

THE EFFECTS OF PROVIDING VARIATIONS OF LOF IN THE SOIL ON THE DIVERSITY OF SOIL MACROFAUNA AND MESOFAUNA IN MARIGOLD (*Tagetes erecta L.*) PLANTS

Isnaini Nur Maghfiroh^{1,*}, Tien Aminatun¹, Suhartini¹, Anna Rakhmawati¹, Bernadetta Octavia¹, Fera Aulia¹

¹Departement of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

Article Info	ABSTRACT
Article history: Received October 7th, 2025 Revised January 12th, 2026 Accepted January 28th, 2026 *Corresponding Email: isnaini42fmipa.2021@student.uny.ac.id	The effects of POC and LOF variation from different MOL have been studied toward physical and chemical properties of soil and the diversity of soil macrofauna and mesofauna. The MOL used were fruit MOL, vegetable MOL, fruit + vegetable MOL, EM4, and water as controls. Data were obtained by pitfall trap, barless, and hand collecting methods. The results showed that the soil was clay/loamy, the soil structure was clumpy (20 mesh), granular (40 mesh), and crumbly (60 mesh). The infiltration rate of the soil treated with LOF was 0.209 seconds and not given LOF was 0.001 seconds. Soil organic matter in the LOF variation treatment showed positive with many bubbles while in the positive control treatment there were few bubbles. The macrofauna that dominates marigold plantings is Hymenoptera and the mesofauna that dominates marigold plantings is entomobryomorpha. Macrofauna and Mesofauna dominate in the Fruit+Vegetable LOF variation treatment. The number of macrofauna and mesofauna is influenced by edaphic factors and the physical and chemical properties of the soil. Keyword: MOL, LOF, Marigold, Macrofauna and Mesofauna Diversities

Introduction

Markets serve as the primary suppliers of household food commodities, with vegetables and fruits representing essential food sources for the community. The high demand for these commodities generates substantial amounts of vegetable and fruit residues that are often discarded indiscriminately around market areas. The accumulation of this organic waste creates large piles of refuse, resulting in unpleasant odors and environmental pollution (Sulistyaningsih, 2020). Inadequate management of vegetable and fruit waste in traditional markets further exacerbates these environmental problems and contributes to odor pollution. As a sustainable solution, this organic waste can be utilized as a raw material for the production of liquid organic fertilizer (LOF). The production of LOF not only represents an effective approach to reducing the volume of organic waste but also provides a more environmentally friendly alternative to chemical fertilizers. The application of LOF benefits farmers by reducing their dependence on chemical fertilizers, the excessive use of which has been shown to degrade the physical, chemical, and biological properties of soil. One of the commonly used fermentation starters for LOF production is Local Microorganisms (MOL) (Nisa et al., 2016).

Local Microorganisms (MOL) are fermented liquid cultures derived from organic materials that are rich in beneficial microorganisms, such as bacteria, yeasts, and fungi, which contribute to soil fertility and plant health. Fundamentally, the production of MOL involves the cultivation and multiplication of microorganisms that naturally occur in fruit and vegetable residues. MOL is commonly

used as a fermentation starter in the production of liquid organic fertilizer (LOF), where it accelerates the decomposition of organic materials by enhancing microbial activity (Mokodemis *et al.*, 2018). Sustainable agriculture has become a necessity rather than an alternative in addressing land degradation, climate change, and the global food crisis. In this context, liquid organic fertilizer (LOF) offers a strategic solution. Beyond serving as a source of plant nutrients, LOF functions as a catalyst for restoring soil ecosystems and provides a fundamental foundation for the future of sustainable agriculture (Suyendran *et al.*, 2025).

Soil is a vital natural resource that supports the survival of organisms and plants and serves as a key component of terrestrial ecosystems (Zakky *et al.*, 2024). Soil macrofauna and mesofauna play crucial roles in maintaining soil ecosystem functions by decomposing organic matter and facilitating nutrient cycling. The abundance and activity of these soil faunal communities largely depend on the availability of energy sources and food resources. The application of liquid organic fertilizer (LOF) enhances the availability of these substrates by supplying organic matter and stimulating microbial activity. In addition to serving as a nutrient source, LOF functions as a bioactivator, revitalizing soil biota through the provision of beneficial microorganisms and organic substrates. The presence of soil fauna, such as earthworms, mites, and Entomobryomorpha, is widely recognized as a key bioindicator of soil health and fertility. These organisms perform essential ecological functions, including the decomposition of organic matter, improvement of soil aggregation, and regulation of nutrient cycling (Muli *et al.*, 2016). The benefits of LOF application can be further enhanced when it is integrated with crop cultivation, as the combined presence of plant roots and organic fertilizer creates more favorable conditions for soil organisms and promotes sustainable soil ecosystem functioning (Nurrohman *et al.*, 2019).

