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Seasonal effects on growth and reproduction of *Eisenia fetida* and *Eudrilus eugeniae*

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Abstract

An experiment was conducted during the winter and summer seasons at Sylhet Agricultural University (SAU), Sylhet, Bangladesh, to examine the seasonal variations in the life cycle, growth, and reproduction of two epigeic earthworm species, *Eisenia fetida* and *Eudrilus eugeniae*. Earthworm species were reared in plastic containers filled with cow dung as the feeding medium, maintaining a moisture level of 60%–80%. Growth and reproductive characteristics were recorded at various stages. The results indicated that *Eisenia fetida* exhibited a longer incubation period (24±4.69 and 23.0±4.16 days), a higher number of hatchlings per cocoon (2.4±1.19 and 2.7±0.96), and greater hatching success rates (82.5% and 87.5%) during both winter and summer seasons, respectively. In contrast, *Eudrilus eugeniae* attained the greatest body length (12.98±0.69 cm and 13.09±0.54 cm per worm) and the highest weight (775.67±66.40 mg and 703.5±55.56 mg per worm) in winter and summer, respectively. Both species reached sexual maturity relatively earlier in winter. Additionally, *E. fetida* produced a higher number of cocoons per worm per week (2.35 ± 0.30 in winter and 3.00 ± 1.35 in summer). Cocoon production per worm per week in *E. fetida* showed a significant positive correlation with temperature (r=0.61**) during winter.

Keywords: Seasonal effects, life cycle, growth, reproduction, *Eisenia fetida, Eudrilus eugeniae.*

Introduction

Earthworms are important soil organisms, usually found in different ecosystems (tropical and temperate regions) around the world (Byambas et al., 2019; Kahneh et al., 2022). They have a significant role in changing the structure of the soil, influencing soil properties, hastening organic matter degradation, promoting soil ecosystems, and adding value to nutrient cycling in soil-plant systems (Hättenschwiler and Gasser, 2005; Baker, 2007; Blouin et al. 2013; Radaei and Izadi, 2016; Lavelle et al. 2016; Yahyaabadi et al., 2018). There are more than 8300 species of earthworms within the class Oligochaeta (Reynolds and Wetzel, 2004) and among them, more than 4,000 species have been described and many are still unknown (Fragoso, 2001). Earthworms are categorized into three ecological types based on their morphological characteristics, habits, and soil location: epigeic, endogeic, and anecic (Bouche, 1977), and grouped into 13 families (Byambas et al. 2019). Epigeic earthworms consume and decompose organic waste materials and live near the soil surface or surface litter. *Eisenia fetida* and *Eudrilus eugineae* are two common epigeic earthworms found in vermiculture and vermicomposting facilities around the world. *E. fetida* is generally referred to as redworm or red wiggler worm, although it is also known as brandling worm, panfish worm, trout worm, tiger worm, and other names. The adult worms have a length of 7-9 cm, a diameter of 3-5 mm, and individual weight of 500-600 mg (Venter and Reinecke, 1988). This worm is captivated by rotting vegetation and is used in both domestic and industrial vermicomposting. *E. eugeniae* is popularly known as the 'African Night Crawler,' is a reddish- brown large worm that grows rapidly and reasonably prolifically at temperatures ranges from 25°C to 30°C (Viljoen and Reinecke, 1992; Segun, 1998). Vermiculture and vermicomposting is

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getting popular day by day at farmers' level in Bangladesh. *Eisenia fetida* and *Eudrilus eugeniae,* these two earthworms species are the most commonly rearing species. Understanding the influence of seasonal variations on the biological parameters of these two epigeic earthworms is crucial for optimizing their commercial culture and ensuring sustainable vermiculture practices. Temperature and moisture fluctuate across seasons, significantly affecting earthworm growth rates, reproductive efficiency, and overall survival. A comprehensive evaluation of these factors can provide valuable insights into species-specific adaptations and resilience, ultimately aiding in the development of strategies to maximize biomass production, cocoon viability and vermiculture business. Moreover, such studies can contribute to refining organic waste decomposition efficiency and soil health improvement through vermicomposting under varying environmental conditions. Few studies have comprehensively evaluated the seasonal impact on the life cycle, growth and reproduction of epigeic earthworms in tropical climates. Said research gaps are needed to be addressed to boost up vermicomposting process. Hence, the current study was undertaken to see the seasonal variations (winter and summer seasons) on life cycle, growth, and reproduction of the two vermicomposting earthworms species (*Eisenia fetida* and *Eudrilus eugeniae*).

Material and Methods

The experiment was conducted over two seasons at the vermicompost production shed and the laboratory of the Department of Soil Science in Sylhet Agricultural University, Sylhet. The experiment was started in the winter season from November 2021 and ended up April 2022. Later it was repeated in summer season, from March 2022 to August 2022.

Collection of earthworms and feeding material

Eisenia fetida and *Eudrilus eugeeniae* were used from the stock in the vermicompost production shed. The earthworm species were reared in plastic containers filled with cow dung as the feeding medium, with moisture levels maintained at 60%–80%. During winter, the ambient temperature in the vermicompost shed varied between 16°C and 25°C, while in summer, it ranged from 17°C to 36°C. The ambient humidity in the vermicompost shed ranged from 40% to 60% during the winter season and from 60% to 80% during the summer. Cowdung was pre-decomposed for 30 days and loosened properly before being used as a nutritive medium for the earthworms.

