



Comparative Evaluation of Composting and Vermicomposting of Black Tea and Floral Wastes using *Eudrilus eugeniae*

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ABSTRACT

Background: Traditional waste management often struggles to efficiently recycle organic waste into high-quality soil amendments. This study evaluated the efficacy of the earthworm *Eudrilus eugeniae* in converting black tea waste (BTW) and floral waste (FW) into nutrient-rich vermicompost, comparing the outcomes against standard composting methods to find a sustainable environment.

Methods: Five distinct treatment groups (T1 to T5) were constructed using varying percentages of black tea waste and floral waste. These organic waste mixtures were subjected to *E. eugeniae*-mediated vermicomposting and evaluated against standard composting control setups to measure biodegradation efficiency, nutrient enrichment and chemical stability.

Result: Vermicomposting significantly enhanced waste biodegradation, leading to superior humification and stability compared to standard compost (p<0.01). Chemical Properties: Vermicompost achieved near neutral pH (up to 7.46), optimal electrical conductivity (up to 2.4 dS/m) and decreased total organic carbon and C/N ratios. Nutrient Profile: Macronutrients (TN, TP, TK), available NPK, total calcium and total magnesium all demonstrated significant comparative increases (p<0.01). Optimal Treatment: Treatment T5 (20% BTW+80% FW) performed the best, exhibiting the highest breakdown efficiency, the lowest C/N ratio and the greatest overall nutritional enrichment, demonstrating that *E. eugeniae*-mediated vermicomposting is a superior strategy for transforming organic wastes into high-quality biofertilizer.

Key words: Black tea waste, Floral waste, Nutrient availability, Vermicomposting.

INTRODUCTION

Globally, organic waste generation from household, agricultural and commercial operations has expanded considerably, posing serious threats to environmental and public health. In developing nations, rapid urbanization causes improper disposal of biodegradable wastes from household, including kitchen scraps, floral debris and tea trash. This type of organic waste adds to landfill growth, greenhouse gas emissions, soil and water contamination and health problems. So, globally, environmental scientists are paying more attention to the sustainable management of these organic wastes employing biological recycling technology, which is becoming increasingly vital for environmental preservation and agricultural sustainability (Khan *et al.*, 2022; Ali *et al.*, 2015). Vermicompost made from earthworms provided a simple and effective option for trash disposal and recycling. Traditional composting, on the other hand, takes longer and may result in less nutrient enrichment due to slower breakdown and mineralization processes (Bernal *et al.*, 2009; Mahaly *et al.*, 2018). This approach employs earthworms, namely *Eudrilus eugeniae*, in cooperation with microorganisms to accelerate the biodegradation and stability of organic substrates. *Eudrilus eugeniae* has the potential to mechanically fragment organic residues, promote interaction with microbial species found in compost and increase surface area for microbial colonization and

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enzymatic processes. The earthworm also encourages microbial populations to proliferate during gut transition, contributing to the breakdown of complex organic substances including cellulose, proteins and lipids. The produced product contains helpful microbes and plant-available nutrients, supporting ongoing mineralisation and humification (Edwards *et al.*, 2011). This approach yields vermicompost with a black granular texture, a near-neutral

pH, strong microbial activity and greater quantities of plant-available nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium (Domínguez and Edwards, 2011).

Black tea waste (BTW) and floral waste (FW) are the two most common biodegradable wastes generated by families, tea businesses, hotels and commercial establishments worldwide. These wastes are high in organic carbon, minerals, phenolic compounds and biodegradable nutrients, making them ideal for composting and vermicomposting (Singh *et al.*, 2011; Mahaly *et al.*, 2018). So, using this material to manufacture vermicompost makes effective recycling of waste and minimizes environmental pollution with a user-friendly strategy with less cost to produce high-quality organic manure that can increase soil structure, microbial diversity, nutrient availability and crop yield (Oyege and Bhaskar, 2023). Earthworm-based vermicomposting studies have shown that this technique reduces total organic carbon (TOC) and C/N ratios while increasing nutrient mineralization and humification (Suthar, 2009; Garg *et al.*, 2006). Earthworms can effectively interact with microbes and help to increase the beneficial bacterial population and their enzyme activity in the gut promotes the release of available nitrogen, phosphate and potassium through gut-associated microbial activity and enzymatic conversions (Aira *et al.*, 2007; Annapoorani and Sindhu (2019). Furthermore, vermicompost enhances physicochemical qualities such as pH balance, electrical conductivity and micronutrient enrichment, making it appropriate for long-term agricultural usage (Arancon *et al.*, 2004). The purpose of this study was to assess the efficacy of composting and vermicomposting domestic waste generated by tea businesses, flower markets and temples. This study used various combinations of black tea trash and floral waste treated with *Eudrilus eugeniae* in control settings to increase biodegradation activities. Following composting, we evaluated the physicochemical properties of the products, including nutrient dynamics, organic carbon reduction, C/N

ratio stabilization and macro element enrichment. The study sheds light on the possible use of tea and floral waste as sustainable substrates for manufacturing nutrient-rich organic manure using vermitechology.