Marigold (*Tagetes erecta* L.) is widely recognized not only for its ornamental value but also for its unique interactions with the soil environment. The application of different liquid organic fertilizer (LOF) formulations can influence marigold growth, the abundance and diversity of soil macrofauna and mesofauna, and the physical and chemical properties of the soil (Kusumastuti *et al.*, 2022). The combined use of LOF and marigold represents a promising approach to supporting sustainable agricultural practices. The application of LOF in marigold cultivation enhances plant growth while maintaining soil quality and minimizing soil degradation. Furthermore, different LOF formulations may exert varying effects on soil macrofaunal and mesofaunal diversity, plant growth, and the physical and chemical characteristics of the soil.

Previous studies have demonstrated that liquid organic fertilizer (LOF) produced from organic waste has considerable potential to enhance plant growth, improve the physical and chemical properties of soil, and stimulate the activity of soil organisms. However, information regarding the effectiveness of different LOF formulations in improving soil quality and supporting soil biota remains limited. This knowledge gap highlights the need for further investigation to achieve a more comprehensive understanding of the relationships among LOF formulation, soil conditions, plant growth, and soil faunal communities in support of sustainable agricultural systems. Therefore, this study aimed to evaluate the effects of different LOF formulations produced from market organic waste on the physical and chemical properties of soil under marigold (*Tagetes erecta* L.) cultivation, as well as on the diversity of soil macrofauna and mesofauna. This research is expected to contribute to the development of environmentally friendly and sustainable agricultural practices by promoting the utilization of organic market waste for LOF production and by providing insights into the effects of different LOF formulations on soil ecosystems in marigold cultivation.

Methods

The study was conducted at the Biology Experimental Garden, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta (FMIPA UNY) from January to April 2025. The experiment employed a single-factor experimental design, with the type of Local Microorganisms (MOL) used as the treatment factor. Different MOL formulations were used as fermentation starters for the production

of liquid organic fertilizer (LOF). The treatments consisted of fruit-based MOL, vegetable-based MOL, EM4, and water (spontaneous fermentation control).

Soil macrofauna and mesofauna were sampled using the pitfall trap, Berlese funnel, and hand-collecting methods. The physical and chemical properties of the soil analyzed included soil texture, soil structure, infiltration rate, and soil organic matter content. Macrofauna and mesofauna samplings were conducted once a week for 12 consecutive weeks. Soil samples for physical and chemical analyses were collected twice, namely before planting and at the end of the harvesting period.

The data collected from each observation were quantified and identified to determine the composition of soil macrofauna, mesofauna, soil texture, soil structure, infiltration rate, and soil organic matter content. The data were then analyzed and presented in the form of tables and figures, followed by descriptive interpretation based on the results obtained.

Results and Discussion

Result of Physical and Chemical Properties of Soil

Liquid organic fertilizer (LOF) plays an important role in binding soil particles into stable aggregates and improving soil texture, structure, organic matter content, and infiltration rate. Healthy soil provides a suitable habitat for soil macrofauna and mesofauna, enabling them to survive, reproduce, and obtain protection from physical disturbances.

Table 1. Soil Texture in Marigold Cultivation

LOF Variations	Fruit	Vegetable	Fruit + Vegetable	EM4	Water	C
Characteristics	Sticky and floury	Sticky and floury	Sticky and floury	Sticky and floury	Sticky and floury	Sticky and floury
Land Fraction	Clay	Clay	Clay	Clay	Clay	Clay

Soil texture is one of the physical properties of soil that indicates its degree of coarseness or fineness. Soil texture is closely associated with permeability, water-holding capacity, aeration, cation exchange capacity, and overall soil fertility (Palupi *et al.*, 2024). Soil texture is also a crucial factor determining the soil's ability to support plant growth as well as the activity of soil macrofauna and mesofauna. In this study, soil texture was assessed using a simple field method and classified according to the USDA (United States Department of Agriculture) soil texture triangle. The observed soil exhibited a sticky consistency when wet and a powdery texture when dry, characteristics that indicate a high clay content. These fine particles reduce pore space, making it difficult for soil macrofauna and mesofauna to obtain sufficient oxygen. The dense texture also physically restricts the movement of soil organisms and limits their ability to burrow. Although clay soils have a high water-holding capacity, they generally exhibit poor drainage. Following rainfall, the soil may become waterlogged, filling pore spaces with water and creating anaerobic conditions (oxygen deficiency) that are detrimental to most soil fauna (Kucera *et al.*, 2024). Organic matter plays an important role in improving clay soil by binding fine clay particles into larger aggregates, thereby increasing pore space, enhancing soil structure, and improving aeration.