Treatments of the experiment

The experiment was designated with the following two species of earthworm - T_1: *Eisenia fetida*, T_2: *Eudrilus eugeniae*

Experimental design

The experiment was conducted following a completely randomized design (CRD) with four replications. Initially, petri-dishes were used for keeping cocoons during the determination of the incubation period. Later, plastic containers were also used to rear the hatchlings of both earthworm species. Height of the plastic containers was 20 cm with 28 cm in diameter.

Experimental details

The experiment was carried out in four distinct steps. The first step was intended to determine the duration of cocoon incubation. Initially, ten newly laid cocoons of each earthworm species were collected from the stock. Collected cocoons were placed on petri-dishes (ten cocoons per petri-dish) to clearly observe the hatching process and emergence of hatchlings. The number of hatchlings cocoon^{-1} as well as their length and weight were also recorded.

The hatching success (%) was computed as follows:

$$\text{Hatching success (\%)} = \frac{\text{Number of cocoons hatched}}{\text{Number of cocoons incubated}} \times 100$$

The second step included the measurement of the length and weight of earthworms at seven-day intervals. Firstly, ten new-born hatchlings of each earthworm species were inoculated on each replication containing 100 g of cowdung after their length and weight had been determined individually. After four weeks, when they had reached juvenile status, they were transferred to new plastic bowls containing cowdung based feed medium (1kg). Thereafter, length and weight of both earthworm species were recorded at seven-day intervals till the end of the experiment. The temperature and moisture content of cowdung of each plastic bowl was also recorded at the same time. The moisture content of 60%–80% was maintained by spraying water as per requirement. During collecting weekly data, the approximate timing of clitellum development was also observed. Hand sorting was used to separate the earthworms from the feeding material after the cowdung was removed from the plastic bowl. After separating them, the development of clitellum,

commencement of cocoon production in each earthworm species was monitored with naked eyes at seven-day intervals.

The third step was aimed to investigate the cocoon production of two earthworm species. Number of cocoons was recorded weekly basis by hand sorted process. Thus, the rate of cocoons production worm^{-1} day^{-1} was calculated as follows and expressed numerically.

$$\text{Rate of cocoon production (cocoon/worm/day)} = \frac{W2 - W1}{T2 - T1}$$

Where, W1= Initial number of cocoons at the first day of cocoon production; W2= Total cocoons number at the end of the experiment; T1= Age of the earthworms at the first day of cocoon production (in days), and T2= Age of the earthworms at the end of the experiment (in days)

Following collection, cocoons were initially kept on a small plastic bowl containing water. The fourth step was included to observe the morphological characteristics of cocoons using a magnifying glass. Before measuring the length and weight, the cocoons were lightly washed with water and dried with tissue paper to remove any debris that had adhered to the sticky hull. The duration of life cycle was measured for both earthworms species from cocoon to cocoon production. Data on different parameters were statistically analyzed using the computer-based statistical program R software version 4.2.1 in accordance with the basic principles outlined by Gomez and Gomez (1984) whereas means were adjudged by LSD test.

Results

Incubation period and hatching performance of cocoons in winter and summer

During winter and summer, incubation period, hatchlings number cocoon^{-1}, and hatching success (%) had not varied significantly for two earthworm species (Table 1).

Table 1. Incubation period and hatching performance of cocoons in winter and summer season

Earthworm species	Incubation period (days)	Hatchlings number cocoon^{-1}	Hatching success (%)
Winter season			
E. fetida	24 ± 4.69	2.4 ± 1.19	82.5
E. eugeniae	21.5 ± 4.00	2.0 ± 1.31	75
LS	NS	NS	-
CV (%)	21.30	64.52	-
Summer season			
E. fetida	23.0 ± 4.16	2.7 ± 0.96	87.5
E. eugeniae	19.75± 4.57	2.2 ± 0.67	80
LS	NS	NS	-
CV (%)	20.45	46.28	-

All values were introduced as the mean ± SD (standard deviation), LS = Level of significance, CV = Co-efficient of variance, NS = Non significant

