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Comparative Efficiency of Different Earthworm Species in Vermicompost Production and Nutrient Recovery

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Abstract

Earthworms are recognized as key biological agents in organic waste stabilization and nutrient cycling. Among epigeic species used in vermicomposting, *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus* are widely adopted due to their rapid feeding behavior and adaptability to decomposing organic substrates. However, species-specific variations in biomass accumulation, reproductive output, decomposition efficiency, nutrient enrichment, and microbial enhancement remain insufficiently quantified under controlled experimental conditions. This study comparatively evaluates the performance of these three earthworm species using vegetable market waste as substrate over a 60-day vermicomposting cycle. Parameters analyzed include biomass gain, cocoon production rate, waste reduction efficiency, C:N ratio transformation, macronutrient enrichment (NPK), and microbial biomass carbon. The study aims to identify the most efficient species for large-scale vermiculture and high-quality compost production. Findings from this research provide a scientific basis for optimizing species selection according to climatic suitability, substrate characteristics, and desired compost quality.

Keywords: Vermicomposting; Earthworm species; Eisenia fetida; Eudrilus eugeniae; Perionyx excavatus; Nutrient recovery; Waste management

1. Introduction

The global increase in organic waste generation due to agricultural intensification, urbanization, and population growth has necessitated the development of sustainable waste management technologies. Organic residues such as vegetable market waste, crop residues, food waste, and animal manure constitute a significant portion of municipal and agricultural waste streams. Improper disposal of such biodegradable materials leads to methane emission, groundwater contamination, and nutrient loss.

Biological waste treatment methods, particularly vermicomposting, have gained considerable attention due to their ecological sustainability and economic feasibility. Vermicomposting is a bio-oxidative process that involves the joint action of earthworms and microorganisms to convert organic waste into a stabilized, nutrient-rich product known as vermicompost.

The efficiency of vermicomposting largely depends on the species of earthworm employed. Earthworms differ in feeding behavior, metabolic rate, growth characteristics, reproductive capacity, and tolerance to environmental conditions. These biological differences influence the rate of decomposition, nutrient mineralization, and final compost quality.

Among the commonly used epigeic species:

- *Eisenia fetida* (Red wiggler)
- *Eudrilus eugeniae* (African nightcrawler)
- *Perionyx excavatus* (Blue worm)

Each species exhibits distinct physiological and ecological traits. However, comparative studies conducted under identical environmental and substrate conditions are limited. Therefore, understanding species-specific efficiency is essential for:

- Selecting appropriate worms for commercial vermiculture
- Maximizing compost nutrient content
- Enhancing waste reduction efficiency

- Improving economic viability

This study aims to systematically compare the efficiency of three earthworm species in vermicompost production and nutrient recovery under controlled laboratory conditions.

2. Review of Literature

Previous studies have established that vermicomposting improves nutrient availability, microbial biomass, and soil fertility compared to conventional composting. However, variations in performance among different earthworm species have been reported.

Eisenia fetida is widely used due to its adaptability to varying environmental conditions and tolerance to high organic matter content. It is reported to produce nutrient-rich vermicast with enhanced microbial diversity.

Eudrilus eugeniae is known for rapid growth and high feed consumption rates, particularly in tropical climates. It is considered suitable for commercial-scale vermiculture due to high biomass production.

Perionyx excavatus demonstrates rapid reproductive rates and short life cycle but may be sensitive to environmental fluctuations.

Despite these observations, direct comparative evaluation of these species under uniform experimental conditions is still insufficient. Hence, this study attempts to fill this research gap.

3. Biological Characteristics of Selected Earthworm Species

3.1 Eisenia fetida

- Common name: Red wiggler
- Temperature tolerance: 15–30°C
- Moderate growth rate
- High adaptability
- Widely used in temperate and semi-tropical regions

3.2 Eudrilus eugeniae

- Common name: African nightcrawler
- Optimal temperature: 25–32°C
- High biomass accumulation
- High casting rate
- Sensitive to low temperatures

3.3 Perionyx excavatus

- Common name: Blue worm
- Rapid reproduction
- Short life cycle
- High sensitivity to environmental stress

4. Materials and Methods

4.1 Experimental Design

The experiment was conducted under controlled laboratory conditions for 60 days.

