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Current status and the significance of local wisdom biofertilizer in enhancing soil health and crop productivity for sustainable agriculture: A systematic literature review

Abstract. Soil fertility is recognized as a crucial factor in supporting plant growth and productivity. The utilization of biofertilizers as environmentally friendly fertilizers is aimed at enhancing soil fertility and plant productivity. This study aims to explore the potential of local material for developing local wisdom biofertilizers (LWB) for achieving sustainable agriculture. A systematic literature review was conducted using bibliometric analysis, Preferred Reporting Items for Systematic Reviews, and Meta-Analyses (PRISMA) method, employing the Scopus search engine with the keywords "local AND wisdom AND biofertilizer" OR "biofertilizer" OR "local AND microorganism" OR "soil AND health OR crop AND productivity OR sustainable agriculture". The search yielded 704 articles, of which 11 were deemed eligible after selection. Based on the literature review, it was found that there are local materials, including fish waste, seaweed, Azolla, fruit waste, *Moringa oleifera*, microalga, bamboo roots, banana hump, golden snail, mangrove leaves, fruit, and vegetable waste that can be used as raw materials for LWB to improve soil health, plant growth, and productivity. The development of LWB as a new fertilizer technology faces challenges such as lack of regulations, low public trust, limited farmer awareness, weak promotion, and raw material shortages. Further research is needed to intensively study and enhance the effectiveness of LWB through enrichment using beneficial microorganisms.

Keywords: Indonesia · Local wisdom biofertilizer · PRISMA · Sustainable agriculture · Waste management

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Introduction

The demand for food, both in Indonesia and globally, is expected to increase in line with population growth. By mid-2023, the population of Indonesia had reached 278 million people (BPS, 2023). The success of agricultural production is vital in meeting food demands. Plant productivity is influenced by both internal and external factors. Internal factors encompass plant genetics (Soeparjono, 2016), while external factors include soil conditions and climate variables such as humidity, rainfall, and environmental temperature (Triharyanto et al., 2020). The increase in average temperatures and occurrences of extreme global climatic phenomena directly affect crop yield stability and production (Setyaningrum et al., 2024). Various efforts have been made to enhance crop production, including agricultural intensification and extensification (Subaedah & Aladin, 2016).

The increase in production through extensification (expansion of land) faces challenges due to high competition for land use, often leading to the utilization of marginal lands. Utilizing marginal lands for agricultural activities poses various constraints, including low soil fertility (Subaedah & Aladin, 2016). The low availability of nutrients during the production phase impedes several plant metabolic processes, thus hindering flower formation, reducing seed quantity, and lowering crop yields (Wei et al., 2017). Improving nutrient availability in the soil can be achieved through fertilization. Fertilizer application aims to supplement the required nutrients for plants, as the nutrients present in the soil are insufficient to support optimal plant growth (Hamid & Tanweer, 2021).

Fertilizers are substances that provide essential nutrients for plant growth (Simanjuntak & Setiawan, 2021). In recent years, the use of agricultural chemicals such as inorganic fertilizers and pesticides has significantly increased (Muktamar et al., 2016). Excessive use of inorganic fertilizers leads to soil fertility decline (Dorota et al., 2020). Long-term application of high doses of inorganic fertilizers can increase soil compaction, reduce organic matter, and disrupt nutrient balance, thus decreasing soil fertility. Moreover, inorganic fertilizers are expensive and have limited availability (Yang et al., 2022). A potential technology that can substitute or even replace the use of inorganic fertilizers is local wisdom biofertilizer.

Local wisdom biofertilizer (LWB), also known as local microorganisms, is a fermentation liquid derived from natural materials containing numerous microorganisms capable of transforming organic matter, thus serving as biofertilizers, decomposers, and organic pesticides (Roeswitawati & Ningsih, 2018). LWB, as a biofertilizer, can be used to nourish plant leaves and stimulate plant growth (Retnowati & Katili, 2021). Implementing LWB at the community level can realize the concept of bio-cycling farming. This is because LWB formulations can utilize materials sourced from local wisdom waste, thus recycling environmental waste and benefiting plant growth (Kumar & Gopal, 2015). Materials that can be utilized include cow urine, vegetable waste, fruit waste, banana humps, leaves, and banana stems (Retnowati & Katili, 2021). Additionally, materials such as seaweed waste, molasses, and earthworm castings can also be utilized (Arfarita et al., 2022).

