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Original Article

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Eco-Enzyme Precipitate Made from Fruit Peel to Increase the Growth of *Ipomoea reptans* Poiret

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Abstract. Organic waste, particularly fruit peels, continues to contribute to environmental problems due to limited utilization despite its potential as a renewable agricultural resource. This study aimed to evaluate the effectiveness of *eco-enzyme* precipitate produced from mixed fruit peels as an alternative solid organic fertilizer for improving the vegetative growth of land kale (*Ipomoea reptans* Poiret). The experiment employed a Completely Randomized Design (*CRD*) consisting of four treatment levels of *eco-enzyme* precipitate concentration, namely 0, 30, 60, and 90 g/1000 mL of water, with three replications for each treatment. Plant height, number of leaves, leaf length, leaf width, and leaf area were observed for 25 days after planting. The precipitate was also analyzed to determine its nitrogen (N), phosphorus (P), and potassium (K) contents before application. The laboratory analysis revealed that the precipitate contained 0.243% nitrogen, 0.01217% phosphorus, and 0.02254% potassium, indicating that its macronutrient content had not yet met the Indonesian National Standard (*SNI*) for solid organic fertilizers. Nevertheless, statistical analysis demonstrated that the application of *eco-enzyme* precipitation significantly enhanced vegetative growth compared with the untreated control. Among the tested concentrations, 60 g/1000 mL consistently produced the most favorable response in plant height, leaf production, leaf dimensions, and total leaf area. Although its nutrient concentration remains relatively low, the precipitation provides sufficient bioactive compounds and organic substances to stimulate plant growth. Therefore, fruit peel-based *eco-enzyme* precipitate has promising potential as an environmentally friendly alternative to organic fertilizer while simultaneously supporting the sustainable utilization of organic household waste.

Keywords: *eco-enzyme* precipitate; fruit peel waste; *Ipomoea reptans* ; organic fertilizer; vegetative growth

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INTRODUCTION

The increasing volume household organic waste management continues to pose a considerable challenge for environmental management in Indonesia. Much of this waste comes from fruit and vegetable waste, which generally ends up in landfills without being recycled. This contributes to higher levels of greenhouse gas emissions, environmental pollution, and the loss of potentially useful organic materials. *The circular economy approach* positions organic waste as a resource that can be processed into value-added products, one approach being *eco-enzyme technology* (Benny et al., 2023; Manalu et al., 2024; Saraswati & Witoyo, 2024).

According to Rosukon Poompanvong, the production of eco-enzymes involves the fermentation of organic waste, sugar, and water, resulting in a liquid product rich in bioactive compounds and a precipitate *that* still contains organic matter, nutrients, and beneficial microorganisms (Ashari et al., 2024). To date, most research has utilized the liquid fraction *of eco-enzymes* , while the precipitate from fermentation is still relatively rarely used as an organic fertilizer. In fact, this residue has the potential to increase soil fertility by providing organic matter and biological activity that supports plant growth (Rasyidah & Nasution, 2024).

The fruit peel waste used came from orange peel, banana peel, pineapple peel, and watermelon peel because they are easily obtained in the research area and have complementary nutritional characteristics. Orange peel contains vitamin C and various antioxidant compounds, banana peel is rich in potassium, pineapple peel contains the enzyme bromelain which helps the decomposition process of organic matter, while watermelon peel has a high water content so it can support the fermentation process (Benny et al., 2023; Istanti et al., 2023). The combination of various types of fruit peel is expected to produce *eco-enzyme* precipitate with better characteristics than using one type of organic material alone.

Eco-enzyme precipitates contain fermented organic matter that has the potential to be used as an alternative organic fertilizer. During the fermentation process, complex organic compounds are transformed into simpler chemical compounds, including organic acids and amino acids, and various enzymes that are more easily utilized by plants. In addition to providing nutrients, the presence of these bioactive compounds can also improve the activity of soil microorganisms, thus supporting nutrient absorption and vegetative plant growth (Ashari et al., 2024; Alfatihah et al., 2023).

The land spinach (*Ipomoea reptans* Poiret) was chosen as the research object because it has a relatively short harvest period, fast growth, and is widely cultivated by the community. This plant is also responsive to changes in growing media conditions and fertilization, making it often used as an indicator plant in organic fertilizer research. In addition to its high economic value, water spinach is a vegetable that contains various vitamins, minerals, and fiber needed by the community, so increasing its productivity has practical value for the agricultural sector (Pohan, 2021).