MATERIALS AND METHODS

Study area and preparation of BTW and FW treatments

The study was carried out during 2024 to 2025 at the Vermicomposting Unit, A.V.C. College (Autonomous) under perfect environmental circumstances, including enough light and moisture levels. To achieve constant trash loading capacity, a common 20 kg plastic pot was used. The trials involved 150 grams of earthworms produced in the department. The species was recognized based on Julka's (1988) criteria. Vermicomposting is the process of decomposing material with Clitellate *E. Eugeniae* earthworms. To avoid cross-contamination, the dried black tea waste and floral debris were crushed and physiochemically evaluated before composting. Table 1 outlines the physicochemical properties of raw black tea waste, floral waste and clay soil. In this study, five treatments with varying mixing ratios of Black Tea Waste (BTW) and Floral Waste (FW) were employed to determine their efficacy in vermicomposting. The experimental details are as follow: T1: 100% clay soil; T2: 80% BTW + 20 FW%. T3: 60% BTW + 40% FW; T4: 40% BTW + 60% FW and T5: 20% BTW + 80% FW. Fresh floral garbage (FW) came from a nearby temple and flower market, but black tea trash (BTW) came from a local tea business. Fig 1 and 1a depict the experimental design, as well as the compost and vermicompost conversion technique.

Composting and vermicomposting of BTW and FW using *Eudrilus eugeniae*

The BTW and FW mixtures were composted in plastic containers for 30 days to prepare treatments (pre-compost) T1 through T5. After composting, vermicomposting was done in the same plastic pot culture. The 45-day experiment employed 150 gm of clitellate earthworms from the *Eudrilus*

Table 1: The physico-chemical characteristics of raw black tea waste, floral waste and clay soil.

Physico-chemical parameters	Black tea waste (BTW)	Floral waste (FW)	Clay soil
pH	4.9	6.71	7.3
EC (dS/m)	0.9	0.2	1.2
TOC%	45	35	26
C/N ratio	35	27	20
TN%	0.81	0.06	1.2
TP%	0.49	0.04	0.9
TK%	0.72	0.09	1.5
Available N%	0.75	0.5	0.7
Available P%	0.46	0.3	0.5
Available K%	0.61	0.6	0.8
TCa%	0.51	0.25	0.6
TMg%	0.31	0.21	0.4

eugeniae species in the breakdown process. Throughout the experiment, water was sprinkled on a regular basis to maintain the moisture content between 60 and 70%.

Determination of physicochemical parameters during composting and vermicomposting

In this investigation, standard methods were used to analyze the physicochemical parameters of the samples. The pH and Electrical Conductivity (EC) were measured using a pH meter and an EC meter, respectively, following the method described by (Falcon *et al.*, 1987). Total Organic Carbon (TOC) was determined using the chromic acid wet digestion method as described by (Walkley and Black, 1934). Total nitrogen (TN) was analyzed using the Macro-Kjeldahl method following Humphries (1956).

Total phosphorus (TP) was quantified using the vanadomolybdate yellow colorimetric method, while total potassium (TK) was determined by flame photometry, following the methods described by Jackson (1973). Available nitrogen (AN) was estimated using the alkaline permanganate method developed by (Subbiah and Asija, 1956). Available phosphorus (AP) was determined by the colorimetric method using a 0.5 M NaHCO_3 extract, as described by (Olsen *et al.*, 1954). Available potassium (AK) was estimated by flame photometry using an N NH_4OAc extract, following (Stanford and English, 1949). Total calcium (TCa) and total magnesium (TMg) were determined after triple-acid digestion using ($\text{HNO}_3\text{H}_2\text{SO}_4\text{HClO}_4$ in a 9:2:1 ratio), followed by extraction and analysis using the Versenate method as described by Piper (1966).