The utilization of locally sourced LWB supports the achievement of sustainable agriculture as it maximizes environmental resources without causing harm. LWB is more resistant to nutrient-leaching processes and can rapidly provide nutrients (Hersanti & Nurusilawati, 2012). LWB not only contains a single type of microorganism but a variety of microorganisms such as *Azospirillum* sp., *Azotobacter* sp., *Rhizobium* sp., *Bacillus* sp., *Pseudomonas* sp., and phosphate-solubilizing bacteria (Roeswitawati & Ningsih, 2018). Implementing this technique is more environmentally friendly and ensures safe and healthy agricultural products. This systematic literature review aims to explore the current status and importance of LWB in sustainable agriculture practice. By systematically analyzing relevant literature, this research aims to assess the effectiveness of LWB in enhancing soil fertility, promoting plant growth, and encouraging sustainable agricultural practices. Through a comprehensive review of existing research, this research provides insights into the potential, benefits, and challenges associated with the adoption of LWB in sustainable agriculture.

Materials and Methods

Search Analysis in Scopus. Searches were conducted in the Scopus database for bibliometric analysis and systematic literature review. The search results were retrieved from the Scopus database using a combination of keywords such as "local AND wisdom AND biofertilizer" OR "biofertilizer" OR "local AND microorganism" OR "soil AND health OR crop AND productivity OR sustainable agriculture". The data on the number of articles published by different categories, such as journals, year, and language, were exported and analyzed.

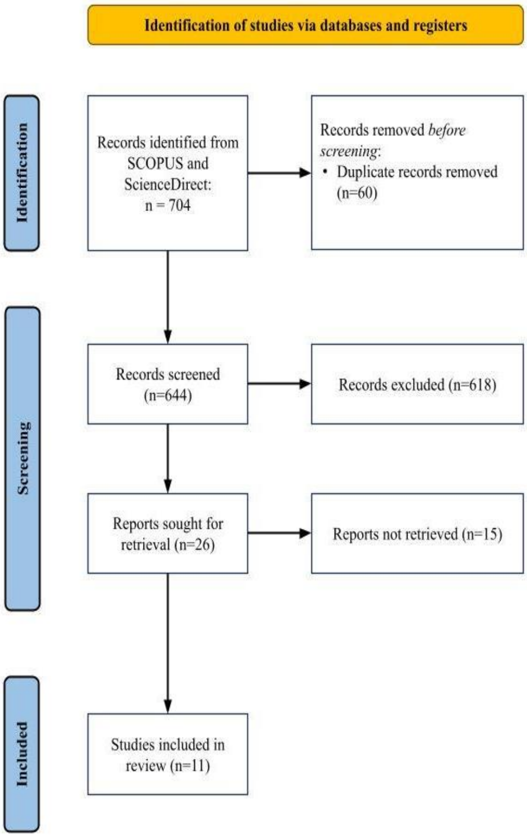

Figure 1. PRISMA flowchart reporting the article selection process for the systematic literature review

Systematic Literature Review using PRISMA. The articles were retrieved from the SCOPUS database and were restricted to the last five years (2020–2024). The relevant articles from the database into ris format for further analysis. Articles published in English alone were included in the search. Inclusion and exclusion criteria are tabulated in Table 1. Data retrieved from Scopus were then assessed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow guidelines or Systematic Literature Review (Figure 1). Duplications were eliminated using Mendeley Reference Manager 2.107.0. Eligibility of the documents included was based on the abstract related to the topic of the article; documents not related to the topic were categorized as ineligible and thus not included for further content analysis (Ariani & Simarmata, 2023)

Results and Discussion

Bibliometric Analysis by VOSViewer. Bibliometric data analysis employed VOSviewer to uncover emerging study themes and research trends from the last five years. By visually mapping keyword co-occurrences through binary counting, 46 key keywords were identified, setting a minimum threshold of 25 co-occurrences among document keywords in research articles. These significant terms effectively reflect the research directions pursued by scientists investigating local wisdom biofertilizers for sustainable agriculture.

