (Hallatt *et al.* 1990), but was somewhat lower than that of *E. eugeniae* (Viljoen & Reinecke 1989a) on the same substrate and under the same environmental conditions.

Maturation

Reared under the conditions mentioned, the individual worms varied considerably in the time needed to reach maturity. The first indication of clitellum development was at the age of 30 days and the last worms attained maturity after 130 days although all were kept under the same conditions and at the same densities. This differs from the other vermicomposting species studied. All specimens of *E. eugeniae* were mature after 45 days (Viljoen & Reinecke 1989a), 28 days were needed for maturation of *P. excavatus* (Hallatt *et al.* 1990) and all specimens of *E. fetida* had well-developed clitellums after 80 days (Venter & Reinecke 1988). Loehr *et al.* (1985) did not mention maturation in their paper, but they noted that *D. veneta* began to produce cocoons only after 170 days, indicating that the worms might have taken longer to reach maturity than in our study. It has been shown that feeding status and the pattern of feeding could influence the rate of maturation in earthworms (Reinecke & Viljoen 1990).

Cocoon production

The mean rate of cocoon production, 0,28 cocoons per day, was lower than that of some other epigeic earthworm species. The maximum production of 0,43 cocoons per worm per day was much lower than the 1,65 of *E. eugeniae* (Viljoen & Reinecke 1989a), and the 1,1 of *P. excavatus* (Hallatt *et al.* 1990), but compare favourably with the 0,35

of *E. fetida* (Venter & Reinecke 1988).

Although there were fluctuations in the cocoon production rate, production was continuous after its commencement on Day 65. During the study by Loehr *et al.* (1985) cocoon production was also low, i.e 0,7 per worm per day, with cocoons produced for the first time on Day 170.

Hatching

The very low hatching success of 19,6% obtained during the present study cannot be explained readily and requires further investigation. Apart from the direct role of the substrate during incubation, low hatching success could also be attributed to the fact that cocoons were incubated at 25°C. This temperature is much higher than the expected optimum temperature for this species.

Loehr *et al.* (1985) obtained a very high hatching percentage (78%) but made no mention of the medium used for the incubation of the cocoons. They incubated the cocoons at 25°C. The number of hatchlings per cocoon that hatched during their study was, however, the same as was found during the present study, i.e. 1,1 hatchlings per cocoon that hatched. This compares favourably with that of *P. excavatus* but is much less than that of *E. eugeniae* and *E. fetida*.

Life-cycle and vermicomposting potential

Our data show that *D. veneta*, in comparison with other epigeic, vermicomposting species, has a fairly long life-cycle when reared on a cattle manure substrate. This life-cycle is presented diagrammatically in Figure 7.

The duration of the life-cycle described here will of course be dependent on the various abiotic factors and on the quality of the organic material used as feeding medium. This worm species grew well at a temperature (25°C) higher than that normally occurring in its natural habitat (15°C). It is, however, possible that some reproductive functions are affected by the higher temperatures, explaining the lower hatching success and lower cocoon production rate compared with the results of Loehr *et al.* (1985).

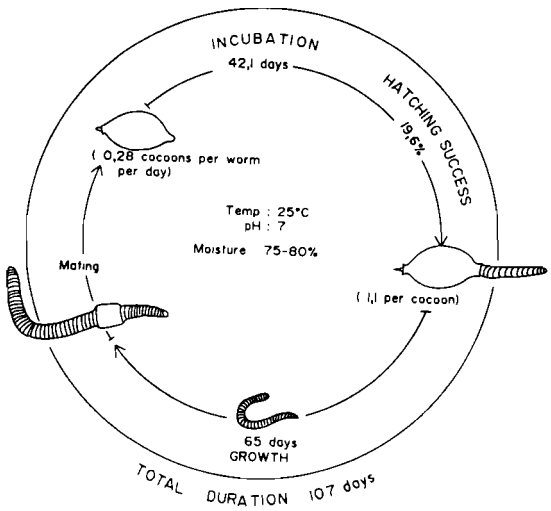

Figure 7 Diagram of the life-cycle of *D. veneta* at 25°C in cattle manure with a moisture content of 75–80%.

Comparing the overall reproductive capacity and growth with that of other detritus feeding species, *D. veneta* seems to be less suitable for vermiculture at 25°C, in terms of its reproductive rate and its ability to colonize organic waste, but no account is taken of the species' activity in the substrate or the rate at which the substrate is worked through.

Acknowledgements

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