The formation of soil aggregates creates macropores or larger void spaces within the soil. These spaces serve as essential habitats for soil fauna. Macropores facilitate soil aeration by providing the oxygen necessary for the respiration of organisms such as earthworms, ants, and beetles. In addition, these pores improve soil drainage, preventing waterlogging and the development of anaerobic conditions that are harmful to most soil organisms. Macrofauna utilizes these channels and pore spaces for movement, burrowing, and foraging. Meanwhile, mesofauna, such as the order *Entomobryomorpha* and mites, inhabit thin water films on the surfaces of soil aggregates and within smaller pore spaces. In

the absence of a well-developed aggregate structure, clay soil becomes dense and compact, creating an environment that is highly unfavorable for soil organisms. Therefore, it can be concluded that clay soil becomes a suitable habitat for soil fauna only when it possesses a well-developed aggregate structure, which is largely influenced by its organic matter content (Larasati *et al.*, 2016).

Table 2. Soil Structure in Marigold Planting

LOF Variations	Fruit	Vegetable	Fruit + Vegetable	EM4	Water	C
20 mesh	Lump	Lump	Lump	Lump	Lump	Lump
40 mesh	Grains	Grains	Grains	Grains	Grains	Grains
60 mesh	Crumb	Crumb	Crumb	Crumb	Crumb	Crumb

Tabel 3. Soil Infiltration Rate

LOF Variations	Fruit	Vegetable	Fruit + Vegetable	EM4	Water	C
Result	0,209 second	0,209 second	0,209 second	0,209 second	0,209 second	0,001 second

Infiltration is the process by which water enters the soil vertically. It is one of the soil conservation techniques used to improve both the quality and quantity of groundwater (Ristianingsih *et al.*, 2015). The presence of macrofauna and mesofauna communities in clay soils has a direct and highly beneficial effect on infiltration capacity. The activities of these soil organisms fundamentally modify the soil's physical properties. The combined activities of macrofauna and mesofauna contribute to improving soil aggregate stability. The formation of stable soil aggregates increases the number of macropores between soil particles, giving the soil a sponge-like structure and enhancing its capacity to absorb and retain water.

Based on the results of this study, soils treated with various liquid organic fertilizer (LOF) formulations, including fruit-based LOF, vegetable-based LOF, mixed fruit-and-vegetable LOF, EM4, and water, exhibited an infiltration time of 0.209 seconds, whereas the control treatment (K) showed an infiltration time of 0.001 seconds. The differences in infiltration time among treatments were influenced by soil texture and soil structure. All soil samples had a clay texture, which is characterized by a sticky consistency when wet and a hard or compact condition when dry. The infiltration experiment demonstrated that soils treated with LOF allowed water to pass through and reach the beaker more rapidly than untreated soils. In contrast, water required a longer time to infiltrate untreated soil and reach the beaker. These findings indicate that soils receiving LOF treatment contained higher levels of organic matter than untreated soils, resulting in improved soil physical properties (Eka *et al.*, 2024).

Soils with higher organic matter content provide a more favorable habitat for soil macrofauna and mesofauna. As these organisms inhabit and move through the soil, they naturally create channels and pore spaces. These pores remain open and serve as pathways for water to flow downward into the beaker, explaining the faster infiltration observed in LOF treated soils compared with untreated soils. Water moves rapidly through these larger macropores under the influence of gravity, thereby substantially increasing the infiltration rate. In contrast, soils with low organic matter content tend to be compact, contain fewer macropores, and allow water to infiltrate only slowly through narrow micropores.

Table 4. Soil Organic Material

LOF Variations	Fruit	Vegetable	Fruit + Vegetable	EM4	Water	C
Result	Positive (high)	Positive (high)	Positive (high)	Positive (high)	Positive (high)	Positive (high)

Organic matter is one of the key determinants of soil quality, and its presence is known to be closely associated with clay soils (Kallenbach *et al.*,2016). Soil treated with liquid organic fertilizer (POC) consistently exhibits a higher organic matter content than soil that does not receive POC treatment. This difference is attributed to the dual effects of POC application (Eka *et al.*,2024).

Based on the results of this study, soils treated with POC showed a positive response, as indicated by the formation of foam after the application of hydrogen peroxide (H₂O₂). The production of foam following the addition of H₂O₂ is commonly used as an indicator of the presence of organic matter in the soil. Directly, POC is a solution rich in dissolved organic compounds, including humic acids, fulvic acids, and various amino acids. When applied to the soil, these compounds are immediately incorporated into the soil matrix, thereby directly increasing the total organic matter content.

Although the untreated soil also produced a positive reaction, the amount of foam generated was considerably lower than that observed in the POC-treated soil. This result may have been influenced by environmental conditions surrounding the experimental site. Rainfall was likely a contributing factor, as rainwater may have transported dissolved POC from adjacent treated plots into the control soil, resulting in a detectable but weaker reaction. In addition, fallen leaves and twigs that accumulate on the soil surface are gradually decomposed by microorganisms and eventually become part of the soil organic matter pool (Ihsan *et al.*,2017).

Furthermore, soil fauna that die within the soil are decomposed and contribute to the accumulation of soil organic matter. The excreta produced by soil fauna during their lifetime also constitute an important source of organic matter, enriching the soil and supporting its biological and physical quality (Lestari *et al.*,2021).