Based on Figure 2, the researcher's focus is divided into three parts, firstly those who use LWB as fertilizer for crop yield (cluster 1), secondly those who study LWB and their relationship with rhizobacteria (cluster 2), and lastly those who investigate plant physiology particularly plant's response to salt stress with LWB application (cluster 3). Cluster 1, indicated in red color, consists of terms such as arbuscular mycorrhizal fungi, cultivation, fertilization, fertilizer, fruit, grain yield, Indonesia, inorganic fertilizer, microorganism, nutrient, organic fertilizer, organic matter, potassium, productivity, rhizobium, soil fertility, sustainable agriculture, and yield. Cluster 2, indicated in green color, consists of terms such as acetic acid, bacillus, IAA, PGPR, phosphate, phosphate solubilization, plant growth, pseudomonas, rhizobacteria, rhizobacterium, rhizosphere, rice, root, seedling, shoot, siderophore, tomato. Cluster 3, indicated in blue color, consists of terms such as chlorophyll, chlorophyll content, foliar application, fresh weight, leaf area, plant height, pod, root length, salinity, salt stress, weight. When examining the publication timeline in Figure 3, it becomes evident that research on local wisdom biofertilizers (LWB) focusing on microorganisms, organic fertilizers, and their impact on plant responses to salt stress emerged as prominent topics towards late 2022 (indicated by yellow color). Notably, publications from 2023 to 2024 did not feature prominently in Figure 3, indicating their minority representation. This suggests a lower number of publications during 2023-2024 compared to the earlier period of 2020-2022..

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Table 1. Inclusion and exclusion criteria used in this study

Criteria	Inclusion	Exclusion
Relevance topics	Journal with focus on local wisdom biofertilizer	Journal without core focus on local wisdom biofertilizer
Date of publication	2020-2024	Years before 2020
Type of Publication	Research article	Books chapter, Encyclopedia, News, Conference abstracts
Language of publication	English	All other language
Access	Open access	No open access
Databases	Scopus and ScienceDirect	Article that are not indexed by Scopus

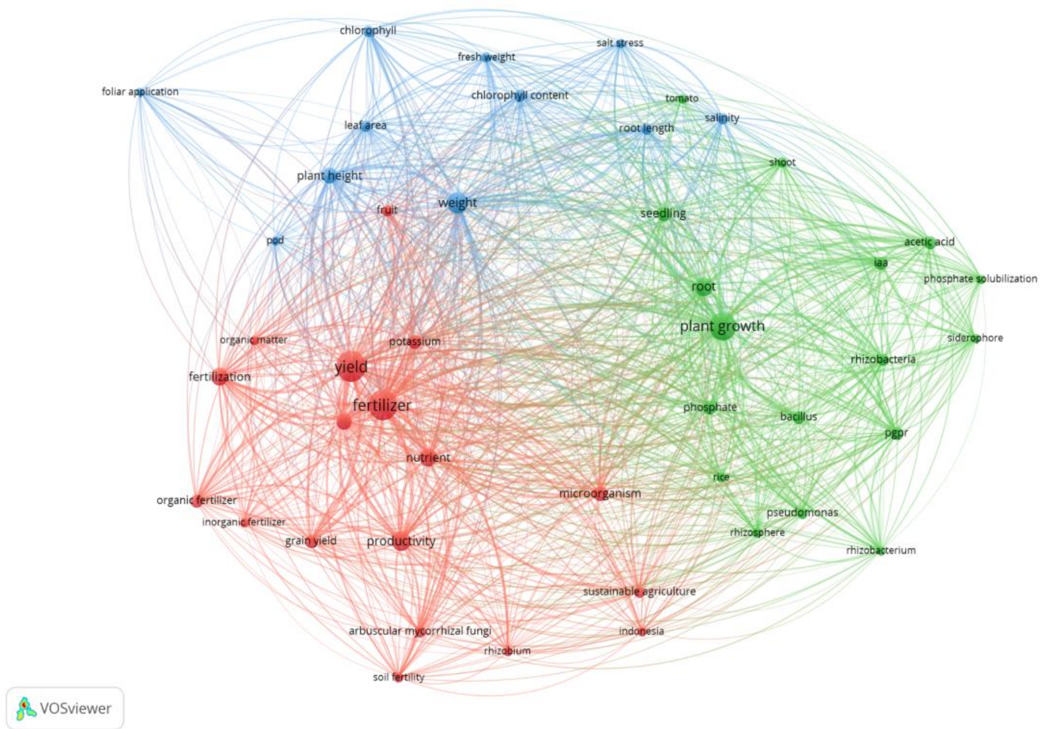

Figure 2. A network visualization of the co-occurrence mapping of pertinent keywords related to research on local wisdom biofertilizer