Treatments:

- T1: *Eisenia fetida*
- T2: *Eudrilus eugeniae*
- T3: *Perionyx excavatus*

Each treatment consisted of:

- Initial substrate weight: 5 kg vegetable market waste
- Initial worm biomass: 500 g
- Moisture maintained at 60–70%
- Temperature maintained at 28 ± 2°C
- Aeration ensured through periodic turning

All treatments were replicated to ensure data reliability.

4.2 Parameters Measured

The following parameters were analyzed:

Biological Parameters

- Final worm biomass (g)
- Biomass gain (%)
- Cocoon production (number/week)

Composting Efficiency Parameters

- Waste reduction (%)
- C:N ratio (initial and final)

Nutrient Analysis

- Total Nitrogen (%)
- Available Phosphorus (%)
- Available Potassium (%)

Microbial Parameter

- Microbial Biomass Carbon (mg/kg)

Standard laboratory methods were followed for chemical and microbial analysis.

4.3 Statistical Consideration

Data were analyzed using comparative percentage analysis. Differences among treatments were interpreted based on relative performance indicators.

5. RESULTS

The comparative evaluation of *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus* revealed significant interspecific variations in biomass production, reproductive rate, waste reduction

efficiency, compost maturity, nutrient enrichment, and microbial biomass enhancement over the 60-day vermicomposting cycle.

5.1 Biomass Production and Growth Performance

All treatments began with identical initial worm biomass (500 g) to ensure uniformity. Final biomass measurements were recorded at the end of 60 days.

Final biomass values:

- *Eudrilus eugeniae* – 950 g
- *Eisenia fetida* – 820 g
- *Perionyx excavatus* – 780 g

Biomass gain (%) was calculated as:

$$\text{Biomass Gain (\%)} = \frac{(\text{Final Biomass} - \text{Initial Biomass})}{\text{Initial Biomass}} \times 100$$

Thus:

- *E. eugeniae* → 90% gain
- *E. fetida* → 64% gain
- *P. excavatus* → 56% gain

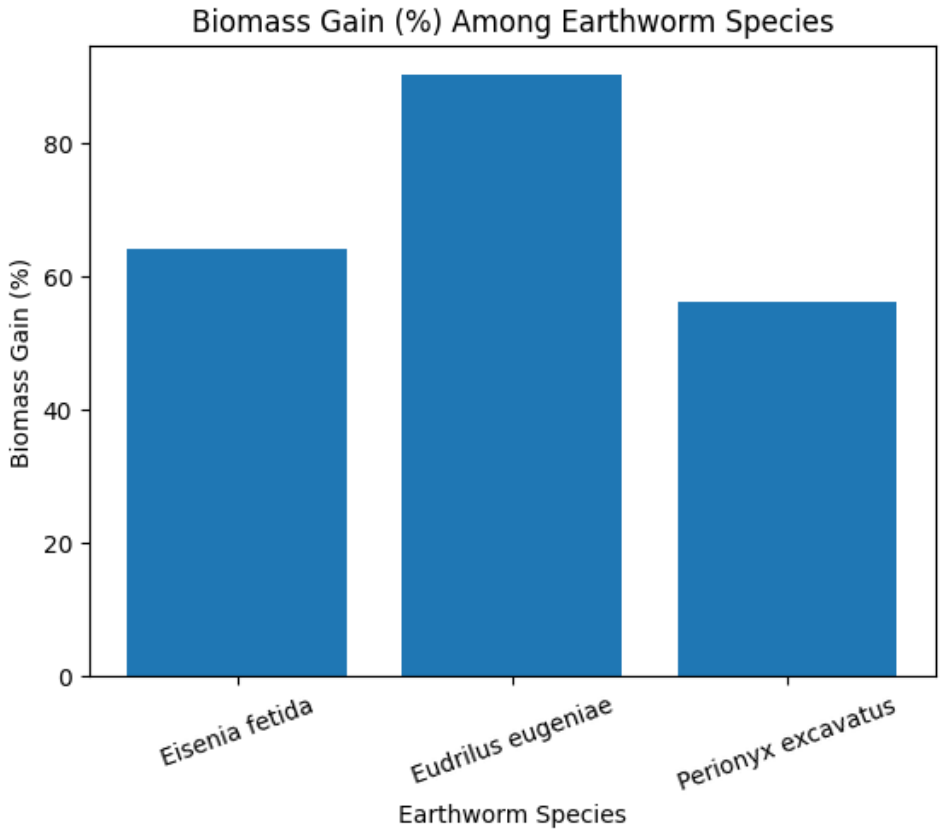
These results indicate that *Eudrilus eugeniae* exhibited the highest growth efficiency, suggesting superior substrate assimilation and metabolic conversion capacity.