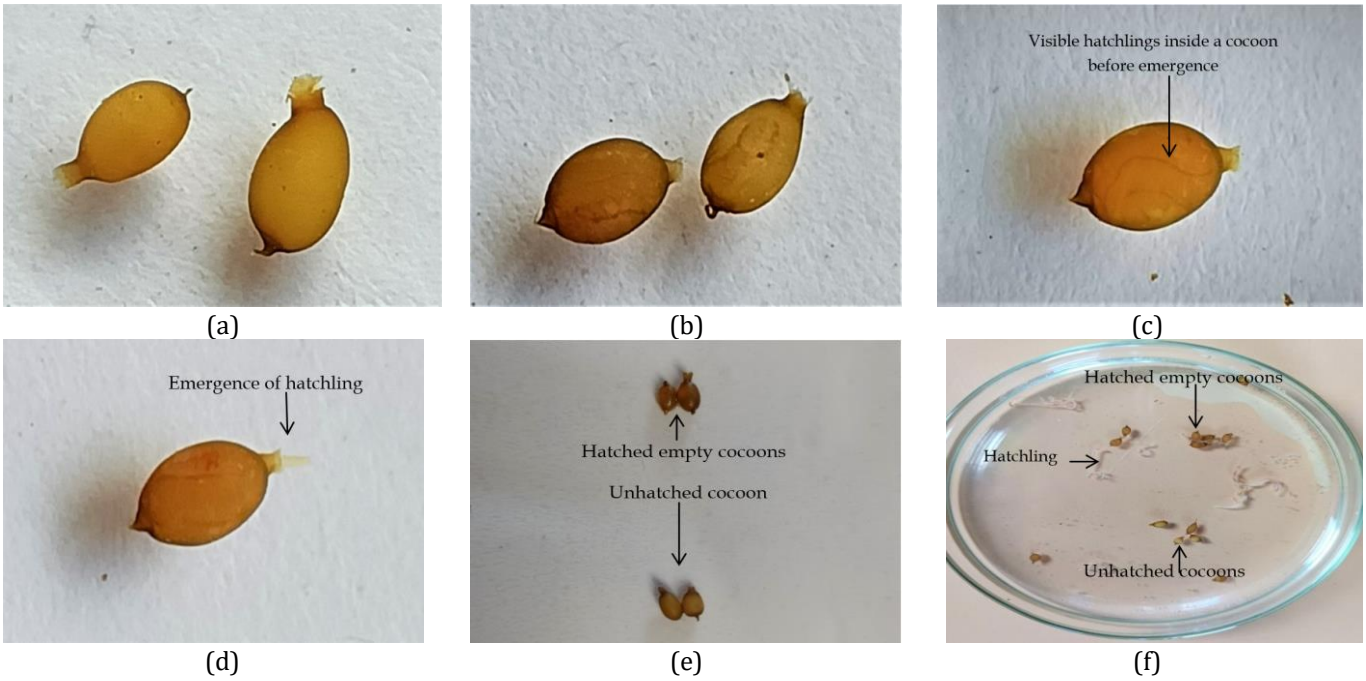
The transformation process of cocoon to hatchling has shown in Figure 1. During incubation period, the cocoons were hardened gradually after emergence and turned brownish. The brown color became deeper over time, eventually turned dark brown just before hatching.

Weekly change in the length of two earthworm species during winter and summer

Significantly greater length was recorded in *Eudrilus eugeniae* compared to *Eisenia fetida* across all measurement dates during both seasons (Figure 2). In winter, *E. fetida* reached its longest length (10.09 ± 0.42 cm worm^{-1}) at the 13th week, while *E. eugeniae* achieved its longest length (12.98 ± 0.69 cm worm^{-1}) at the 16th week. In summer, *E. fetida* reached its longest length (10.05 ± 0.69 cm worm^{-1}) at the 15th week, and *E. eugeniae* attained its longest length (13.09 ± 0.54 cm worm^{-1}) at the 16th week. After reaching their maximum length, the growth of both earthworm species slowed down, remaining relatively stable till the 22nd week.

Weekly change in the weight of two earthworm species during winter and summer

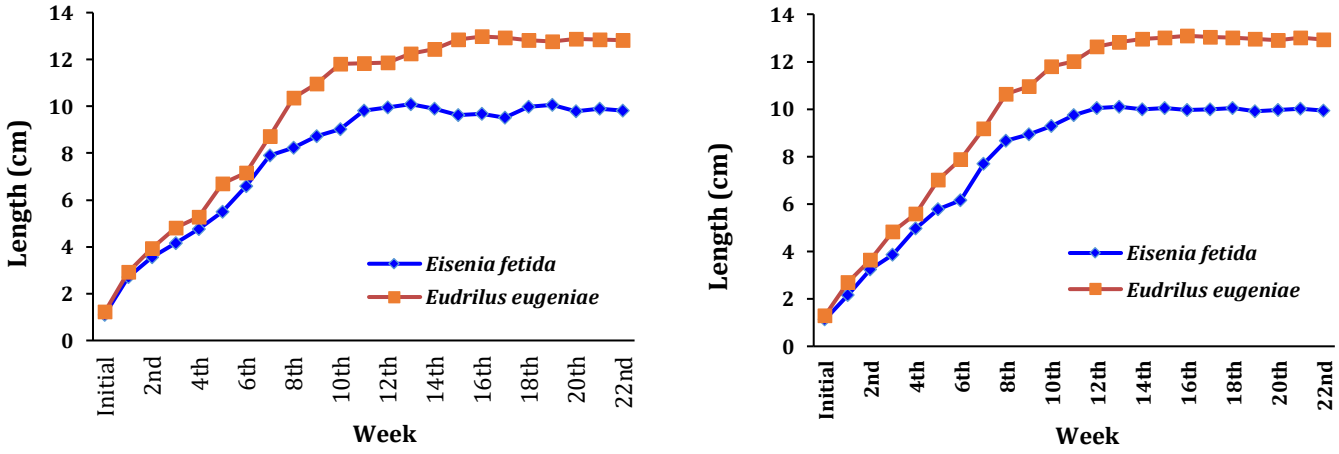
Eudrilus eugeniae consistently attained significantly higher weight than *Eisenia fetida* at all measurement dates during both seasons (Figure 3). In winter, the highest weight for *E. fetida* was recorded at the 14th week (565.2 ± 17.32 mg worm^{-1}), while *E. eugeniae* reached its highest weight of 775.67 ± 66.40 mg worm^{-1} at the 15th week. In summer, *E. fetida* attained its highest weight of 516.45 ± 19.89 mg worm^{-1} at the 15th week, whereas *E. eugeniae* achieved its highest weight of 703.5 ± 55.56 mg worm^{-1} at the 16th week. After reaching their peak weight, both earthworm species exhibited a gradual decline in weight till the 22nd week in both seasons.



