



Molecular Identification and Functional Applications of Native Earthworm Species in Kodaikanal Hills

M. Razia¹, M. Lavanya¹, R. Merlyn Sujatha²

¹ Department of Biotechnology, Mother Teresa Women's University, Kodaikanal -624101, Tamil Nadu, India

² Department of Biochemistry, St. Peter's Institute of Higher Education and Research, Chennai-600054, Tamil Nadu, India

*Corresponding authors: M. Razia; razia.bt@motherteresawomenuniv.ac.in

Abstract

The extensive use of chemical fertilizers and pesticides, along with environmental stressors, has raised concerns regarding soil biodiversity and sustainable crop production. Earthworms are key soil organisms, and their occurrence and distribution vary across soil ecosystems, particularly in high-altitude regions. The present study aimed to isolate and molecularly identify dominant earthworm species from different soil habitats of the Kodaikanal Hills and to evaluate the effects of vermicompost prepared using these earthworms on vegetable crops. Earthworms collected from domestic waste-dumped areas and uncultivated land were subjected to molecular identification using partial sequencing of the cytochrome c oxidase subunit I (COI) gene, which identified *Lampito mauritii* and *Eisenia fetida* as dominant species. The identified earthworms were introduced into vermicompost pits containing vegetable waste and cow dung and incubated for 45 days, resulting in the formation of dark, granular compost. The prepared vermicompost was applied under pot conditions to assess its effects on seed germination, growth parameters, yield attributes, and nutrient composition of radish (*Raphanus sativus* L.) and carrot (*Daucus carota* L.). Vermicompost-treated plants exhibited higher germination indices, improved growth characteristics, increased yield parameters, and enhanced nutrient content compared with untreated controls. The results demonstrate the applicability of vermicompost derived from molecularly identified earthworm species for improving vegetable crop performance under high-altitude conditions of the Kodaikanal Hills.

Keywords: Earthworm, Vermicast, Vermicompost, Vegetable waste, Nutrient analysis

1. Introduction

Recent studies have demonstrated that vermicompost application can improve plant growth, yield attributes, and nutrient uptake in vegetable crops by enhancing nutrient availability, root development, and soil physicochemical properties (Muthukannan et al. 2024; Almaramah et al. 2024). In root vegetables such as radish (*Raphanus sativus* L.) and carrot (*Daucus carota* L.), yield performance is closely associated with early seed germination, root elongation, and efficient nutrient acquisition. Experimental evidence from diverse agroecosystems indicates that vermicompost-based nutrient management can result in measurable improvements in biomass accumulation and harvest indices compared with conventional fertilization practices (Sande et al. 2024, Rahmani et al. 2023). Vermicompost agronomic performance does not depend on a single factor, but is determined by a variety of factors, such as feedstock composition, composting environment, and especially on the species of earthworms in the composting process. The species of earthworms vary in their feeding habits, burrowing behavior and efficiency in processing organic matter which also impacts the nutrient profile and the biological quality of the vermicompost that is generated (Ganapathy et al. 2025). Proper identification of the species of earthworms in vermicomposting is thus critical in terms of reproducibility and comparability in the studies. Morphological identification does not always prove to be easy, as there is phenotypic plasticity and cryptic diversity, and molecular methods to identify it are often used to complement earthworm biodiversity studies and species validation, i. e. cytochrome c oxidase subunit I (COI) barcoding (Barraux et al. 2024).

Although there has been an upsurge in the research on the use of vermicompost as a nutrient management tool, significant gaps in the research exist. To date, in India and especially to agroecosystems in high altitudes like the Kodaikanal Hills, there is very little information that has been given associating molecularly authenticated native earthworm species to the

production of vermiculite and the resultant assessment of plant growth, yield, and nutrient content in vegetable crops. The majority of available studies either measure the effect of vermicompost without comparing the earthworm species used or they determine earthworm diversity without their agronomic performance of using vermiculite earthworm based on native species. Moreover, the high-altitude areas have specific climatic and soil conditions, which may affect earthworm distributions, composting activity, and nutrient cycles of plants, which emphasize the necessity of explorations in the regions.