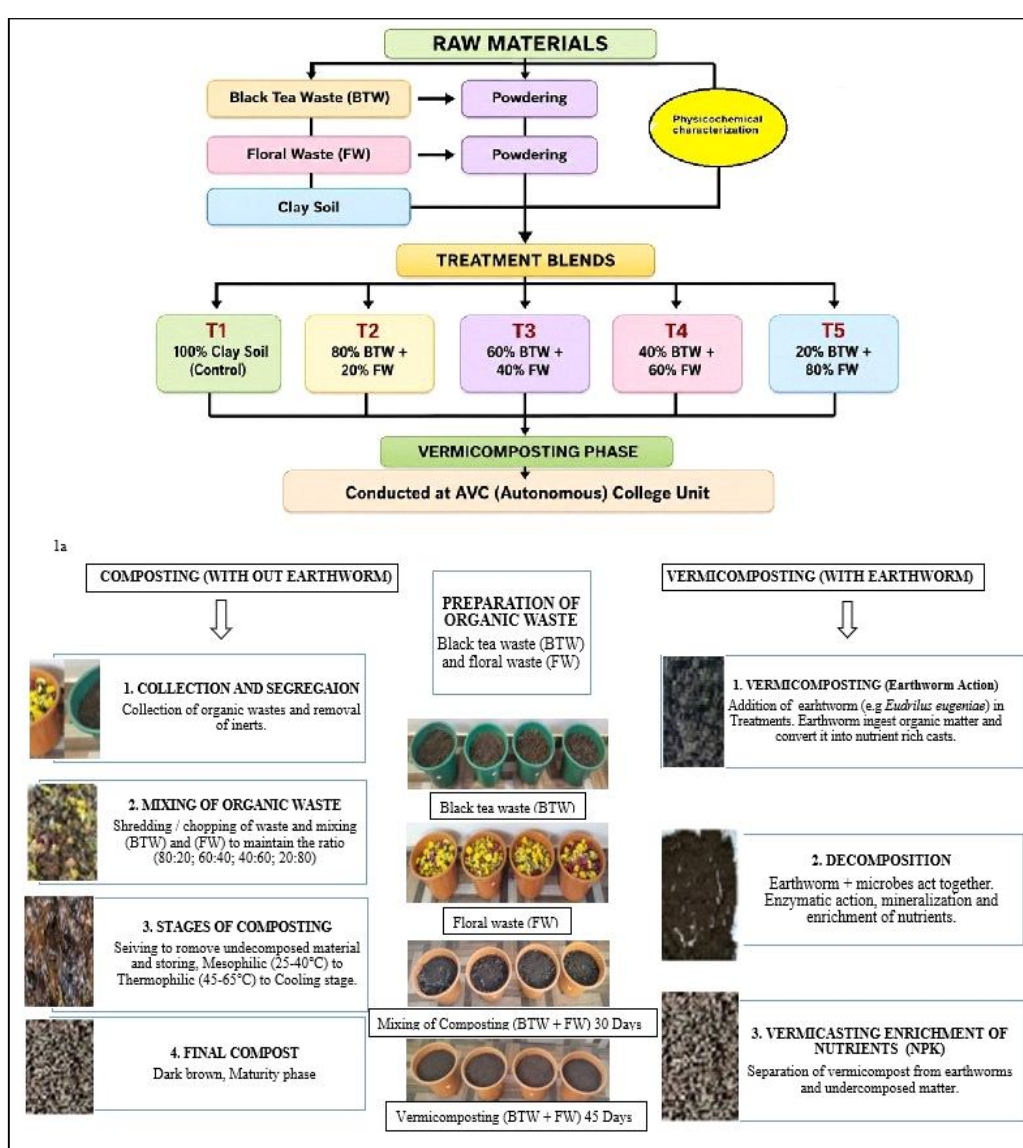


Fig 1: Experimental design and conversion procedure (1a) display both the experimental design and the compost and vermicompost conversion processes.

Data analysis

The statistical significance of treatments was determined using two-way analysis of variance (ANOVA). P values <0.05 were used to determine statistical significance of tests. The data from various samples were computed, together with the mean values and standard error (S.E).