(a) (b) (c)

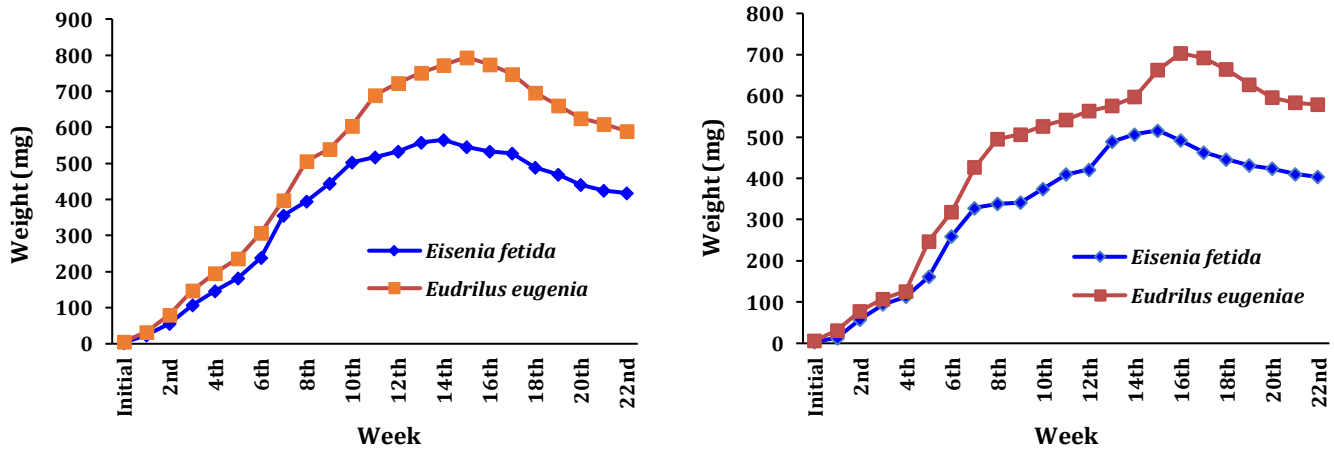
(d) (e) (f)

Figure 1. (a) Cocoons become deeper in colour over time (b) Cocoons turned dark brown just before hatching (c) Cocoon just before emergence of cocoon , (d) Emergence of hatchling from cocoon (e) Hatched and unhatched cocoons (f) Hatched cocoons, unhatched cocoons and hatchlings in a petri-dish



(a) (b)

Figure 2. Weekly change in the length of two earthworm species in (a) winter and (b) summer



(a) (b)

Figure 3. Weekly change in the length of two earthworm species in (a) winter and (b) summer

Percentage of clitellum development at different week during winter and summer

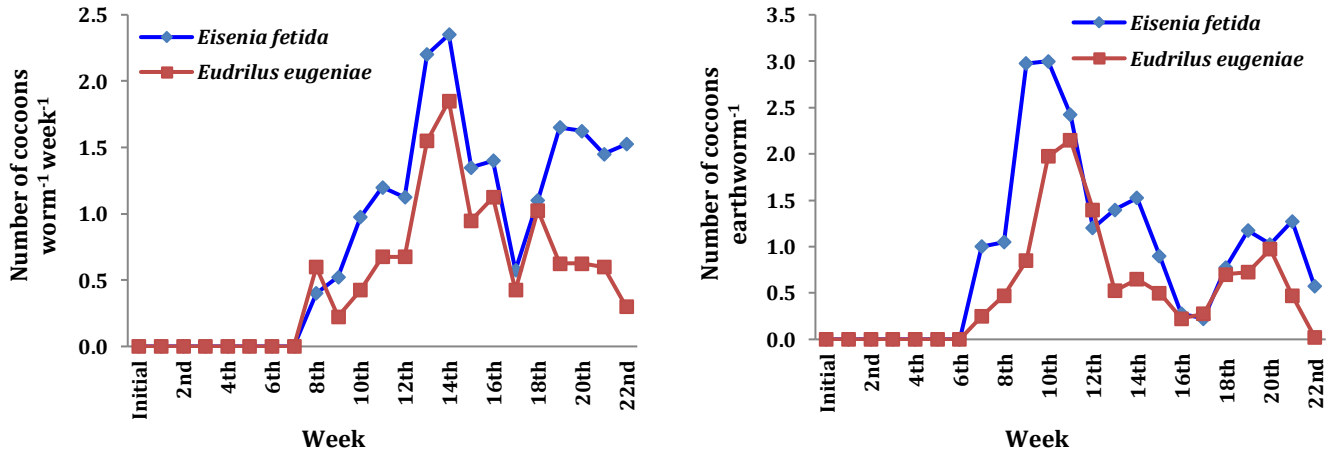
A number of worms of *E. fetida* and *E. eugeniae* started to develop clitellum from 7th week and completed (100%) within 10th and 12th week, respectively during winter (Table 2). In summer, a number of *E. fetida* worms (27.5%) began to develop clitellum as early as the 6th week, and completed (100%) within 7th week. In case of *E. eugeniae*, a few numbers of worms (17.5%) began to develop clitellum at 6th week, and completed (100%) within 8th week.