Amount of Macrofauna and Mesofauna in Marigold Plantings

Soil with good fertility and quality provides a favorable habitat for the reproduction and survival of soil macrofauna and mesofauna. Liquid organic fertilizer (LOF) also supplies the organic matter and nutrients required by these soil organisms, enabling them to survive and thrive in the soil.

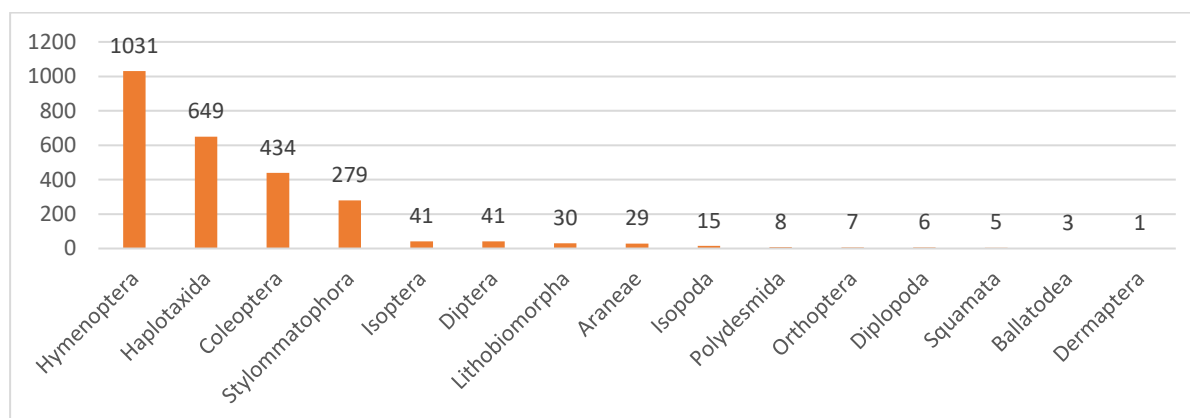


Figure 1. Overall Amount of Macrofauna Individuals Marigold Plantings

The results showed that the highest abundance was recorded in the order Hymenoptera. Hymenoptera was the most dominant order observed, primarily because ants exhibit eusocial behavior. This eusocial characteristic makes ants highly competitive, enabling them to defend food resources and territories from other soil macrofauna. Consequently, ants can dominate macrofaunal communities within a given area (Haneda and Ajeng 2021). The dominance of Hymenoptera also provides important ecological benefits to the soil. Ants contribute to soil bioturbation through their nest-building activities, during which they continuously transport soil particles from deeper layers to the surface. This process improves soil structure and enhances soil aeration. In addition, ants play a

significant role in decomposition by redistributing nutrients. They collect and transport organic residues into the soil, where these materials are further decomposed by soil mesofauna and microorganisms, thereby accelerating nutrient cycling (Adhi et al., 2017). Furthermore, ants function as effective biological regulators through their generalist predatory behavior. They exert significant predation pressure on a wide range of invertebrates, effectively suppressing potential population outbreaks of prey species (Sapto et al., 2021). This mechanism prevents the dominance of a single taxonomic group, allowing ants to play a crucial role in maintaining ecological balance and preventing resource monopolization. Through competition, ants also influence the structure of surrounding communities. The aggressive territorial behavior of dominant ant colonies creates a "landscape of fear," an ecological pressure that forces competing organisms to adapt their behavior, thereby contributing to the regulation of species distribution and community dynamics.

The second most abundant individuals belonged to the order Haplotaxida, which consists of earthworms. Earthworms were frequently found in soils with stable moisture conditions because they respire through their thin, permeable skin, which requires a moist environment. To survive, earthworms burrow into the soil and spend most of their life underground. These burrows function as water channels, facilitating faster water infiltration into the soil and thereby reducing the risk of surface erosion (Lesmana, 2022). Earthworms are detritivorous organisms, meaning that they feed on dead organic matter. Through their feeding and burrowing activities, earthworms accelerate the decomposition of organic materials, enhance nutrient cycling, and improve soil structure and fertility. The third most abundant soil macrofauna belonged to the order Coleoptera. Members of this order are widely recognized as important biological control agents within soil ecosystems because many species act as predators that regulate the populations of other organisms, including agricultural pests. Their presence contributes to maintaining ecological balance and supporting the stability of soil communities.

The fourth most abundant order was Stylommatophora, whose members function as decomposers by feeding on dead organic matter. Through this process, they contribute to soil fertility by producing nutrient-rich feces that enrich the soil. The fifth order was Isoptera (termites), which act as ecosystem engineers due to their ability to collect and process dead organic matter. The accumulated organic residues provide a suitable substrate for fungi of the genus *Termitomyces*, which in turn serve as a food source for smaller soil organisms. In addition, termite activities enhance nutrient cycling and improve soil structure through the decomposition and redistribution of organic materials. The sixth order was Diptera, whose members function as decomposers by breaking down organic matter on the soil surface. Their feeding activities fragment organic residues into smaller particles, facilitating their incorporation into the soil where they become an important food source for other soil organisms and contribute to the decomposition process.