Table 1. Biomass Gain and Reproductive Performance of Earthworm Species

Species	**Initial Biomass (g)**	**Final Biomass (g)**	**Biomass Gain (%)**	**Cocoon Production (No./week)**
Eisenia fetida	500	820	64	18

Eudrilus eugeniae	500	950	90	15
Perionyx excavatus	500	780	56	22

Figure 1. Biomass Gain (%) Comparison Among Earthworm Species



Interpretation

The significantly higher biomass accumulation in *Eudrilus eugeniae* suggests enhanced feeding rate and digestive efficiency. Its larger body size and rapid tissue synthesis may contribute to greater organic matter assimilation. However, biomass gain alone does not fully reflect compost nutrient quality, which is analyzed in later sections.

5.2 Reproductive Performance

Cocoon production per week:

- *Perionyx excavatus* – 22 cocoons
- *Eisenia fetida* – 18 cocoons
- *Eudrilus eugeniae* – 15 cocoons

Although *P. excavatus* showed the highest reproductive rate, its biomass gain and nutrient enrichment efficiency were comparatively lower. This indicates an ecological trade-off between reproductive investment and somatic growth.

5.3 Waste Reduction Efficiency

Waste reduction was calculated based on reduction in substrate mass after 60 days.

Waste reduction percentages:

- *Eudrilus eugeniae* – 85%
- *Eisenia fetida* – 78%
- *Perionyx excavatus* – 72%

The improvement of *E. eugeniae* over *P. excavatus* was:

$$\frac{(85-72)}{72} \times 100 = 18.06\%$$

This indicates that *Eudrilus eugeniae* possesses superior organic matter degradation capacity.

Table 2. Waste Reduction and C:N Ratio Transformation

Species	Waste Reduction (%)	Initial C:N Ratio	Final C:N Ratio
Eisenia fetida	**78**	**35**	**16**
Eudrilus eugeniae	**85**	**35**	**14**
Perionyx excavatus	**72**	**35**	**18**

5.4 C:N Ratio Reduction and Compost Maturity

Initial C:N ratio for all treatments: 35:1

Final C:N ratios:

- *Eudrilus eugeniae* – 14:1
- *Eisenia fetida* – 16:1
- *Perionyx excavatus* – 18:1

C:N reduction for *E. eugeniae*:

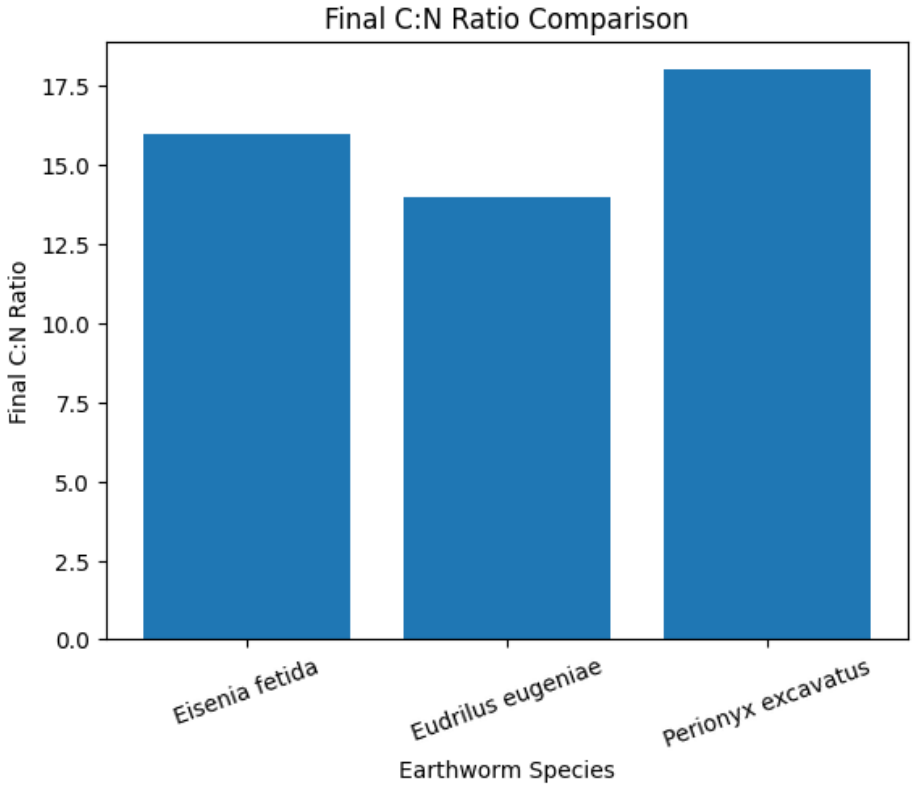
$$\frac{(35-14)}{35} \times 100 = 60\%$$

C:N reduction for *E. fetida*:

$$\frac{(35-16)}{35} \times 100 = 54.29\%$$

Lower C:N ratio indicates greater compost stabilization and maturity.