Various previous studies have reported that *eco-enzymes* can be used as organic fertilizers and plant growth promoters. However, the results show varying responses depending on the type of organic waste, fermentation method, formulation, and application dosage. Some studies found significant increases in plant growth, while others showed that *eco-enzyme effectiveness* is strongly influenced by its concentration and nutrient content (Ulmillah et al., 2025). These differences indicate that research on the use of *eco-enzyme precipitates* still needs to be developed to obtain more effective formulations.

This research is novel because it utilizes the fermented precipitate from a mixture of fruit peels as a solid organic fertilizer for land kale plants, rather than just using the liquid fraction *of eco-enzyme* . In addition to evaluating the nutrient content of nitrogen, phosphorus, and potassium in the precipitate, this study also tested the effect of several application concentrations on plant vegetative growth parameters. This approach is expected to provide scientific insights into the potential utilization of fruit peel waste as an environmentally friendly organic fertilizer while supporting sustainable organic waste management.

Based on the description, this study aims to analyze the use of *eco-enzyme precipitate* made from fruit peel as an organic fertilizer to increase the growth of land spinach (*Ipomoea reptans* Poiret) and to determine the application concentration that provides the best vegetative growth response.

MATERIALS AND METHODS

Research Design

This study employed an experimental approach to evaluate the effect of fruit-peel-derived *eco-enzyme* precipitate on the vegetative growth of water spinach (*Ipomoea reptans* Poiret). A *Completely Randomized Design* (CRD) was applied, consisting of one treatment factor, namely the concentration of *eco-enzyme* precipitate. Four treatment levels were tested, with each treatment replicated three times, resulting in a total of twelve experimental units. The treatments comprised P0 as the control without *eco-enzyme* precipitate, P1 with

30 g of precipitate per 1,000 mL of water, P2 with 60 g per 1,000 mL of water, and P3 with 90 g per 1,000 mL of water. This experimental design was used to determine the most effective concentration of *eco-enzyme* precipitate for promoting the vegetative growth of water spinach.

Table 1. Experimental treatments

Treatment	Description
P0	Control (without precipitate)
P1	30 g precipitate/1000 mL water
P2	60 g precipitate/1000 mL water
P3	90 g precipitate/1000 mL water

Research Location and Time

The research was conducted in Tulang Bawang Regency, Lampung Province. *Eco-enzyme production* , fermentation, planting, plant maintenance, and growth monitoring were carried out. Analysis of the nitrogen (N), phosphorus (P), and potassium (K) content of the precipitate was conducted in a designated laboratory. All stages of the research were systematically structured, from precipitate production to analysis of the results.

Materials and Equipment

The main ingredients used were orange peel, banana peel, pineapple peel, and watermelon peel as organic waste sources, brown sugar as a carbon source, clean water as a fermentation medium, water spinach seeds (*Ipomoea reptans* Poiret), soil, and a growing medium. Fruit peels were chosen because they are readily available at the research site and contain different organic compounds, thus expected to produce precipitates with better characteristics.

The equipment used includes a covered fermentation container, digital scales, measuring cups, stirrers, buckets, *polybags* , shovels, rulers, documentation cameras, stationery, and laboratory equipment used for analyzing the nutrient content of N, P, and K.

Preparation of *Eco-Enzyme* Precipitate

The *eco-enzyme* precipitate was prepared by fermenting fruit peel waste using the ingredient proportions specified in the research procedure. The fruit peel waste, brown sugar, and water were combined in a sealed fermentation container and subjected to anaerobic fermentation for approximately three months. Upon completion of the fermentation process, the fermented mixture was separated into its liquid and solid components to obtain the precipitate, which was subsequently utilized as an organic fertilizer in this study. Prior to its application to the plants, the precipitate was analyzed to determine its nitrogen (N), phosphorus (P), and potassium (K) contents.