The current study combines molecular identification of dominating native earthworm species with vermicompost production and plant growth, yield and nutrient factor assessment under the conditions of high altitude of the Kodaikanal Hills. Before vermicompost was prepared, the Earthworm species were authenticated by the use of COI gene sequencing to enhance biological accuracy over the traditional morphology-based methods that are mostly reported. Quantitative evidence on the appropriateness of native earthworm sourced organic inputs in the sustainable management of nutrients in a high-altitude vegetable production system is presented by the effects of the resultant vermicompost on the performance of radish (*Raphanus sativus* L.) and carrot (*Daucus carota* L.). The present study was collect and molecularly identify dominant earthworm species from selected soil habitats of the Kodaikanal Hills using COI gene sequencing and prepare vermicompost using the identified native earthworm species; and evaluate the effects of the prepared vermicompost on seed germination, plant growth, yield indices, and nutrient composition of radish (*Raphanus sativus* L.) and carrot (*Daucus carota* L.).

2. Materials and Methods

2.1 Study area and Earthworm collection

According to the approach proposed by Kathigeyan et al. (2019), in Kodaikanal, Earthworm samples were collected by digging and using hand sorting method.

2.2 Molecular Identification of Earthworm and Phylogenetic analysis

The earthworms were carefully rinsed with distilled water and samples of tissues (muscular body wall) were collected at the back of the clitellum (mostly end of the tail) and stored in 70% ethanol. DNA was extracted and PCR amplification was done by the use of hexa-codon universal primers. The agarose gel electrophoresis was used to purify and analyse the PCR product. The maximum Neighbor-Joining method was used to compute the evolutionary distances (MEGA7 software).

2.3 Preparation and Nutrient analysis of Vermicompost

A layer of loamy soil or garden soil was added to Vermicompost and it was filled by sprinkling with small lumps of fresh cattle dung. This serves as a live growing medium of earthworms. In the vermibed approximately 100 earthworms (native species) were introduced. It was covered with straw, litter and farm residue of vegetable waste. Cow dung Slurry sprinkled. This same number of layers was added until the height reached 1 m and sprinkled with water to keep the content of moisture. When harvesting took place, it was on 45th day and the worms were also removed and the vermicast (Singh et al. 2010).

2.4 Effect of Vermicompost on Plant yield, Growth and Nutrient content

The native farmers were purchased with the seeds of the native tuberous root vegetables (radish and carrot). The seedlings were grown in broad pots i.e. 60 cm wide and transferred to small pots. The pots were filled with the red soil, sand and vermicompost in the ratio of 1:1:1; the plants were kept under the conditions of the garden land. The control and treated groups had 10 plant replicates that were kept in three pots. Measurements were made of length of shoot (cm), inter node (cm), the numbers of leaves and branches were counted manually. It was calculated in germination indices (Total germination, speed of emergence, germination

index) and Yield indices (Vegetable weight and harvest index). The germination and Harvest parameters (Germination percentage, Mean emergence time) and Harvest (vegetable weight, yield) was determined based on the procedures that were established by Karunaratna and Seran (2010). Standard procedures were used to determine proximate analysis, ash, moisture, fibre, protein, carbohydrate and secondary metabolites (Makkar et al. 2017).

2.6 Statistical Analysis

Mean and standard error (SE) were used to express all experiment data considering three replicates. Descriptive data summarization was done to determine the differences between the control and vermicompost treatments.

3. Results and Discussion

3.1 Earthworm collection and Molecular Identification

Earthworm samples were randomly collected from different locations in and around the Kodaikanal Hills. In the present study, four earthworm species belonging to three different families were morphologically identified and segregated. The results indicated that four species were abundantly distributed across the sampling sites. Among these, *Lampito mauritii* was the most abundant species across all locations, followed by *Eisenia fetida*.

In Tamil Nadu, India, only limited information is available regarding the distribution patterns of earthworms. Earlier studies have reported earthworm distribution in regions such as the Palani Hills (Jamieson, 1977), Madras (Ismail and Murthy, 1985), and the Sirumalai Hills (Karmegam and Daniel, 2007). The present molecular identification results further confirmed that *Lampito mauritii* was the dominant species among the collected samples.