Table 2. Percentage of clittelum development in two earthworms species during winter and summer season

Earthworm species	Weeks						
	6th	7th	8th	9th	10th	11th	12th
				(%)			
Winter season							
Eisenia fetida	-	40	70	92.5	100	100	100
Eudrilus eugeniae	-	35	55	62.5	70	75	100
Summer season							
Eisenia fetida	27.5	100	100	-	-	-	
Eudrilus eugeniae	17.5	95	100	-	-	-	

Weekly cocoon production by two earthworm species in winter and summer

The number of cocoons worm^{-1} week^{-1} was recorded significantly higher in *E. fetida* over *E. eugeniae* at all the dates in both seasons (Figure 4). During winter, cocoon production worm^{-1} week^{-1} by *E. fetida* and *E. eugeniae* was initially followed an increasing trend and then a zigzag trend till 22nd week. The highest number of cocoon worm^{-1} week^{-1} in *E. fetida* (2.35 ± 0.30) and *E. eugeniae* (1.85 ± 1.73) had laid on 14th week. The total number of cocoons worm^{-1} (19.22 ± 2.83) and rate of cocoon production (0.18 ± 0.02 cocoon worm^{-1} day^{-1}) was observed significantly higher in *E. fetida* over *E. eugeniae* (Table 3).



(a) (b)

Figure 4. Weekly cocoon production by two earthworm species in (a) winter and (b) summer

During summer, higher number of cocoons was significantly produced in *E. fetida over E. eugeniae* at most of the dates (Figure 4). Cocoon production worm^{-1} week^{-1} by *E. fetida* and *E. eugeniae* was initially followed an increasing trend and then a zigzag trend till 22nd week. In *E. fetida,* the highest number of cocoon worm^{-1} week^{-1} of 3.0 ±1.35 was recorded at 10th week whereas *E. eugeniae* laid the highest number of cocoon worm^{-1} week^{-1} of 2.15 ± 0.54 at 11th week. Table 3 shows that *E. fetida* had significantly a higher total number of cocoons worm^{-1} (20.80 ± 2.88) and rate of cocoon production (0.19±0.02 cocoon worm^{-1} day^{-1}) than *E. eugeniae*. After completing mating process, both earthworms species were laid cocoons within feeding materials and then cocoons were separated through hand sorting (Figure 5).

Effect of temperature on cocoon production during the winter and summer

During winter, both earthworm species had a significant positive correlation between temperature and the number of cocoon production worm^{-1} week^{-1} (Figure 6). Cocoon production in *E. fetida* showed higher positive correlation with temperature (r = 0.61**) than in *E. eugeniae* (r = 0.55**).

During summer, both earthworm species showed non-significant positive correlation between temperature and the number of cocoons produced worm^{-1} week^{-1} (Figure 6). Numerically, cocoon production in *E. fetida* relatively had a higher positive correlation with temperature (r = 0.31) than *E. eugeniae* (r = 0.27).

Table 3. Cocoon production by two earthworm species in the winter and summer

Earthworm species	Total no. of cocoons produced worm^{-1}	Highest no. of cocoon produced worm^{-1} week^{-1}	Rate of cocoon production (cocoon worm^{-1} day^{-1})
Winter season			
Eisenia fetida	19.22 ± 2.83	2.35 ± 0.30	0.18 ± 0.02
Eudrilus eugeniae	11.83 ± 1.29	1.85 ± 0.17	0.12 ± 0.01
LS	**p<0.01	*p<0.05	**p<0.01
CV (%)	15.52	11.66	14.90
Summer season			
Eisenia fetida	20.80 ± 2.88	3.00 ± 1.35	0.19 ± 0.02
Eudrilus eugeniae	11.98 ± 1.03	2.15 ± 0.54	0.12 ± 0.01
LS	**p<0.01	*p<0.05	**p<0.01
CV (%)	13.21	12.36	13.91

All values were introduced as the mean ± SD (standard deviation), LS = Level of significance, CV = Co-efficient of variance, NS = Non significant, '*' = Significant at 5% level of probability, '**' = Significant at 1% level of probability

Table 4. Morphological features of cocoons of two earthworms species in winter season

Parameters	*E. fetida*	*E. eugeniae*
Shape	Oval to irregular oval	Oval to irregular oval
Ornamentation	Bristle at one end and other end pointed	Bristle at one end and other end pointed
Colour	Light yellowish	Light straw
Frequency of cocoon production	Continuous	Continuous
Winter season		
Length range (mm)	3.0-4.7	3.1-4.5
Mean length (mm)	4.02 ± 0.45	3.93 ± 0.39
Fresh weight (mg cocoon^{-1})	12.67 ± 0.62	12.30 ± 0.67
Summer season		
Length range (mm)	3.2-5.3	3.0-4.9
Mean length (mm)	4.08 ± 0.69	4.02 ± 0.37
Fresh weight (mg cocoon^{-1})	12.70 ± 0.29	12.25 ± 0.31