RESULTS AND DISCUSSION

Organic solid waste is disposed of using typical composting methods. Composting and vermicomposting use two biological mechanisms to turn organic waste into nutrient-dense organic manure. The traditional composting process is primarily dependent on microbial activity; however, in vermicompost, the breakdown is performed by the earthworm, which also interacts with microbes and promotes nutritional compositions. In addition, the enzyme present on the earthworm increases digestion and strongly promotes nutritional composting. In conventional waste disposal, composting procedures were used. First, garbage was collected, then shredding was done and finally aerobic decomposition, maturation and curing was done in solid waste disposal beds. This produces stable compost and improves soil fertility. Composting produces CO₂, water vapour and heat as organic matter decomposes through mineralization and humification (Bernal *et al.*, 2009; Epstein, 1997; Tuomela *et al.*, 2000). Earthworms such as *Eudrilus eugeniae* work with bacteria in vermicomposting to accelerate the decomposition of organic waste. Following a brief pre-composting stage, earthworms devour and fragment waste, boosting microbial activity, nutrient mineralization and humus production. The resulting vermicompost is dark, granular, odourless and high in nutrients, beneficial bacteria, enzymes and plant growth-promoting compounds. The step wise composting process was shown in Fig 1a. In this study, we focused on the differences in macronutrient content between vermicompost and normal compost created from black tea waste and floral waste gathered from hotels, tea stores, flower markets and temples. The physicochemical characteristics of compost and vermicompost products were studied using products made with varying amounts of black tea waste (BTW) and floral waste (FW). Fig 2a depicts the pH and electrical conductivity findings of the treatments after traditional composting and vermicomposting. The results confirmed that the pH and EC values differed between compost and vermicompost, indicating earth worm activity. The vermicompost's strong black color indicated significant humification and substrate stabilization. The pH of compost without earthworms varied from 6.82 in T1 (100% clay soil) to 7.24 in T3. The pH levels in vermicompost including *E. eugeniae* ranged from 6.92 in T1 to 7.46 in T5. The higher pH seen in vermicompost than compost could be attributable to improved microbial breakdown, ammonification and mineralization of organic components by earthworm activity. Earthworms shred organic substrates and enhance microbial communities in the stomach and

surrounding substrate, resulting in the production of ammonia and humic chemicals, which buffer the pH toward neutral. The pH of mature vermicompost ranges from near-neutral to slightly alkaline, indicating that the organic material has stabilized and matured enough to be used in agriculture. T5 had the highest pH of the treatments, indicating that increased quantities of floral debris assisted in the humification and breakdown processes.

Electrical conductivity (EC) increased gradually in all treatments after vermicomposting. Compost without earthworms showed EC values that ranged from 1.2 dS/m in T1 to 1.8 dS/m in T5. In contrast, vermicompost with *E. eugeniae* showed higher EC values, ranging from 1.4 dS/m in T1 to 2.4 dS/m in T5. The higher EC in vermicompost indicates that soluble mineral salts such as nitrogen, phosphorous, potassium, calcium and magnesium are more easily liberated during the breakdown process. Earthworm activity increases biodegradation by increasing aeration, enzymatic activity and microbial biomass, hence improving the conversion of complex organic compounds into plant-available nutrients. The greatest EC found in T5 indicates that treatments with bigger floral waste fractions had higher breakdown efficiency and nutrient release. The dark black colour of the vermicompost indicated that the substrate had undergone advanced humification and attained greater stability (Moorthi and Nagarajan, 2011). The total organic carbon (TOC%) values from the compost and vermicomposting products are displayed in Fig 2b. We discovered that, depending on the composition ratio, the test sample's TOC content gradually decreased. Vermicompost prepared with *Eudrilus eugeniae* displayed a more notable decrease in TOC values (T1 to T5), whereas compost without earthworms had TOC values of about 48±3.2%. Vermicompost consistently had lower TOC levels than typical compost in all treatments, with the T1 showing a value of about 38±3.3% and the T5 recording 22±3.9%. The difference was statistically significant (p=0.003). The results revealed that the vermicompost method significantly composted organic matter while also rapidly decomposed and mineralized waste materials due to the combined activities of earthworms and microorganisms. Initially, Earthworm species mechanically split the substrate, increasing the surface area and making more phases available for microbial colonization, which enhances enzymatic breakdown and organic carbon oxidation. Microbial respiration breaks down carbonaceous compounds into simpler molecules, which are then released as CO₂. The decrease in TOC indicates the organic waste material's stability and maturation. T5 (BTW 20% + FW 80%) had the lowest TOC value of all the treatments, indicating increased decomposition efficiency and organic matter transformation. The produced vermicompost's are intense black colour and fine texture demonstrated advanced humification and stability (Garg *et al.*, 2006; Kaushik and Garg, 2004) all showed similar reductions in TOC during vermicomposting, attributing the

carbon loss to microbial mineralization and earthworm-assisted decomposition.