3.2 Phylogenetic Reconstruction and Genetic Identification of Distinct Earthworm

To accurately identify the collected earthworm specimens and elucidate their evolutionary relationships, mitochondrial cytochrome c oxidase subunit I (COI) gene sequences of *Eisenia fetida* MTWUMR01 and *Lampito mauritii* MTWUMR02 were analyzed. Sequence alignment using BLAST against the NCBI GenBank database revealed high similarity with corresponding reference sequences, thereby confirming the taxonomic identities initially established through morphological characterization. Based on the nucleotide sequences of the mitochondrial COI gene, the evolutionary relationships among different earthworm species were analyzed using the Maximum Likelihood (ML) method with the Tamura–Nei (1993) nucleotide substitution model. Bootstrap analysis was performed with 1000 replicates to determine the reliability of the inferred phylogenetic relationships. The resulting phylogenetic tree (Fig. 1) revealed two major clusters. The first cluster included genera such as *Drawida*, *Lampito*, and *Sparganophilus*, which are predominantly soil-burrowing species. The second cluster consisted mainly of epigeic species such as *Eisenia*, *Eiseniella*, and other lumbricid worms. The two target species, *Eisenia fetida* MTWUMR01 and *Lampito mauritii* MTWUMR02, were clearly positioned within their respective clades with high bootstrap support values. *E. fetida* showed a bootstrap value of 98,

confirming its genetic identity and indicating strong similarity with global populations. Similarly, *L. mauritii* MTWUMR02 showed a bootstrap value of 100, suggesting a highly conserved genetic structure with minimal variation among populations.

E. fetida is widely recognized as a dominant species in vermicomposting systems due to its rapid reproduction and adaptability to organic waste environments (Dominguez & Edwards, 2004). Its placement within the lumbricid clade is consistent with its epigeic ecological behavior. In contrast, *Lampito mauritii* is a larger endogeic species that inhabits deeper soil layers and plays a crucial role in soil aeration and nutrient cycling.

The phylogenetic placement of *L. mauritii* within the Moniligastridae family aligns with previous studies highlighting its importance in tropical agricultural ecosystems (Julka & Paliwal, 2005). Some species such as *Pontodrilus litoralis* and *Travoscolides schengamurres* diverged earlier in the evolutionary lineage. The high genetic similarity observed in both *E. fetida* and *L. mauritii* suggests relatively low genetic variability among populations. Molecular validation of earthworm species has important implications for agricultural and environmental applications. Accurate species identification ensures the effective selection of earthworms for vermicomposting and soil fertility improvement programs.