The seventh most abundant order was Lithobiomorpha, whose members function as predators within the soil ecosystem. As predators, they help regulate the populations of other soil organisms, suppress pest populations, and contribute to biological regulation. As dominant predators in their habitat, they play an important role in maintaining ecological balance by preventing excessive population growth of prey species (Yulianingsih et al., 2020). The eighth order was Araneae (spiders), which also function as predators. Spiders play a crucial role in controlling the abundance and potential population outbreaks of other soil-dwelling organisms, thereby contributing to the stability and balance of soil communities. The ninth order was Isopoda, which are recognized as highly efficient decomposers in the litter layer. These organisms feed on dead organic matter, fragmenting plant residues into smaller particles and facilitating the decomposition process. This activity accelerates nutrient cycling and enhances the availability of organic matter for other soil organisms. The tenth order was Polydesmida, whose members also function as decomposers and are considered important detritivores in soil ecosystems. By consuming and fragmenting decaying organic materials, they promote decomposition, nutrient recycling, and the maintenance of soil fertility.

The eleventh order was Orthoptera, represented by *Valanga nigricornis* and *Teleogryllus occipitalis*. *Valanga nigricornis* contributes naturally to nutrient cycling, as its feces deposited on the soil surface provide concentrated sources of nutrients and organic matter that are readily decomposed

by other decomposers. In addition, *Teleogryllus occipitalis* functions as a detritivore by feeding on decaying plant residues and breaking down coarse organic matter. This species also burrows into the soil, creating small tunnels that improve soil aeration on a local scale (Iskandar *et al.*, 2021). Through these activities, *T. occipitalis* contributes to organic matter decomposition and supports soil ecosystem functioning. The twelfth order was Diplopoda, represented by *Trigoniulus corallinus*. This species functions as a detritivore by consuming large quantities of leaf litter and decaying wood. Its feces contribute to humus formation, which is essential for improving soil structure, enhancing soil fertility, and promoting nutrient cycling within the soil ecosystem.

The thirteenth order was represented by Squamata, specifically the family *Eutropis multifasciata*, which functions as a predator by regulating prey populations and thereby contributing to the maintenance of ecosystem balance. The diversity of organisms identified in this study highlights the complexity of the soil ecosystem. It comprises predators that regulate population dynamics, decomposers that recycle nutrients, herbivores that may act as agricultural pests, and specialized scavengers. The balance among these functional groups plays a crucial role in determining overall soil health and productivity. The fourteenth order was Blattodea, whose members function as decomposers by consuming a wide range of dead organic materials, thereby facilitating the breakdown of organic matter and nutrient recycling. The fifteenth order was Dermaptera, represented by *Labidura riparia*, which also serves as a decomposer. This species is highly efficient at decomposing tough and resistant organic materials, such as dry leaves and decaying wood, which are often inaccessible to other soil organisms (Sapto *et al.*, 2021).