The carbon/nitrogen (C/N) ratio is a good indicator of organic waste composting and quality. Fig 2b shows a gradual drop in the C/N ratio across all composting and vermicomposting treatments. In the absence of earthworms, compost's C/N ratio decreased from 24 ± 3.1 in T1 to 14 ± 3.5 in T5. Vermicomposting with *E. eugeniae* led to considerable reductions, from 18 ± 2.3 in T1 to 11 ± 2.6 in T5. Vermicompost consistently had lower C/N ratios than compost and the difference between treatments was statistically significant ($p = 0.002$). The C/N ratio decreases during vermicomposting, indicating higher decomposition efficiency, nitrogen availability and organic substrate stabilization. Microbial respiration reduces carbon content while enriching nitrogen through earthworm excretory products and microbial biomass, lowering the C/N ratio. Earthworm activity increases organic matter turnover, nitrogen mineralization and nutrient retention in the

substrate. A lower C/N ratio is typically associated with mature and stable vermicompost appropriate for agricultural use. The lowest C/N ratio in T5 shows that treatments with higher quantities of floral waste perform better in terms of breakdown and nutrient enrichment. According to (Senesi, 1989), mature vermicompost has a C/N ratio of 14 to 22, although values below 15 suggest advanced stability and maturity. Higher C/N ratios reported in T1 and T2 compost treatments may be due to the substrate's higher carbonaceous content and slower breakdown rate. Edwards *et al.* (2011) published similar findings, emphasizing the importance of the C/N ratio in determining mineralization and compost maturity during organic waste decomposition.

Fig 3 shows the macronutrient composition of compost and vermicompost made from various combinations of black tea waste (BTW) and floral waste (FW). In comparison to conventional composting, all vermicompost treatments showed significant increases in total nitrogen (TN), total phosphorus (TP) and total potassium (TK). Compost's total