Experimental Procedure

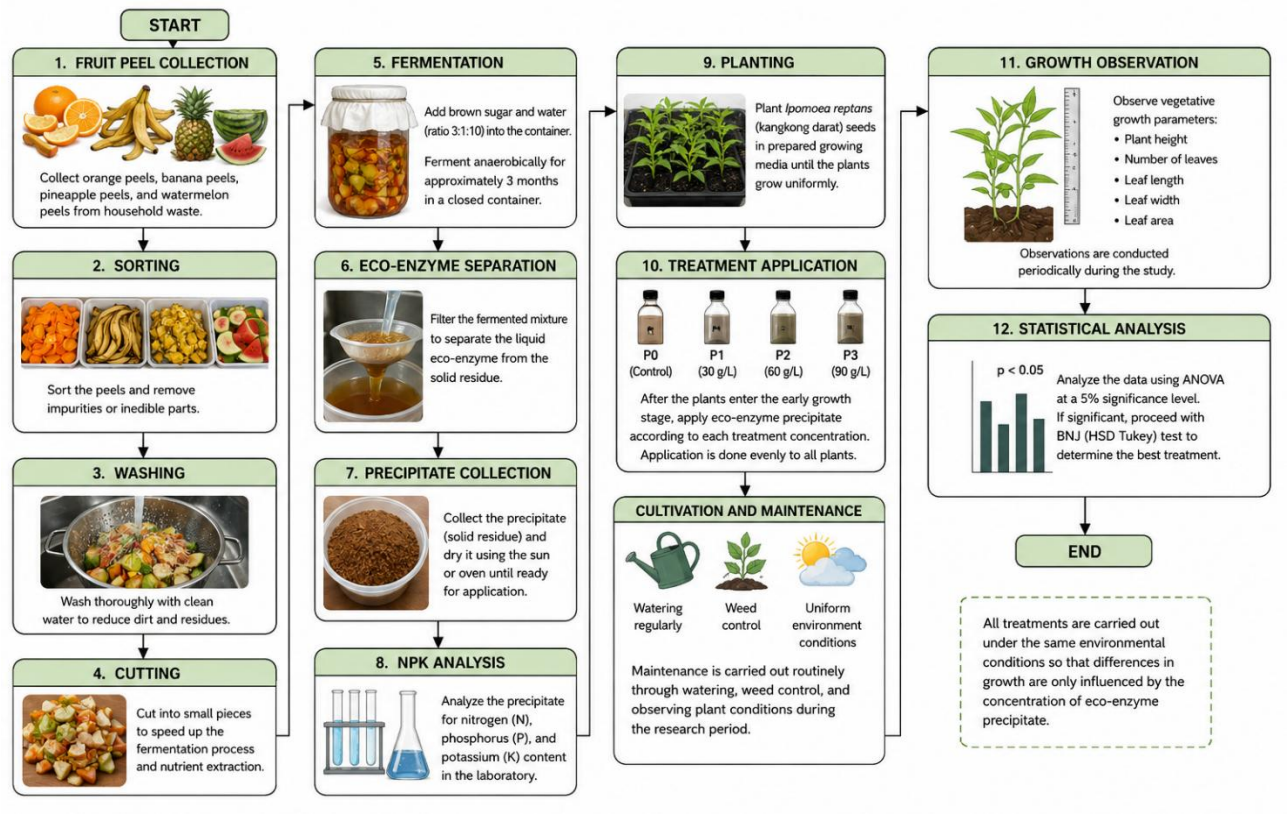


Figure 1 . Flowchart of research procedures.

Land spinach seeds were planted in prepared growing media until they grew uniformly. After the plants entered the initial growth phase, *eco-enzyme precipitate* was administered according to the concentrations specified for each treatment. Plant maintenance was carried out routinely through watering, weed control, and monitoring plant condition throughout the study period. All treatments received identical environmental conditions, so differences in plant growth were expected to be influenced only by the concentration of *eco-enzyme precipitate* .

Observation Parameters

The parameters evaluated in this study consisted of plant height, number of leaves, leaf length, leaf width, and leaf area. Measurements were carried out periodically over a 25-day observation period after planting to assess the response of vegetative growth to the application of *eco-enzyme* precipitate. In addition to the plant growth parameters, the fermented precipitate was analyzed for its nitrogen (N), phosphorus (P), and potassium (K) contents. The results of this nutrient analysis were used as supporting information in evaluating the effectiveness of the precipitate as an organic fertilizer.