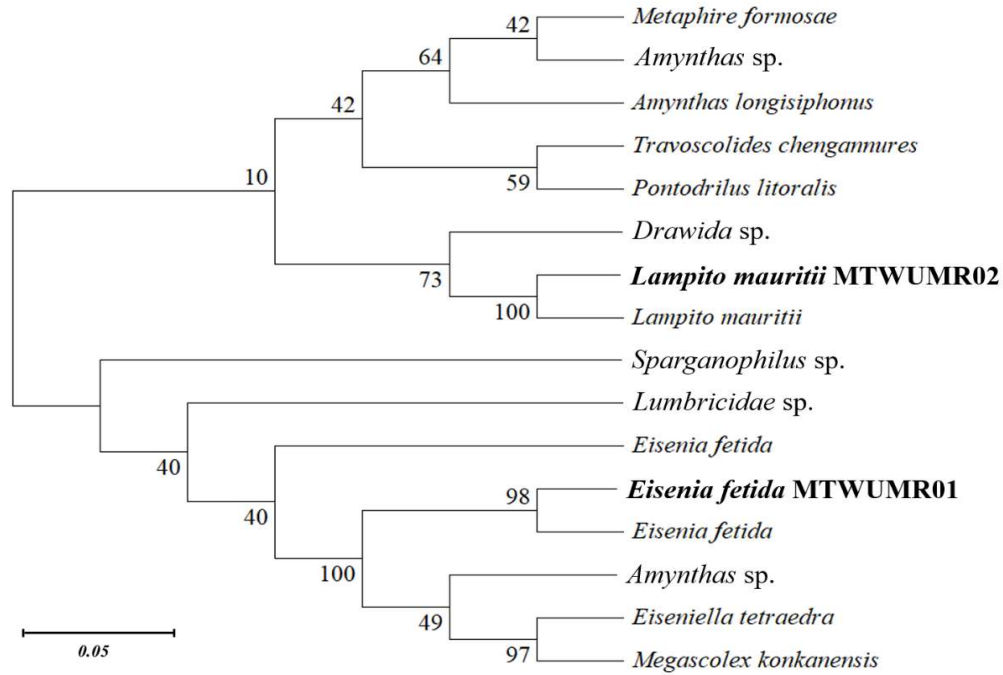


Fig.1 Evolutionary Relationship between *Eisenia fetida* MTWUMR01 and *Lampito mauritii*MTWUMR02 Inferred through Maximum Likelihood Phylogenetic analysis

3.3 Soil analysis

Soil analysis was conducted for soil samples collected from Attuvampatti (Collection Site 2) due to the richness and abundance of earthworm species observed at this location. The coexistence of multiple earthworm species within the same soil environment can significantly enhance soil fertility, and such associations are commonly observed in natural ecosystems (Singh et al., 2010).

The physicochemical characteristics of the soil samples are presented in Table 1. The results indicated that the soil collected from Naidupuram contained relatively higher concentrations of essential nutrients such as nitrogen, phosphorus, and potassium (NPK), which support the growth and proliferation of earthworm populations. In addition, the observed soil pH and temperature were within a favorable range for earthworm survival and activity.

Table 1: Physico-chemical parameters of study area soil

S.No	Parameters	Attuvampatti	Villpatti	Naidupuram
1.	Soil texture	Loam	Loam	Loam
2.	Calcareousness	Non calcareous	Non calcareous	Non calcareous
3.	pH	5.56	5.25	6.13
4.	EC (dS/m)	0.19	0.17	0.12
5.	Organic carbon (%)	15.53	11.25	12.28
6.	Available N (kg/ha)	672	644	1280
7.	Available P (kg/ha)-Bray	60.1	63.5	61.7
8.	Available K (kg/ha)	864	886	388
9.	Fe (mg/kg)	52.23	61.93	25.60
10.	Zn(mg/kg)	3.28	3.92	3.92
11.	Mn (mg/kg)	18.58	21.15	13.30
12.	Cu (mg/kg)	1.76	4.32	1.47

3.4 Preparation of Vermicompost

The selection of earthworm species for vermicompost preparation was based on their ability to survive and reproduce under controlled conditions. Among the identified species, *Lampito mauritii* was selected for the vermicomposting process. During the composting period, degradation and decomposition of organic waste materials were continuously monitored. Moisture levels were maintained consistently, and the composting pits were regularly inspected. The

composting process was completed within approximately 60 days. After completion, the vermicompost was harvested and subjected to nutrient analysis. The results are presented in Table 2. Earthworm castings play a crucial role in improving soil fertility by providing essential nutrients required for plant growth. The nutrient analysis revealed that the prepared vermicompost contained balanced levels of NPK along with significant amounts of macro- and micronutrients necessary for plant development.



Table 2: Nutrient analysis of prepared Vermicompost

S.No	Parameters	Percentage
1	Moisture content	42.60%
2	Ash content	9.50%
3	Nitrogen	1.20%
4	Phosphorous	0.90mg
5	Potassium	0.70 mg
6	Zinc	12.80 mg
7	Copper	6.50 mg
8	Manganese	3.60 mg
9	Magnesium	35.30 mg
10	Iron	4.40 mg
11	Sodium	0.50 mg
12	Calcium	18.20 mg

3.5 Effect of Vermicompost on *Raphanus sativus* and *Daucus carota* germination

Prior to sowing, the effect of the prepared vermicompost on the germination of *Raphanus sativus* (radish) and *Daucus carota* (carrot) seeds was evaluated using the Petri dish germination method. Different concentrations of vermicompost were tested, while tap water was used as the control treatment. The highest

germination percentage for *R. sativus* (60 ± 2.4) and *D. carota* (90 ± 1.2) was observed at a vermicompost concentration of 7.5 g per 100 ml. In addition, the mean emergence time for seedlings treated with vermicompost was shorter than that of the control group, as presented in Table 3. During land preparation, the determined optimal quantity of vermicompost was incorporated into the soil.