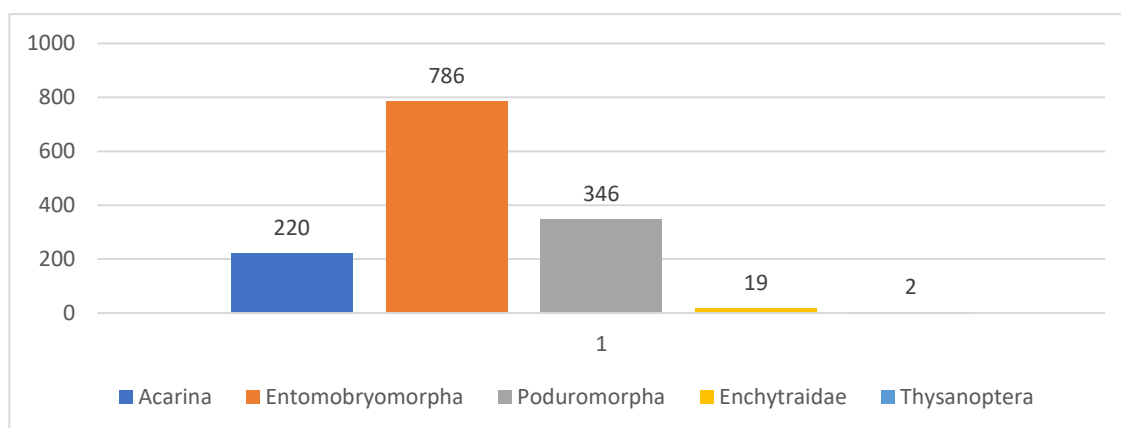


Figure 2. Overall Amount of Macrofauna Individuals Marigold Plantings

Entomobryomorpha was the most abundant order identified in this study because its members are capable of utilizing a wide range of organic food resources, including decaying leaves, decomposing wood, fungal spores, fungi, and bacteria. The continuous availability of these food sources supports the maintenance of large populations. Their extremely small body size also enables them to inhabit soil pores, where they are protected from larger predators and buffered against harsh surface environmental conditions, such as drought and high temperatures (Crowther *et al.*, 2019). In addition, Entomobryomorpha has a relatively short life cycle and a high reproductive rate, allowing its populations to increase rapidly and become widely distributed in the soil (Puspitasasi *et al.*, 2021). Despite their small size, members of Entomobryomorpha play an important role in maintaining soil health and fertility. They are often regarded as ecosystem engineers because they contribute significantly to the early stages of organic matter decomposition and serve as one of the primary decomposers responsible for breaking down organic residues, thereby facilitating nutrient cycling within the soil ecosystem (Chairunnisa *et al.*, 2022).

Other mesofauna identified in this study belonged to the orders Acarina and Poduromorpha. These organisms contribute to the fragmentation of organic matter into smaller particles, thereby

accelerating the decomposition process. Acarina also includes predatory species that naturally regulate soil pest populations and help maintain ecosystem balance, whereas Poduromorpha primarily functions as a detritivore and fungivore, contributing to organic matter decomposition and nutrient cycling in the soil (Crowther *et al.*, 2019). In addition, Acarina plays an important ecological role as a food source for ants, spiders, and beetles, thereby contributing to the soil food web (James *et al.*, 2019). Another mesofauna group identified was Enchytraeidae, which functions as a decomposer and contributes to soil fertility. Members of this family decompose organic matter by feeding on leaf litter and decaying plant materials, thereby accelerating the breakdown of organic residues and enhancing nutrient recycling. The final mesofaunal group identified was Thysanoptera, which acts as a plant pest. The feeding activity of these insects causes physical damage to plant tissues, resulting in adverse effects on plant growth and productivity (Oktaviany *et al.*, 2015).

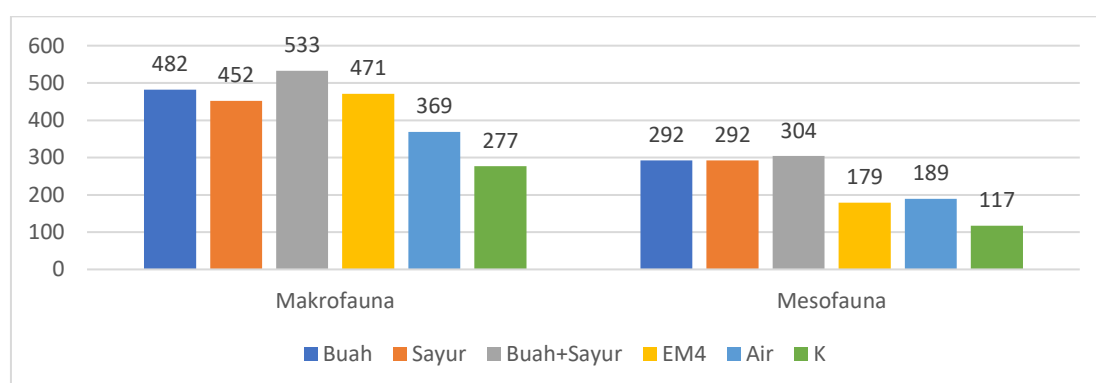


Figure 3. Macrofauna and mesofauna in LOF variations

The results showed that the fruit + vegetable liquid organic fertilizer (LOF) treatment produced the highest total abundance of both macrofauna and mesofauna. This is likely because soil macrofauna and mesofauna require a balanced source of energy and nutrients to support their growth and reproduction. The combination of fruit and vegetable materials provides simple sugars, as well as fiber rich in cellulose, lignin, and nitrogen (Puspitasari *et al.*, 2021). The fruit + vegetable LOF was more effective in creating a favorable habitat for soil macrofauna and mesofauna due to its multifunctional role as a food source, a habitat enhancer, and a contributor to the stability of the soil food web. Simple sugars derived from fruits serve as an immediate energy source that rapidly stimulates the activity of soil microorganisms, particularly bacteria and fungi. These microorganisms constitute the primary food source for many soil macrofauna and mesofauna. Meanwhile, vegetables provide cellulose, which serves as a long-term carbon source because it decomposes more slowly, while nitrogen is an essential component for protein synthesis and the growth and development of soil macrofauna and mesofauna (Puspitasari *et al.*, 2021).