Data Analysis

The collected data were subjected to analysis *of variance (ANOVA*) at a 95% confidence level to determine whether the application of eco-enzyme precipitate produced significant effects on the observed growth parameters. When the ANOVA results indicated a significant treatment effect, a subsequent post-hoc test was performed to identify differences among the treatment groups. The findings were presented in tables and interpreted by relating the experimental results to relevant theoretical concepts and previous research.

RESULTS AND DISCUSSION

Characteristics of Fruit Peel-Based *Eco-Enzyme* Precipitate

The eco-enzyme precipitate used in this study was obtained through the fermentation of orange peel, banana peel, pineapple peel, and watermelon peel for approximately three months. After the fermentation process was complete, two phases were formed: a liquid phase consisting of *eco-enzymes* and a solid phase

consisting of precipitate. The precipitate was blackish-brown in color with a characteristic sour aroma of fermentation, indicating the ongoing decomposition of organic matter into simpler compounds. This condition is in line with the description in the study which states that the fermentation process produces precipitate containing organic compounds resulting from decomposition, organic acids, amino acids, and various enzymes that have the potential to support plant growth.

Laboratory analysis revealed that the precipitate contained nitrogen (N), phosphorus (P), and potassium (K), although the concentrations of these nutrients were relatively low. The analysis recorded nitrogen content at 0.243%, phosphorus at 0.01217%, and potassium at 0.02254% indicated that the precipitate still did not meet national solid organic fertilizer standards. However, the presence of these nutrients still indicates that the fermented residue still has potential as a source of organic nutrients for plants (Siregar et al., 2024).

Table 2. Nutrient composition of fruit peel-based *eco-enzyme* precipitate

Parameter	%
Nitrogen (N)	0.243
Phosphorus (P)	0.01217
Potassium (K)	0.02254

These results indicate that the benefits of precipitate are not only determined by the content of macronutrients, but also by the presence of microorganisms, organic acids, and m

etabolites resulting from fermentation that can improve the biological conditions of the growing medium. Several studies have reported that *eco-enzyme residues* still contain active organic materials that can increase soil microbial activity and improve nutrient availability for plants, so they still have the potential to be used as an alternative organic fertilizer (Ashari et al., 2024; Hijriah et al., 2024; C. Tuhumurya et al., 2024).

Effect of *Eco-Enzyme* Precipitate on the Growth of *Ipomoea reptans*

eco-enzyme precipitate resulted in different responses to each growth parameter of land spinach. In general, all treatments resulted in better growth compared to the control, although the degree of improvement varied depending on the concentration administered. Statistical analysis showed that the precipitate the concentration significantly influenced vegetative plant growth, as reflected in plant height, number of leaves, leaf length, leaf width, and leaf area.

Among all treatments, a concentration of 60 g/1000 mL water (P2) provided the best growth response. This treatment resulted in plants with more uniform growth, a greater number of leaves, and greater leaf area development compared to the other treatments. Conversely, higher concentrations (90 g/1000 mL) did not always result in greater growth increases. These results suggest that an increase in organic fertilizer dosage does not necessarily produce a proportional improvement in the physiological response of plants.

The effectiveness of *eco-enzyme* precipitate appears to depend on the interaction between nutrient availability, microbial activity, and the capacity of plant roots to absorb and utilize nutrients. At relatively low concentrations, the nutrients supplied may be insufficient to support optimal plant growth. Conversely, excessive concentrations may lead to the accumulation of certain organic compounds, which could interfere with nutrient uptake and reduce the efficiency of root absorption.

The findings of this study are consistent with previous research on organic fertilizers, which generally indicates that optimal fertilizer concentrations tend to produce better plant growth responses. An appropriate concentration can provide nutrients in a balanced manner while minimizing the risk of physiological stress, thereby supporting more effective nutrient utilization and plant development. Therefore, the effectiveness of organic fertilizers is determined more by the optimum dosage than the amount of fertilizer applied.

Effect of *Eco-Enzyme* Precipitate on Vegetative Growth of *Ipomoea reptans* Poiret

Plant Height

Plant height is one of the main indicators for evaluating the success of vegetative growth because it reflects the activity of cell division and elongation during the early growth phase. Based on the results of the study, the administration of *eco-enzyme precipitate* had a significant effect on the height of land kale plants. Plants that received the treatment showed better growth than the control, while the treatment with a concentration of 60 g/1000 mL of water (P2) produced the highest plant height at the end of the observation period. These results

indicate that moderate concentrations are able to provide the most suitable conditions for the vegetative growth process of plants.