Table 3: Germination parameters of Radish and Carrot

Vegetable	Treatment	Germination index	Mean Emergence time
Radish	Control	40 ± 2.1	3.1 ± 0.2
	Vermicompost	60 ± 2.4	2.3 ± 1.2
Carrot	Control	50 ± 0.4	4.2 ± 1.2
	Vermicompost	90 ± 1.2	1.1 ± 0.4

Results are expressed as Mean± standard error (n=3)

3.6 Root formation, Fresh weight and Dry weight

Vegetable yield is closely associated with root development. In the present study, a higher level of root formation was observed in radish and carrot plants grown in vermicompost-amended soil compared with the control groups (Table 4). The average root length of radish grown with vermicompost was recorded as 14.3 ± 1.2 cm, while carrot showed a root length of 10.1 ± 0.4 cm. Similarly, the fresh weight of radish and carrot leaves was significantly higher in vermicompost-treated plants (Table 5). The tuberous root weight in the control group was lower than that observed in plants grown in vermicompost-treated soil. Comparable trends were also observed in dry weight measurements (Table 6). Overall, the results clearly demonstrated that vermicompost treatment

significantly improved root development, fresh biomass, and dry matter accumulation in both crops. Previous studies by Karunaratna and Seran (2010) reported that dry matter accumulation in tuberous roots is generally higher than in leaves, and the translocation of assimilates from leaves to roots contributes to increased root biomass. The results obtained in the present study are consistent with these findings.

3.7 Yield of Radish and Carrots

The yield of radish and carrot plants grown in vermicompost-treated soil was significantly higher compared with that of the control group (Table 7). The increased availability of nutrients in vermicompost-amended soil likely contributed to enhanced plant growth and yield performance (Xinyou et al., 2003).

Table 4: Root formation in Radish and Carrot

Vegetable	Treatment	Tuberous root diameter (cm)	Tuberous root length (cm)	Total root length (cm)
Radish	Control	6.5 ± 0.4	7.4 ± 2.1	9.6 ± 3.2
	Vermicompost	10.3 ± 1.2	12.1 ± 3.2	14.3 ± 1.2
Carrot	Control	4.2 ± 1.2	5.3 ± 0.2	6.4 ± 2.1
	Vermicompost	7.8 ± 2.3	9.2 ± 1.2	10.1 ± 0.4

Results are expressed as Mean± standard error (n=3)

Table 5: Fresh weight of Radish and Carrot

Vegetable	Treatment	Plant weight (g)	Tuberous root weight (g)	Leaf weight (g)
Radish	Control	103.7 ± 0.2	60.3 ± 3.2	43.4 ± 1.3
	Vermicompost	127.5 ± 3.2	77.2 ± 4.6	50.3 ± 3.6
Carrot	Control	79.3 ± 1.2	49.4 ± 4.1	29.9 ± 4.2
	Vermicompost	85.6 ± 4.8	57.2 ± 3.2	28.4 ± 4.1

Results are expressed as Mean± standard error (n=3)

Table 6: Dry weight of Radish and Carrot

Vegetable	Treatment	Plant weight (g)	Tuberous root weight (g)	Leaf weight (g)
Radish	Control	50.3 ± 3.2	31.6 ± 1.2	18.7 ± 1.3
	Vermicompost	61.4 ± 4.2	36.9 ± 3.6	24.5 ± 3.6
Carrot	Control	36.2 ± 1.2	23.4 ± 2.1	12.8 ± 4.2
	Vermicompost	41.4 ± 4.6	27.8 ± 4.2	13.6 ± 4.1

Results are expressed as Mean± standard error (n=3)