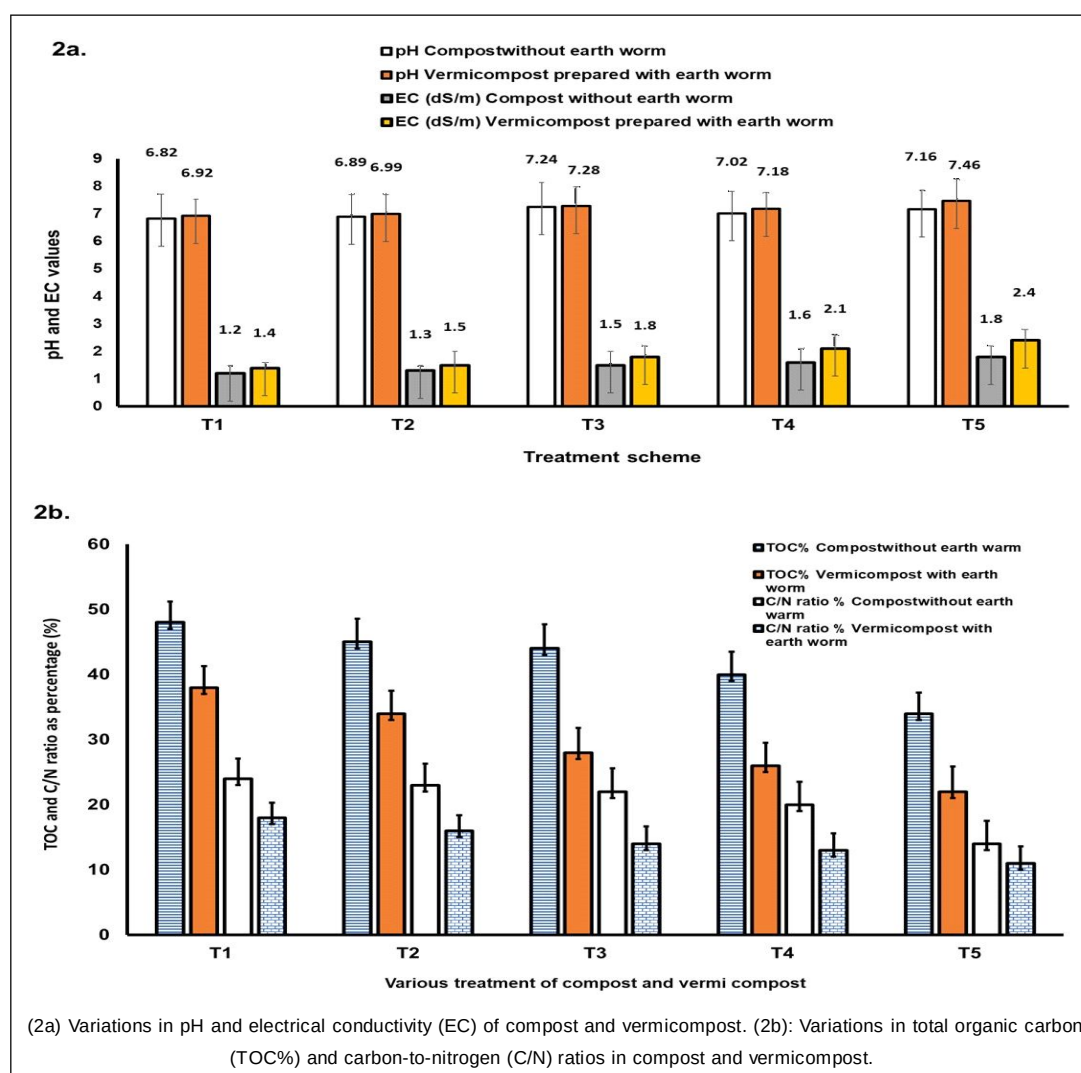


Fig 2: Results of physical and chemical investigation of compost and vermicompost.

nitrogen (TN%) content increased from $2.1 \pm 0.3\%$ in T1 to $4.2 \pm 0.3\%$ in T5. Vermicompost made with *Eudrilus eugeniae* had higher TN values, ranging from $2.4 \pm 0.2\%$ in T1 to $4.7 \pm 0.3\%$ in T5. The increase in nitrogen concentration during vermicomposting can be due to improved microbial degradation, organic matter mineralization and earthworm secretion of nitrogenous metabolites. Earthworm activity hastens decomposition and boosts microbial communities that transform organic nitrogen into plant-available compounds like ammonium and nitrate. Mucus secretion, earthworm casts and microbial biomass all contribute to nitrogen enrichment in vermicomposts. Similarly, the total phosphorus (TP%) content increased gradually across all treatments. Compost treatments had TP values ranging from $1.5 \pm 0.2\%$ in T1 to $3.1 \pm 0.4\%$ in T5, whereas vermicompost had considerably greater phosphorus levels ($2.0 \pm 0.2\%$ in T1 to $3.9 \pm 0.3\%$ in T5). The enhanced phosphorus availability in vermicompost may be attributed to phosphate-solubilizing bacteria and phosphatase enzymes present in the earthworm gut and vermicast, which facilitate the conversion of insoluble phosphorus into soluble and plant-available forms. (Moorthi *et al.*, 2016; Mahaly *et al.*, 2018). The breakdown and humification processes also help to release phosphorus from complicated organic materials.

Total potassium (TK%) content increased significantly during vermicomposting. Compost TK levels varied from $1.9 \pm 0.2\%$ in T1 to $3.5 \pm 0.3\%$ in T5, while vermicompost had higher values of $2.5 \pm 0.2\%$ in T1 to $4.1 \pm 0.2\%$ in T5. The rise in potassium concentration may be linked to increased mineralization and microbial decomposition of organic materials, resulting in the release of exchangeable potassium ions from the substrate matrix. Earthworm-mediated fragmentation of organic wastes enhances nutrient mobilization and speeds up nutrient cycling during vermicomposting (Mahaly *et al.*, 2018).

Among all treatments, T5 (BTW 20% + FW 80%) had the greatest TN, TP and TK contents, indicating better nutrient enrichment and breakdown. The greater nutrient concentrations detected in vermicompost compared to compost show that *E. eugeniae* is excellent at converting organic wastes into nutrient-rich biofertilizer. Statistical investigation demonstrated that compost and vermicompost had significantly different TN, TP and TK contents ($p = 0.0001$).

The enrichment of macronutrients in vermicompost may also be related to the reduction in total organic carbon and the concentration impact caused by organic matter mineralization. Earthworms increase nutritional availability through gut-associated microbial activity, enzyme release and the generation of growth-promoting compounds. The vermicompost's black granular structure and stable nature supported the substrate's advanced humification and maturity. (Domínguez and Edwards, 2011; Aira *et al.*, 2007; Lazcano and Domínguez, 2011) and it also increases in TNPK contents after vermicomposting.