The diversity of food resources (soft, hard, sugary, and fibrous materials) successfully attracted a greater number of decomposers macrofauna species, such as ants and earthworms, each of which has different feeding preferences (Abdul *et al.*, 2020). The presence of a large decomposer population subsequently attracted predators, including centipedes and ground beetles, thereby establishing a more complex and stable food web. Therefore, LOF derived from a mixture of fruit and vegetable waste proved to be superior because it not only provides a food source but also creates a complete microecosystem. This combination offers diverse nutrients, a favorable physical habitat, and stable moisture conditions, which synergistically support a larger and more complex community of soil organisms (Widyabudiningsih *et al.*, 2021).

Mixture of fruit and vegetable waste provides an ideal substrate for microbial proliferation, as the simple sugars derived from fruits stimulate rapid fermentation by bacteria and yeasts (Puspitasari *et al.*, 2021). Bacterivorous and fungivorous mesofauna are subsequently attracted to consume the microbial biomass present in the LOF, thereby promoting rapid exponential reproduction during the

early stages of decomposition (Husamah *et al.*, 2017). This microbial population bloom directly supplies an abundant and readily available food source that supports a large mesofaunal community. The fruit-vegetable LOF treatment provides the most favorable habitat for mesofauna due to a well-balanced two-stage synergistic process. In the first stage, fruit-derived sugars stimulate a rapid increase in microbial populations, creating an immediate food source that enhances mesofaunal abundance. In the second stage, vegetable-derived fibers provide a sustained fungal-based food resource while simultaneously forming a more complex and stable physical habitat structure (Puspitasari *et al.*, 2021). This combination creates optimal conditions for attracting and sustaining the largest and most diverse mesofaunal community.

Tabel 7. Edaphic Factors

LOF Variations	Fruit	Vegetable	Fruit Vegetable	EM4	Water	C
Soil Temperature	26,7	24,5	26,5	26,3	26,8	26,7
pH	7	7,2	7	6,9	6,9	6,9
Humidity	Dry	Dry	Dry	Dry	Dry	Dry

Edaphic factors, including soil temperature, soil pH, and soil moisture, constitute the fundamental foundation that plays a decisive role in plant growth and the survival of soil faunal communities. These factors serve not only as habitat conditions but also as essential determinants of energy availability for soil fauna. Optimal and stable edaphic conditions promote the persistence, survival, and reproduction of soil organisms (Purba *et al.*, 2021). The regular application of liquid organic fertilizer (LOF) increases soil organic matter content. Soil organic matter acts like a sponge by improving soil structure and enhancing its water-holding capacity. Optimal soil temperature accelerates nutrient uptake by plant roots and increases the rate of decomposition of organic matter by soil organisms. Likewise, soil pH directly influences the survival and activity of soil organisms. Soil moisture is closely associated with soil water content and is essential for plants, as water is required for photosynthesis and the maintenance of cell turgor (Muhammad *et al.*, 2022). Based on the results presented above, the highest soil pH (7.0) was recorded in the fruit- and vegetable-based LOF treatment. This finding can be attributed to the application of organic matter, which helps reduce soil acidity and restore a near-neutral pH. The application of LOF increases soil organic carbon (SOC) availability, thereby improving soil buffering capacity and contributing to the normalization of soil pH.

Tabel 8. Macrofauna diversity index

Variasi	Indeks value			
	Diversity	Equality	Riches	Domination
Fruit	3,632	1,386	2,529	0,184
Vegetable	3,659	1,399	2,520	0,173
Fruit+Vegetable	3,563	1,383	2,452	0,200
EM4	3,480	1,306	2,709	0,215
Water	3,412	1,336	2,488	0,211
C	3,223	1,470	1,845	0,195

The high macrofaunal diversity index observed in the treatment receiving vegetable-based liquid organic fertilizer (LOF) can be attributed to the heterogeneity and nutritional completeness of the raw materials used, which directly establish the foundation for a more complex and stable soil food web. Therefore, the superiority of vegetable-based LOF in enhancing macrofaunal diversity results from the synergistic effects of its ability to provide a diverse array of nutrient resources, maintain ecosystem stability, and simultaneously improve the physical quality of the soil habitat. The composition of

vegetable waste, which is rich in a wide range of organic compounds such as carbohydrates, proteins, and vitamins, serves as an attractive food source for various soil organisms with different nutritional requirements (Puspitasari *et al.*, 2021). According to the table, the highest species richness index among the LOF treatments was recorded in the EM4-activated treatment, with a value of 2.709. The high species richness observed in the EM4-based liquid organic fertilizer (LOF) treatment can be attributed to the composition of microorganisms present in EM4, which is inherently more diverse and functionally active than those found in other activators or in spontaneous fermentation processes. The dual role of EM4-based LOF, serving both as a nutrient source and as an ecosystem inoculant, is derived from its unique microbial composition.

Based on the results, the highest evenness index was recorded in the control treatment, with a value of 1.470. The higher evenness index observed in control treatment compared with the other treatments indicates that the soil macrofaunal community in the control plots was more stable and evenly distributed. This can be explained by the fact that the control plots, which did not receive any external intervention or treatment, represented a relatively undisturbed baseline ecosystem. The absence of stress factors, such as chemical inputs and physical disturbances, allowed different macrofaunal species to coexist under natural levels of competition, thereby promoting a more balanced community structure (David *et al.*, 2019).