Table 7: Yield and Harvest index of Radish and Carrot

Vegetable	Treatment	Yield (%)	Harvest Index (%)
Radish	Control	42.3 ± 4.2	56.3 ± 0.4
	Vermicompost	72.4 ± 4.6	74.2 ± 3.2
Carrot	Control	51.4 ± 3.2	61.9 ± 4.3
	Vermicompost	87.9 ± 1.2	91.4 ± 4.1

Results are expressed as Mean± standard error (n=3)

3.8 Nutrient analysis of Radish and Carrot

The nutrient analysis results indicated that vegetables grown in vermicompost-treated soil exhibited improved nutritional composition (Table 8). Both radish and carrot samples showed higher levels of essential minerals such as sodium, potassium, magnesium, calcium, iron, and zinc. Plants obtain both macro- and

micronutrients from the soil, and the availability of these nutrients directly influences the nutritional quality of the harvested vegetables. Therefore, the present results suggest that vermicompost application enhances soil fertility and improves the nutrient profile of vegetable crops, ultimately leading to higher yield and better nutritional quality.

Table 8: Nutrient composition of Radish grown in soil treated with Vermicompost

S.No	Parameters	Radish	Carrot
1	Moisture content	11.70%	13.70%
2	Ash content	32.20%	30.50%
3	Crude protein	13.30%	15.90 %
4	Crude fat	0.50%	0.50%
5	Total carbohydrate	42.30%	39.40%
6	Crude fibre	5.90%	8.70%
7	Phosphorous	0.50 mg	0.60 mg
8	Potassium	8.50 mg	11.70 mg
9	Zinc	3.10 mg	4.20 mg
10	Copper	1.20 mg	1.50 mg
11	Manganese	1.30 mg	1.90 mg
12	Magnesium	3.40 mg	4.50 mg
13	Iron	2.20 mg	1.50 mg
14	Sodium	18.30 mg	22.70 mg
15	Calcium	6.30 mg	8.50 mg
16	Sugar	14.20 mg	19.50 mg
17	Vitamin B1	10.50 mg	15.90 mg
18	Vitamin B2	9.30 mg	16.40 mg

4. Conclusion

This study demonstrated that vermicompost produced using molecularly authenticated earthworm species *Lampito mauritii* and *Eisenia fetida* significantly enhanced seed germination, vegetative growth, yield attributes, and nutrient composition of radish (*Raphanus sativus* L.) and carrot (*Daucus carota* L.) under pot culture conditions in the high-altitude agro-ecosystem of the Kodaikanal Hills. Prior confirmation of earthworm identity through COI gene sequencing strengthened the methodological reliability and reproducibility of the work. The vermicompost, prepared from locally available vegetable residues and cow dung, represents a low-input, resource-recycling approach that can reduce reliance on energy-intensive synthetic fertilizers and mitigate associated environmental impacts. The positive plant responses observed highlights the agronomic potential of native earthworm-based vermicompost as an effective organic nutrient source for vegetable cultivation in hill regions. Although derived from controlled pot experiments, these findings provide a scientific basis for incorporating locally produced vermicompost into integrated nutrient management strategies aimed at sustaining soil health and minimizing chemical inputs in high-altitude agriculture, warranting further validation through multi-location field trials across diverse cropping systems.

5. Acknowledgment

The authors are grateful to The Tamil Nadu State Council for Science and Technology, Tamil Nadu, India for the financial support Project Code: ES458.