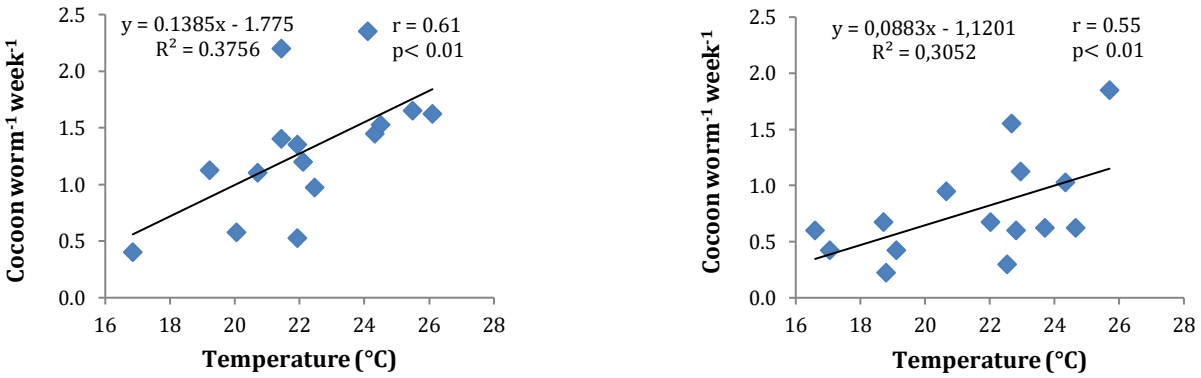

(a)

(b)


(c)

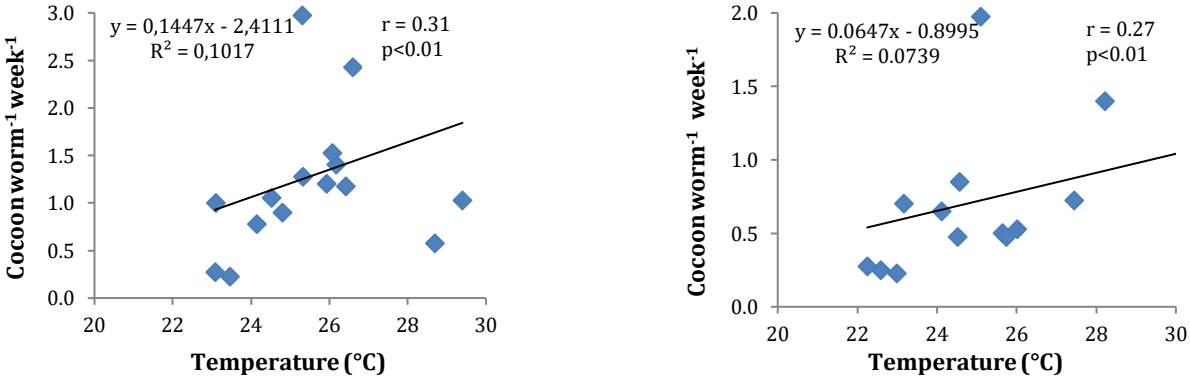

(d)

Figure 5. (a) Mating of earthworms (*E. fetida*), (b) Separating cocoons from cowdung by hand sorting, (c) Cocoons of *E. fetida,* (d) Cocoons of *E. eugeniae*



(a) (b)

Figure 6. Correlation between temperature and number of cocoon production worm^{-1} week^{-1} for (a) *E. fetida* and (b) *E. eugeniae* in winter



(a) (b)

Figure 7. Correlation between temperature and number of cocoon production worm^{-1} week^{-1} for (a) *E. fetida* and (b) *E. eugeniae* in summer

Life cycle of *Eisenia fetida* and *Eudrilus eugeniae*

The life cycle of *Eisenia fetida* and *Eudrilus eugeniae* is illustrated in Figures 8 and 9. The incubation period for cocoons was longer in *E. fetida*. Hatchlings of both species transitioned to the juvenile stage within four weeks, reaching sexual maturity within 7–10 weeks in winter and 6–7 weeks in summer. Once sexually mature, the earthworms developed a clitellum and initiated mating. Cocoon production began one week after clitellum formation in mature earthworms.