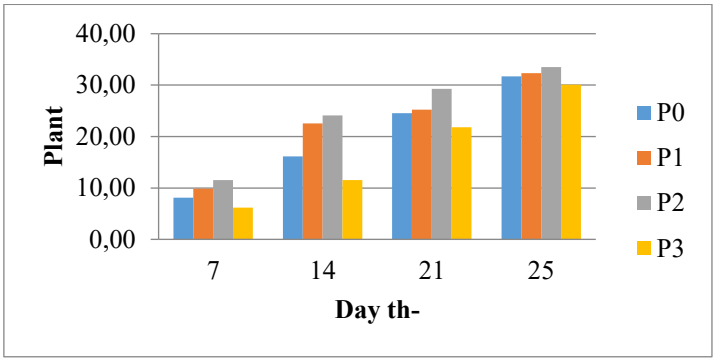


Figure 2 . Effect of eco-enzyme precipitate concentration on plant height.

The increase in plant height is thought to be related to the presence of nitrogen, organic compounds, and fermentation metabolic products still present in *the eco-enzyme precipitates* . Nitrogen plays a vital role in chlorophyll formation, protein synthesis, and meristem tissue development, thereby accelerating stem growth (Solangi et al., 2024; Nanda et al., 2022). Although the nitrogen content of the precipitates in this study was relatively low, this element still contributes to plant physiological processes when applied appropriately.

The results of this study align with various studies on the use of *eco-enzymes* as organic fertilizers, which show that application at optimum concentrations can increase plant vegetative growth. However, increasing the concentration does not always result in higher growth because the effectiveness of organic fertilizers is influenced by nutrient balance, microbial activity, and the plant's ability to absorb nutrients. Research on water spinach also shows that *eco-enzymes* have the potential to increase growth, although the response depends on the dose and frequency of application (Iswari & Astuti, 2024; Yu et al., 2024).

Number of Leaves

Leaf number is a parameter that describes a plant's ability to form photosynthetic organs. The results showed that the administration of *eco-enzyme precipitate* increased leaf number compared to control plants. Treatment P2 (60 g/1000 mL) produced the highest number of leaves, indicating that this concentration is able to provide a more balanced nutritional condition during the vegetative phase.

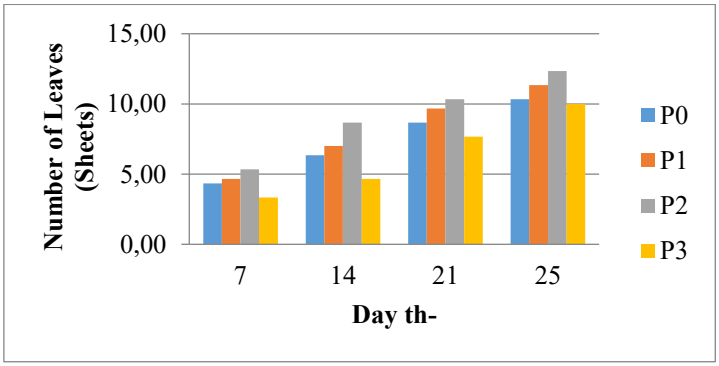


Figure 3 . Number of leaves under different treatments.

The increase in leaf number is thought to be influenced by the availability of nitrogen, which plays a role in new tissue formation, protein synthesis, and the activity of enzymes that regulate cell division. Furthermore, fermented organic matter can also improve soil microbial activity, thereby increasing the efficiency of nutrient absorption by plant roots (Solangi et al., 2024). This biological activity supports more optimal new leaf formation.

The results of this study support reports from several previous studies that stated that *eco-enzyme application* can enhance vegetative growth of vegetable plants by improving nutrient availability and soil microbial activity (Kurniawan et al., 2024) . However, excessively high concentrations do not always provide optimal results because they can reduce the efficiency of nutrient utilization by plants.

Leaf Length and Leaf Width

Leaf length and width are parameters that indicate the development of a plant's photosynthetic surface area. Research results showed that the administration of *eco-enzyme precipitate* affected both parameters. The P2 treatment produced larger leaves than the other treatments, indicating that this concentration supports optimal leaf tissue development.