References

1. Aira, M., Monroy, F., Domínguez, J. 2006. C to N ratio strongly affects population structure of *Eisenia fetida* in vermicomposting systems. European J. soil boil. 42:S127-S131.
2. Almaramah, S.B., Abu-Elsaoud, A.M., Alteneiji, W.A., Albedwawi, S.T., El-Tarabily, K.A., Al Raish, S.M. 2024. The impact of food waste compost, vermicompost, and chemical fertilizers on the growth measurement of red radish (*Raphanus sativus*): a sustainability perspective in the United Arab Emirates. Foods13:1608.
3. Barraux, A., Noel, S., Roy, V., Dupont, L. 2024. Challenges of molecular barcode-based identification of earthworm specimens for biodiversity assessment. Front.Eco.Evol. 12:1358984.
4. Blakemore, R. J. 2012. Cosmopolitan earthworms: an eco-taxonomic guide to the peregrine species of the world. Robert J. Blakemore.
5. Ganapathy, N.R.V., Elango, A.C., Balaji, G., Sankaranarayanan, M., Sharma, M. 2025. A comprehensive review of earthworm-derived vermiproducs and their role in sustainable agriculture. Discover Appl.Sci. 7:995.
6. Ismail, S.A., Murthy, V.A. 1985. Distribution of earthworms in Madras. Proceedings of Indian Acad.Sci. 94:557-566.
7. Jamieson BGM.1977. Preliminary descriptions of Indian earthworms (Megascolecidae: Oligocaheta) from the Palnihills. Bullet. M. Nat.SecA. 313:478-502.
8. Julka, J.M., Paliwal, R., Kathireswari, P. 2009. Biodiversity of Indian earthworms- An overview. In: Proceedings of Indo-US Workshop on Vermitechnology in Human Welfare (Eds.: C. A. Edwards, R. Jayaraaj and I. A. Jayraaj). Rohini Achagam, Coimbatore, India, pp. 36-56.
9. Karmegam, N., Daniel, T. 2007. Effect of physicochemical parameters on earthworm abundance: a quantitative approach. J Appl.Sci. Res.3:369-1376.
10. Karthigeyan, M., Mani, P., Alagesan, P. 2019. Collection, molecular identification and study of earthworm species procured from different soil habitats of Madurai district, Tamil Nadu, India. The PharmaInno. Jou. 8:34-39.
11. Karunarathna, B., Seran, T.H. 2010. Effect of paired row planting of radish (*Raphanus sativus* L.) intercropped with vegetable

- Amaranthus (*Amaranthus tricolor* L.) on yield components of radish in sandy regosol. *J Agri.Sci.* 4:1-11.
12. Makkar, C., Singh, J., Parkash, C. 2017. Vermicompost and vermiwash as supplement to improve seedling, plant growth and yield in *Linum usitassimum* L. for organic agriculture. *Int.IJ.Recycl.Organic Waste Agri.* 6:203–218.
13. Muthukannan, J., Rani, J., Bala Mohan, R., Prabha, D. 2024. Comparative growth analysis of *Raphanus sativus* L.: effects of vermiwash and vermicompost applications on plant development. *Dis. Food*, 4: 64.
14. Rahmani, R., Khalesro, S., Heidari, G., Mokhatssi-Bidgoli, A., 2023. Vermicompost and Zeolite Improve Yield, Nutrient Uptake, Essential and Fixed Oil Production, and Composition of *Nigella Sativa* L. *Front Sustain Food Sys.* 7:1214691.
15. Sande, T.J, Tindwa, H.J, Alovisi A.M.T., Shitindi, M.J., Semoka, J.M., 2024. Enhancing sustainable crop production through integrated nutrient management: focus on vermicompost, bio-enriched rock phosphate, and inorganic fertilisers—a systematic review. *Front Agron.* 6:1422876.
16. Singh, R., Gupta, R.K., Patil, R.T., Sharma, R.R., Asrey, R., Kumar, A., Jangra, K.K., 2010. Sequential foliar application of vermicompost leachates improves marketable fruit yield and quality of strawberry (*Fragaria x ananassa* Duch.). *Scientia Hort.* 124:34-39.
17. Xinyou, Y., Schapendonk, A.D.H.C.M., Xuhua, Z., 2003. Quantitative Relationships between Leaf Area Index and Canopy Nitrogen Content and Distribution. *Annals Bot.* 9: 893-903.

Access this Article in Online	
	Website: www.ijarbs.com
	Subject: Vermitechnology
Quick Response Code	
DOI: 10.22192/ijarbs.2026.13.04.005	

[How to cite this article:](#)

M. Razia, M. Lavanya, R. Merlyn Sujatha. (2026). Molecular Identification and Functional Applications of Native Earthworm Species in Kodaikanal Hills. *Int. J. Adv. Res. Biol. Sci.* 13(4): 47-56.

DOI: <http://dx.doi.org/10.22192/ijarbs.2026.13.04.005>