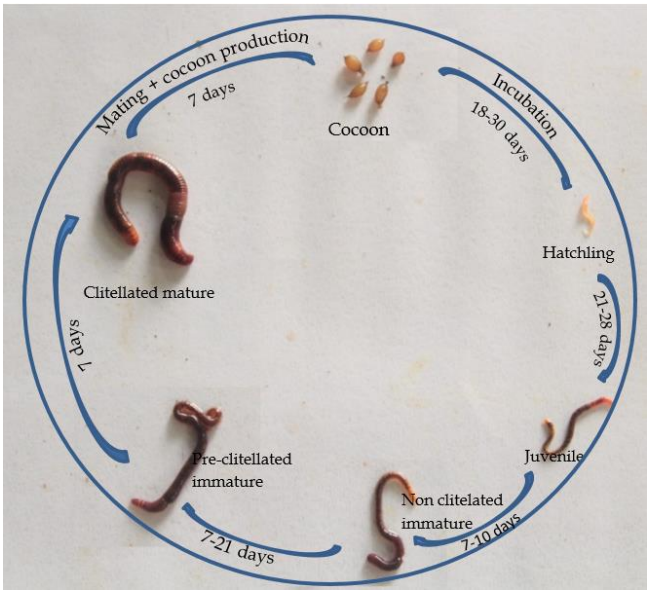


Figure 8. Life cycle of *E. fetida*

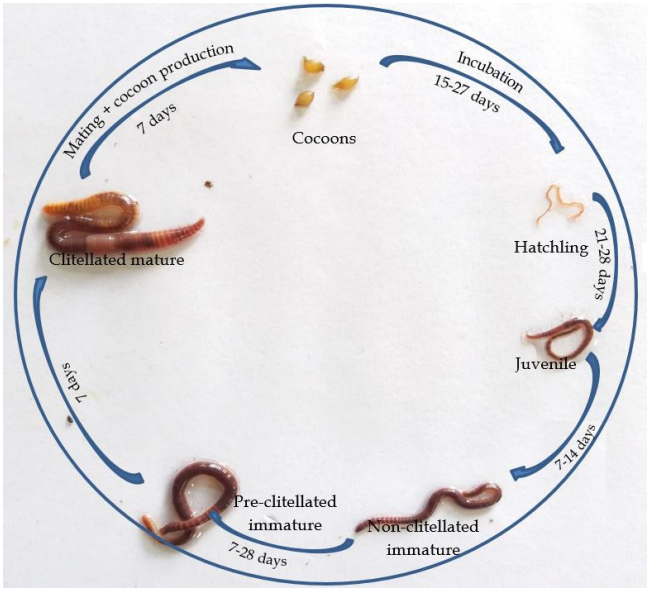


Figure 9. Life cycle of *E. eugeniae*

Life cycle of *Eudrilus eugeniae*

Figure 9 depicts the life cycle of *E. fetida*. Incubation time for *E. eugeniae* cocoons ranges from 21.5 ± 5.00 and 19.75 ± 4.57 days in winter and summer, respectively. Hatchlings become juvenile within 4 weeks and attain sexual maturity within 6 to 12 weeks in winter and within 6-8 weeks in summer. Then, with the development of clitellum, sexually matured earthworms began to mate. Cocoon formation starts within one week after clitellum development in mature earthworms.

Discussion

Incubation period, hatching success, and hatchlings number

The present study revealed that *Eisenia fetida* had a longer incubation period and a higher cocoon hatching success rate than *Eudrilus eugeniae* in both seasons. The hatching success of cocoons for both species was greater in summer than in winter, likely due to the higher temperatures (20–30°C) in summer, which were more favorable compared to the winter temperatures (15–26°C). The incubation period observed for *E. fetida* was consistent with the findings of Bondhare and Desai (2019), while the incubation period for *E. eugeniae* closely aligned with the results reported by Parthasarathi (2007).

The results indicated that temperature influenced the number of hatchlings per cocoon. In *Eisenia fetida*, the number of hatchlings per cocoon was recorded as 2.4 ± 0.96 in winter and 2.7 ± 1.19 in summer. Venter and Reinecke (1988) reported a similar hatchling count of 2.7 for *E. fetida*, whereas higher values of 3.5 and 3.8 were observed by Graff (1982) and Loehr et al. (1985), respectively. For *Eudrilus eugeniae*, the average number of hatchlings per cocoon was 1.9 ± 1.31 in winter and 2.2 ± 1.19 in summer. Previous studies reported hatchling numbers of 2.2 (Graff, 1982), 2.5 (Loehr et al., 1985), and 2.7 (Knieriemen, 1984) for *E. eugeniae*, all of which closely align with the findings of the present study.

Growth

Eudrilus eugeniae exhibited significantly greater length and weight than *Eisenia fetida* in both seasons. The length of both species increased progressively during the initial weeks, followed by a slower growth rate. This trend is likely due to the natural growth pattern of living organisms, where size increases over time until reaching full maturity. In terms of weight, both species experienced a rapid increase in the early weeks, followed by a slower growth phase in the middle weeks and a gradual weight decline thereafter. During winter, the highest weight gain occurred between the 5th and 11th weeks, whereas in summer, peak weight gain was observed between the 5th and 7th weeks. This pattern may be attributed to the transfer of earthworms to a fresh feeding medium, which provided optimal conditions for growth and increased energy availability. These findings align with the observations of Venter and Reinecke (1988), Mba (1983), and Knieriemen (1984).

During winter, the weight gain of *Eisenia fetida* and *Eudrilus eugeniae* slowed down in the middle weeks (10th to 17th and 11th to 15th, respectively), although biomass continued to increase. A similar pattern was observed in the summer season, with *E. fetida* and *E. eugeniae* showing slower growth between the 7th to 15th and 8th to 14th weeks, respectively. This slower growth was likely due to the onset of cocoon production and the shift to the reproductive phase, where energy was allocated for cocoon formation in addition to growth. A slower growth rate during the reproductive phase has also been reported by Viljoen and Reinecke (1994) and Graff (1982).