Fig 4 shows the variations in available nitrogen (AN), phosphorus (AP) and potassium (AK) in compost and vermicompost. Compost nitrogen levels increased from $0.5 \pm 0.01\%$ in T1 to $1.9 \pm 0.2\%$ in T5, while vermicompost had higher values ranging from $1.1 \pm 0.02\%$ to $2.4 \pm 0.3\%$.

Similarly, the available phosphorus rose from $0.3 \pm 0.02\%$ to $1.4 \pm 0.2\%$ in compost and $0.8 \pm 0.02\%$ to $1.9 \pm 0.2\%$ in vermicompost. Potassium levels gradually increased from $0.7 \pm 0.01\%$ to $1.8 \pm 0.2\%$ in compost and $1.0 \pm 0.1\%$ to $2.1 \pm 0.4\%$ in vermicompost (Ramesh *et al.*, 2020). Vermicompost has considerably greater accessible nutrient levels than compost.

The enhanced availability of NPK nutrients in vermicompost may be associated with increased mineralization, microbial decomposition and humification facilitated by earthworm activity. Earthworms fragment the

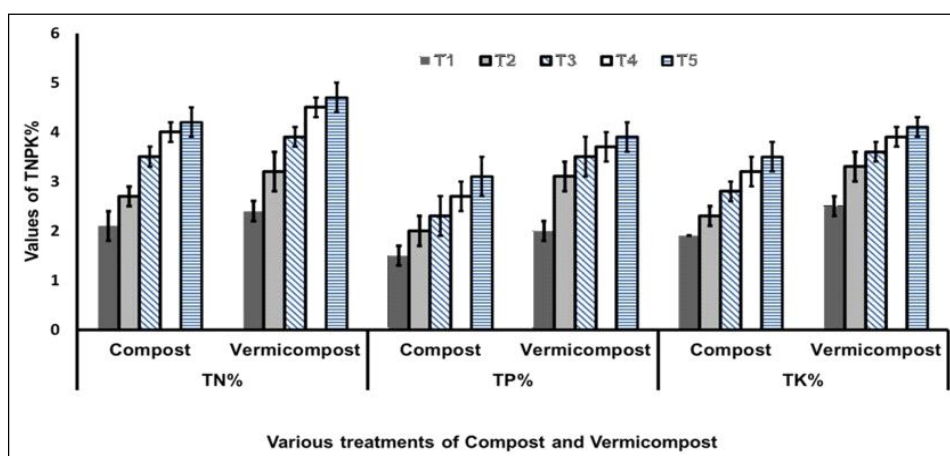


Fig 3: Macronutrient composition of compost and vermicompost derived from different combinations of black tea waste (BTW) and floral waste (FW).

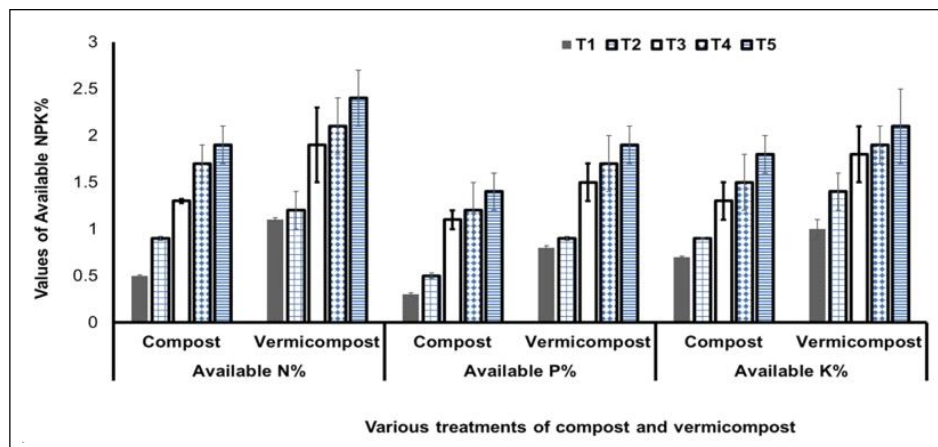


Fig 4: Fluctuations in available nitrogen (AN), phosphorus (AP) and potassium (AK) in compost and vermicompost.