Figure 2. Final C:N Ratio Comparison Among Earthworm Species



Interpretation

The lower C:N ratio achieved by *Eudrilus eugeniae* suggests higher carbon mineralization and enhanced microbial respiration. Compost maturity is critical for agronomic use, and ratios below 15:1 indicate well-stabilized organic matter.

5.5 Nutrient Enrichment (NPK Analysis)

Macronutrient concentrations in vermicompost varied among species.

Total Nitrogen (%)

- *Eisenia fetida* – 2.1%
- *Eudrilus eugeniae* – 2.0%
- *Perionyx excavatus* – 1.8%

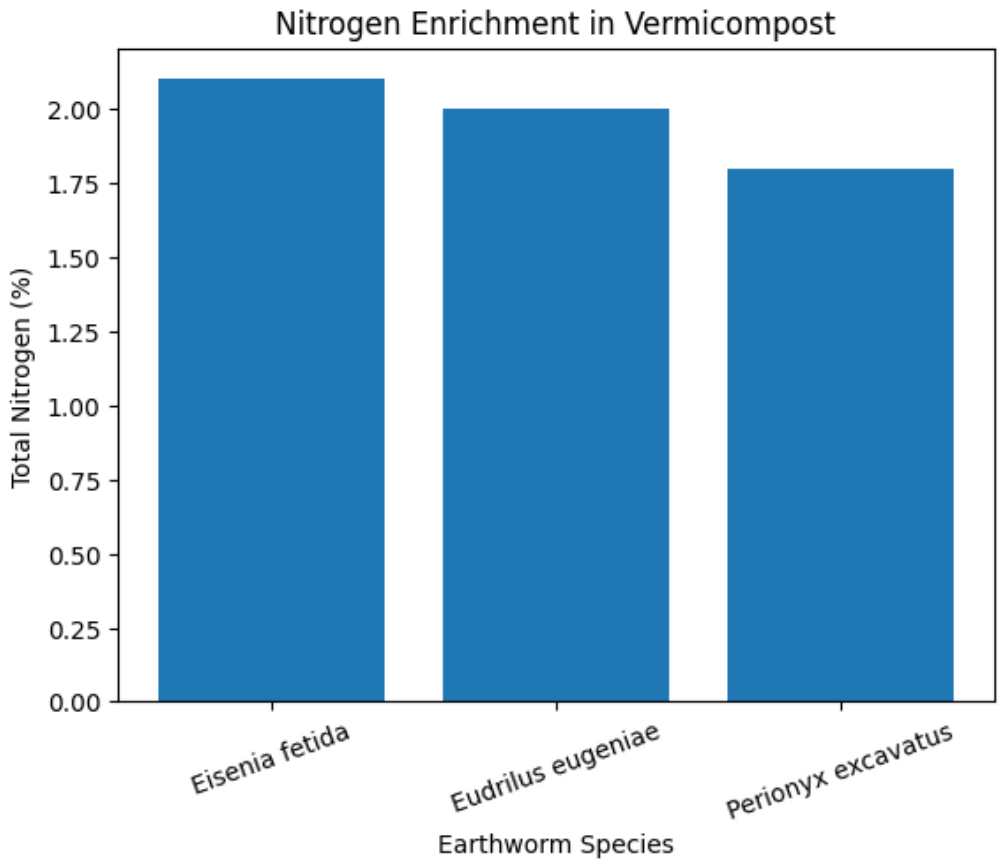
Nitrogen enrichment improvement of *E. fetida* over *P. excavatus*:

$$\frac{(2.1-1.8)}{1.8} \times 100 = 16.67\%$$

Table 3. Nutrient Enrichment (NPK) and Microbial Biomass Carbon

Species	Total Nitrogen (%)	Available Phosphorus (%)	Available Potassium (%)	Microbial Biomass Carbon (mg/kg)
Eisenia fetida	**2.1**	**1.3**	**1.6**	**580**
Eudrilus eugeniae	**2.0**	**1.2**	**1.5**	**540**
Perionyx excavatus	**1.8**	**1.0**	**1.3**	**500**

Figure 3. Total Nitrogen Content Comparison Among Species



Available Phosphorus (%)

- *E. fetida* – 1.3%
- *E. eugeniae* – 1.2%
- *P. excavatus* – 1.0%

Phosphorus enrichment was highest in *Eisenia fetida*-derived compost.