The highest dominance observed in this study was recorded in the EM4-based liquid organic fertilizer (LOF) treatment. The superior dominance value observed in the EM4-based LOF treatment, compared with LOF activated using other decomposers or produced through spontaneous fermentation, can be attributed to the quality and efficiency of the decomposition process mediated by its microbial composition. In contrast, LOF produced through spontaneous fermentation undergoes an uncontrolled fermentation process that relies solely on the indigenous microorganisms naturally present in the organic materials. Consequently, the higher dominance observed in the EM4-based LOF treatment reflects the cumulative effects of a controlled, efficient, and functionally effective fermentation process. Therefore, the high macrofaunal dominance recorded in the EM4-based LOF treatment indicates that this system was highly efficient in transforming organic matter into an abundant and readily available resource, which was subsequently exploited predominantly by the most well-adapted macrofaunal species.

Tabel 9. Mesofauna diversity index

Variasi	Nilai Indeks			
	Diversity	Equality	Riches	Domination
Fruit	2,929	1,514	1,306	0,335
Vegetable	2,450	1,299	1,317	0,339
Fruit+Vegetable	2,921	1,437	1,441	0,367
EM4	2,316	1,373	1,156	0,318
Water	2,486	1,435	1,126	0,326
C	2,269	1,433	1,085	0,344

The results showed that the diversity index for all liquid organic fertilizer (LOF) treatments was below 3, indicating a relatively low level of mesofaunal diversity. This low diversity can be attributed to both natural environmental pressures and anthropogenic disturbances. In agricultural lands or other disturbed areas, soil tillage physically disrupts microhabitats and interferes with the life cycles of soil mesofauna. Furthermore, the homogeneity of available resources and habitat conditions also plays a crucial role. Ecosystems dominated by monoculture vegetation produce relatively uniform litter, which provides a less diverse food source than that found in mixed forests. This limited diversity of food resources directly restricts the number of mesofaunal species with different feeding preferences that are able to coexist within the same habitat (David *et al.*, 2019). The species richness index was low across all liquid organic fertilizer (LOF) treatments, with values below 3.5. The highest species richness was observed in the fruit- and vegetable-based LOF treatment, indicating that this combination of

nutrients created the most favorable environment for a wide variety of mesofaunal species. In contrast, the negative control (K-) exhibited the lowest species richness value (1.085), demonstrating that, in the absence of additional nutrient inputs, only a limited number of mesofaunal species were able to inhabit the soil.

The highest mesofauna evenness index was recorded in the fruit- and vegetable-based liquid organic fertilizer (LOF) treatment, with a value of 1.437. An evenness index greater than 0.6 is generally considered a strong indicator of a balanced and stable community structure. Ecologically, this finding suggests that no single species dominated the community excessively, and individuals were distributed relatively evenly among the species present. This pattern is primarily attributable to stable and favorable physical and chemical environmental conditions. Factors such as near-neutral soil pH, adequate soil moisture, and the absence of toxic compounds or pollutants created an optimal habitat that supported the growth and persistence of a wide range of mesofaunal species. Therefore, the high evenness observed in this treatment can be attributed to the synergistic effects of favorable environmental conditions, diverse resource availability, and complex biological interactions, all of which contribute to maintaining community stability (David *et al.*, 2019). The dominance index (D) value of 0.367 observed in the soil mesofaunal community indicates a low to moderate level of dominance. Ecologically, this value is considered a positive indicator, suggesting that no single mesofaunal taxon or a small number of taxa excessively dominated the community. Such a relatively low dominance index is most likely the result of several interacting ecological factors. These include stable soil physical and chemical conditions, as well as the availability of diverse organic matter resources that support a wide range of mesofaunal species (David *et al.*, 2019).

Conclusion

Based on the results of this study, it can be concluded that the application of different liquid organic fertilizer (LOF) formulations did not affect soil texture or soil structure, as these physical properties remained similar between treated and untreated soils. In contrast, soil infiltration rate and organic matter content differed between soils receiving LOF treatments and those without LOF application. The highest abundance of both soil macrofauna and mesofauna was observed in the fruit + vegetable LOF treatment. The greatest macrofaunal diversity was recorded in the fruit LOF treatment, whereas the highest mesofaunal diversity was found in the vegetable LOF treatment. These findings suggest that the composition of liquid organic fertilizer influences soil biological communities and selected soil physicochemical properties, with the combined fruit and vegetable formulation providing the most favorable conditions for supporting soil fauna abundance. Therefore, the application of fruit- and vegetable-based LOF has the potential to improve soil quality and promote soil biodiversity, making it a promising sustainable alternative for enhancing soil ecosystem functions.

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