Table 3. Mean leaf length

Treatment	N	Subset for alpha = 0.05		
		1	2	3
P3	3	6.2667 [a]		
P0	3		8.4000 [b]	
P1	3			10.9000 [c]
P2	3			11.4000 [c]
Sig.		1,000	1,000	.073

Table 4. Mean leaf width

Treatment	N	Subset for alpha = 0.05		
		1	2	3
P3	3	.8667 [a]		
P0	3	1.0333 [a]	1.0333 [a]	
P1	3		1.2333 [a]	
P2	3			1.5333 [a]
Sig.		.143	.087	1,000

Leaf size development is influenced by cell division and enlargement, which require a supply of nutrients and energy from photosynthesis. Fermented organic compounds are thought to improve the condition of the growing medium, enabling roots to absorb nutrients more efficiently. Furthermore, the presence of fermented organic acids can increase the availability of several nutrients around the root zone, thus supporting leaf tissue development (Lei et al., 2024).

The findings of this study are consistent with research on the use of *eco-enzymes* on various horticultural crops, which showed an increase in leaf size when organic fertilizer concentrations were at optimum levels. Conversely, applying excessively high doses did not always increase leaf size because nutrient balance is a major factor in determining plant growth responses (Kurniawan et al., 2025).

Leaf Area

Leaf area is an important parameter because it directly affects a plant's ability to photosynthesize. The larger the leaf surface area, the greater the plant's potential to capture sunlight and produce the photosynthates necessary for growth.

In this study, the 60 g/1000 mL water treatment resulted in the largest leaf area compared to other treatments. These results indicate that this concentration is able to create a nutritional balance that supports optimal leaf tissue formation. A larger leaf area contributes to increased photosynthetic activity, resulting in better vegetative growth (Nanda et al., 2022).

Table 5. Mean leaf area

Treatment	N	Subset for alpha = 0.05		
		1	2	3
P3	3	3.46196 [a]		
P0	3		5.53744 [b]	
P1	3			8.56268 [c]
P2	3			11.13636 [c]
Sig.		.012	.045	.350

Although the N, P, and K content of the precipitate does not meet national organic fertilizer standards, the presence of organic compounds, microorganisms, and fermented metabolites still provides benefits for

plant development (Ashari et al., 2024; Sabrina, 2022; Yu et al., 2024). This condition indicates that the effectiveness of *the eco-enzyme precipitate* is not only determined by the levels of macronutrients, but also by the biological activity that occurs in the root area.

Overall, the observed growth parameters demonstrate that *eco-enzyme* precipitate derived from fruit peels has potential for use as an alternative organic fertilizer. Among the treatments evaluated, the application of 60 g of precipitate per 1,000 mL of water resulted in the most favorable vegetative growth response in water spinach. These findings support the potential utilization of fruit peel waste as a value-added organic resource that can contribute to sustainable agricultural practices while helping to reduce the accumulation of household organic waste.

CONCLUSION

This study demonstrates that *eco-enzyme* precipitate produced from orange, banana, pineapple, and watermelon peels has potential as an alternative organic fertilizer for promoting the vegetative growth of water spinach (*Ipomoea reptans* Poiret). Although laboratory analysis indicated that the nitrogen (0.243%), phosphorus (0.01217%), and potassium (0.02254%) contents were below the requirements established by national standards for solid organic fertilizers, the application of the precipitate still produced a positive response in plant growth. The treatment using 60 g of precipitate per 1,000 mL of water resulted in the most favorable outcomes for plant height, number of leaves, leaf length, leaf width, and leaf area compared with the other treatments.

These results suggest that the effectiveness of *eco-enzyme* precipitate may not depend solely on its macronutrient content but may also be associated with organic matter, microorganisms, and bioactive compounds generated during the fermentation process. These components may contribute to improving the conditions of the growing medium and supporting plant development. Therefore, fruit-peel-derived *eco-enzyme* precipitate has potential for further development as an environmentally friendly organic fertilizer while simultaneously supporting sustainable household organic waste management and more environmentally responsible agricultural practices

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to this research or the publication of this article. The authors are fully responsible for the content, interpretation, and conclusions presented in the article.

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