The weight of *Eisenia fetida* and *Eudrilus eugeniae* began to decline gradually after the middle weeks in both seasons. This weight loss could be attributed to the reduced availability of feeding materials, as no new feeding materials were added during the later weeks of the experimental period. The limited supply of food likely acted as a constraint on the growth of the earthworms. These findings align with the work of Bhat et al. (2015). Tiwari (1993) noted that adding organic matter increases worm population density and biomass. The availability of food is a key factor influencing both biomass and reproductive rates in earthworms (Garg et al., 2005; Sangwan et al., 2008). Overall, *E. eugeniae* demonstrated a greater growth advantage compared to *E. fetida*, consistent with the results reported by Emperor et al. (2016) and Venter and Reinecke (1988).

Maturation

The findings of the current study clearly indicated that *Eisenia fetida* reached sexual maturity faster than *Eudrilus eugeniae* during both seasons. Both species required less time to mature in the summer, likely due to the favorable temperature range of 20–30°C. This is consistent with the findings of Dominguez et al. (2001), who reported that worms reach sexual maturity most quickly when temperatures range from 25 to 30°C, regardless of population density. The time required for reproduction to begin can vary even among individuals of the same species, potentially due to environmental factors (Podolak et al., 2020). Previous

studies have reported varying timeframes for sexual maturity in *E. fetida*, such as 28 to 30 days (Dominguez and Edwards, 2011), 30 days (Lofs-Holmin, 1985), six to eight weeks (Edwards, 1988), four to six weeks for 50% of individuals and ten weeks for all worms (Neuhauser et al., 1979), and 60 days (Venter and Reinecke, 1988). In the case of *E. eugeniae*, Viljoen and Reinecke (1989) reported sexual maturity within 45 days after hatching, while Edwards (1988) stated it took approximately five weeks.

Cocoon production

During both seasons, the total number of cocoons produced worm^{-1} week^{-1} and the rate of cocoon production (cocoon worm^{-1} per^{-1}) were significantly greater in *E. fetida*. This could be species specific adaptations to the experimental conditions. Cocoon production was found to be higher in summer for both earthworm species while temperature ranged from 20-30°C. A similar finding was reported by Thirumagal and Deivanayaki (2017). During winter, a lower number of cocoon worm^{-1} week^{-1} was recorded in *E. eugeniae* over *E. fetida*. It is possibly due to *E. eugeniae* is very sensitive to low temperature and has a narrow tolerance range for temperature. Temperature ranges from 22-28 °C is favourable for higher growth, maturation rate, cocoon production and fecundity of *E. eugeniae* (Shagoti et al. 2001; Viljoen and Reinecke, 1992). There were a lot of variations in cocoon production in different weeks. Results of this study showed that cocoon production worm^{-1} week^{-1} was increased along with increase in temperature during winter. Cocoon production in *E. fetida* increases linearly as temperature rises from 10 to 25°C (Reinecke and Kriel 1981). The findings indicated that both earthworm species were sensitive to extreme temperatures, making regions with excessively high or low temperatures unsuitable for vermiculture. Further research is needed to explore this aspect. The small sample size and limited seasonal duration were constraints in this study. To gain a deeper understanding of these earthworm species and vermiculture practices, future research should involve a larger sample size and year-round studies on growth and reproduction.

Morphology of cocoons

Initially, the freshly laid cocoon of *Eisenia fetida* was light straw in color, while the cocoon of *Eudrilus eugeniae* appeared light yellowish. As the vascularization of the pre-emergent hatchling increases, the cocoon gradually hardens and turns brownish after emergence (Debnath and Chowdhury, 2020). Over time, the brown color deepens, eventually becoming dark brown just before hatching. Different earthworm species produce cocoons of varying shapes and sizes (Dominguez and Edwards, 2011; Edwards and Arancon, 2022).

Life-cycle

Both earthworm species required comparatively less time to complete egg to egg cycle during summer whereas *E. eugeniae* took less time than *E. fetida*. *E. eugeniae* exhibited a short life span and a high reproduction rate when raised on cattle manure (Viljoen and Reinecke, 1988; Parthasarathi, 2007).

It is clear from the findings that, growth of both earthworms species were comparatively higher in winter, whereas the reproductive activity of both species was lower. It is possibly due to lower winter temperatures reduced reproductive activity in both earthworm species, which could result in weight gain due to a reduction in reproductive costs and a reallocation of resources toward growth. Similar finding was reported by Kawecki and Stearns, (1993). Dissimilar result was found by Seenappa (2011) and Biradar et al. (2003), who reported that growth and reproduction of *E. fetida* and *E. eugeniae* were significantly more in winter and monsoon than in summer.

Conclusion

The study found that *Eudrilus eugeniae* exhibited greater growth advantages, while *Eisenia fetida* demonstrated better reproductive performance across both seasons. The growth of both earthworm species was higher in winter, whereas reproductive activity peaked in summer. Cocoon production worm^{-1} week^{-1} showed a positive correlation with temperature for both species during winter. New farmers in Bangladesh could benefit economically from vermiculture with *Eisenia fetida*, as it has a higher reproductive rate than *Eudrilus eugeniae* in both seasons.

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