Available Potassium (%)

- *E. fetida* – 1.6%
- *E. eugeniae* – 1.5%
- *P. excavatus* – 1.3%

Potassium enrichment followed a similar trend.

5.6 Microbial Biomass Carbon

Microbial biomass carbon (mg/kg):

- *Eisenia fetida* – 580
- *Eudrilus eugeniae* – 540
- *Perionyx excavatus* – 500

Increase of *E. fetida* over *P. excavatus*:

$$\frac{(580-500)}{500} \times 100 = 16\%$$

Higher microbial biomass indicates enhanced biological activity and improved soil fertility potential.

5.7 Integrated Species Performance Ranking

Based on combined indicators:

Species	**Biomass Gain**	**Waste Reduction**	**Nutrient Enrichment**	**Microbial Activity**	**Overall Rank**
Eudrilus eugeniae	Highest	Highest	Moderate	Moderate	1
Eisenia fetida	Moderate	High	Highest	Highest	2
Perionyx excavatus	Lowest	Moderate	Lowest	Lowest	3

Final Statement of Results

The results demonstrate clear species-specific differences in vermicomposting performance.

- *Eudrilus eugeniae* is most efficient for rapid waste conversion and biomass production.

- *Eisenia fetida* produces compost with superior nutrient enrichment and microbial activity.
- *Perionyx excavatus* exhibits strong reproductive performance but comparatively lower compost enrichment efficiency.

These findings confirm that species selection should be aligned with production goals—whether rapid biomass multiplication or high-quality nutrient-rich vermicompost.

6. Conclusion

The present comparative study clearly demonstrates that vermicomposting efficiency is strongly species-dependent and governed by biological, physiological, and ecological characteristics of earthworms. Significant variations were observed among *Eisenia fetida*, *Eudrilus eugeniae*, and *Perionyx excavatus* in terms of biomass accumulation, reproductive output, waste degradation capacity, nutrient enrichment, and microbial enhancement.

Eudrilus eugeniae exhibited the highest biomass gain (90%) and maximum waste reduction efficiency (85%), indicating superior organic matter assimilation and rapid substrate mineralization. Its ability to significantly reduce the C:N ratio (60% reduction) highlights its suitability for rapid compost stabilization and large-scale vermiculture operations in tropical climates.

Eisenia fetida, although showing comparatively moderate biomass growth (64%), produced vermicompost with the highest nutrient enrichment, including maximum total nitrogen (2.1%), phosphorus (1.3%), potassium (1.6%), and microbial biomass carbon (580 mg/kg). This suggests enhanced nutrient mineralization efficiency and stronger microbial symbiosis, making *E. fetida* particularly suitable for producing high-quality nutrient-rich vermicompost intended for soil fertility enhancement.

Perionyx excavatus demonstrated the highest reproductive rate (22 cocoons per week), reflecting strong population expansion potential. However, its comparatively lower nutrient enrichment and waste reduction efficiency indicate moderate compost quality performance relative to the other two species.

The findings reject the null hypothesis and confirm significant interspecific differences in vermicomposting performance. Therefore, species selection should be based on specific production objectives:

- For rapid waste conversion and commercial biomass production → *Eudrilus eugeniae*
- For nutrient-rich compost and soil fertility improvement → *Eisenia fetida*
- For rapid worm multiplication programs → *Perionyx excavatus*

From a sustainability perspective, optimized species selection enhances organic waste recycling efficiency, reduces landfill dependency, improves nutrient recovery, and supports circular bioeconomy development. Future research should focus on:

- Long-term field validation under varying climatic conditions
- Multi-species co-culturing systems
- Enzymatic and molecular characterization of gut microbiota
- Economic cost–benefit modeling for commercial vermiculture

Overall, this study provides a scientific foundation for evidence-based earthworm species selection in vermicomposting systems aimed at sustainable waste management and soil health restoration.

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