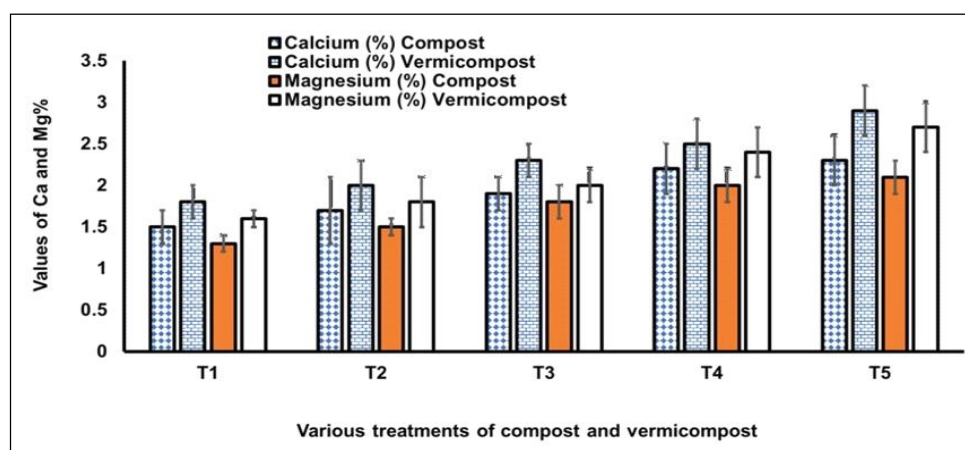


Fig 5: Differences in calcium (Ca) and magnesium (Mg) concentration between compost and vermicompost.

substrate and stimulate microbial populations, thereby accelerating the release of nutrients into plant-available forms. Phosphatase enzymes present in the earthworm gut and vermicast can convert insoluble phosphorus into soluble and plant-available forms, thereby enhancing phosphorus availability (Mahaly *et al.*, 2018; Moorthi *et al.*, 2016). T5 (BTW 20% + FW 80%) had the maximum nutritional availability, indicating improved breakdown and nutrient enrichment. previous reports (Singh *et al.*, 2011; Raihing and Vijayalakshmi (2022) also reported similar results and the improved nutrient availability in vermicomposted organic wastes was observed.

Fig 5 depicts differences in calcium (Ca) and magnesium (Mg) content in compost and vermicompost. Compost calcium concentration rose from $1.5 \pm 0.2\%$ in T1 to $2.3 \pm 0.3\%$ in T5, while vermicompost had higher values ranging from $1.8 \pm 0.2\%$ to $2.9 \pm 0.3\%$. Similarly, total magnesium concentration increased from $1.3 \pm 0.1\%$ to $2.1 \pm 0.2\%$ in compost and from $1.6 \pm 0.1\%$ to $2.7 \pm 0.3\%$ in vermicompost. Vermicompost consistently had considerably

more calcium and magnesium than compost (Ca: $p = 0.002$; Mg: $p = 0.002$).

The elevated calcium and magnesium levels in vermicompost may be attributed to earthworm intestinal activity, mineral transformation, and enhanced microbial activity during the decomposition process. (Moorthi and Nagarajan, 2011; Mahaly *et al.*, 2018). Earthworm casts have been shown to include higher quantities of exchangeable calcium and magnesium due to better mineral solubilization and organic matter decomposition. The progressive increase of Ca and Mg from T1 to T5 demonstrates successful nutrient mineralization in treatments with greater floral waste fractions. (Hartenstein and Hartenstein, 1981) found that vermicomposting caused similar increases in calcium and magnesium.

The findings showed that *Eudrilus eugeniae* effectively transformed black tea and floral waste into nutrient-rich vermicompost with better physicochemical characteristics and nutrient availability than conventional composting. Vermicomposting increased organic matter stabilization

and improved macro and micronutrient enrichment, indicating that it has the potential to be an environmentally friendly and sustainable organic waste management technique for increasing soil fertility and crop yield.

CONCLUSION

In conclusion, this paper described the successful generation of biofertilizer from black tea waste (BTW) and floral waste (FW) utilizing the vermicomposting biological recycling method using *Eudrilus eugeniae*. The earthworm efficiently converts garbage into nutrient-dense organic manure. The physicochemical metrics confirmed that vermicomposting outperformed traditional composting. The experimental results revealed that the produced vermicompost had increased total nitrogen, phosphorus, potassium, calcium and magnesium, indicating improved mineralization and nutrient availability due to earthworm and microbial activity. Among all treatments, T5 (BTW 20% + FW 80%) exhibited the maximum breakdown efficiency and nutritional enrichment. Overall, this study demonstrates that vermicomposting is a rapid, environmentally beneficial and sustainable method of managing tea and floral waste. In addition, they can be converted into high-quality organic fertilizer on a big scale to boost soil fertility and agricultural yield.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Not applicable for this study.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No A-6618 funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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