These results showed that LWB contributes to enhancing soil health and crop productivity party as well as answering the problem of abiotic stress factors in plants. Exploring the potential of blending traditional agricultural techniques with modern farming practices to pave the way for sustainable agriculture (Sekhar et al., 2024). For instance, blue-green algae can contribute 30–40 kg N/ ha, whereas the use of phosphate-solubilizing microbes can potentially cut down chemical phosphorus fertilizer usage by half which is potential to boost soil health (Susanti et al., 2024). Significantly, the combination of *Alcaligenes faecalis* and *Metabacillus indicus* with half of the recommended doses of N, P, and K fertilizers resulted in a substantial increase in rice grain yields (Fatema et al., 2024). *Pseudomonas* spp., isolated from cotton rhizospheric soil, exhibit potential for suppressing plant diseases and could be beneficially used in seed biopriming to enhance the growth and productivity of *Triticum aestivum* L. plants, particularly in alkaline soils (Kankariya et al., 2024).

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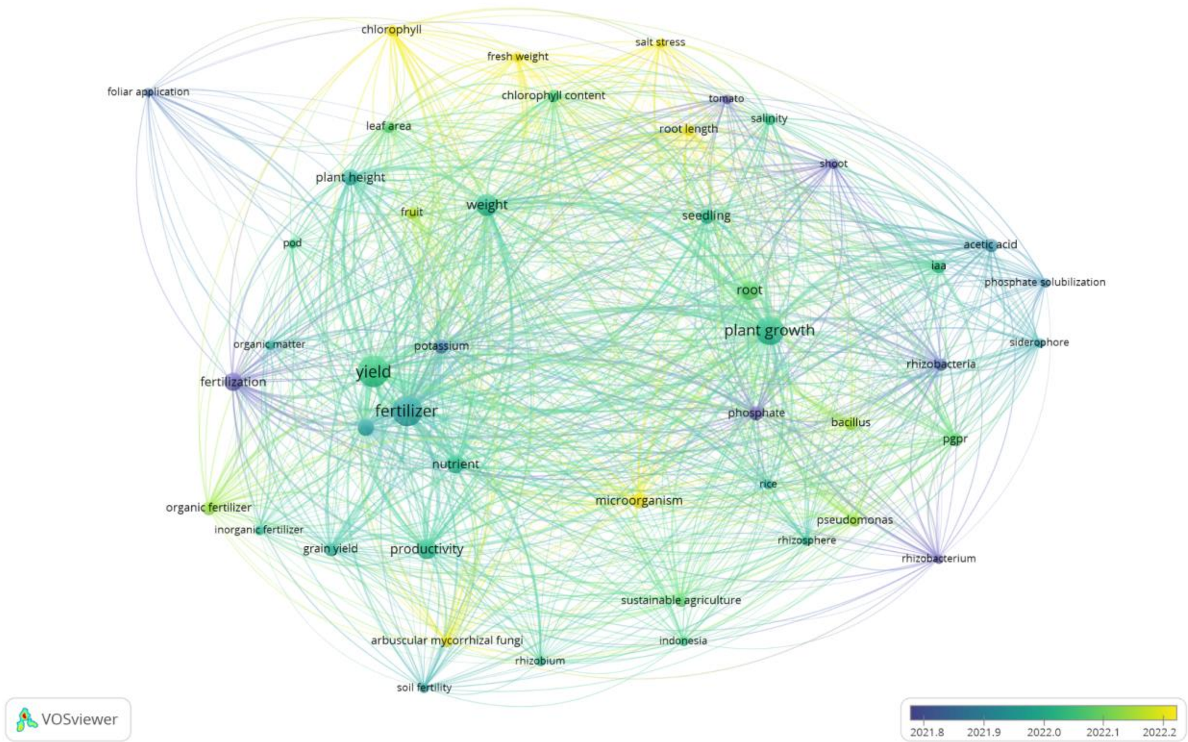

Figure 3. An overlay visualization of the publication year mapping related to research on local wisdom biofertilizer

Inorganic Fertilizer VS Local Wisdom Biofertilizer. The use of inorganic fertilizer (IF) aims to increase crop productivity, yet excessive utilization can have negative impacts on soil and the environment (Rossel & Bouma, 2016). Intensive and prolonged IF application can decrease soil organic matter, disrupt soil structure, and lead to environmental pollution. Reduction in organic matter results in decreased availability of N, P, and K, leading to toxin accumulation for plants and reduced nutrient availability in the soil (Soebandiono et al., 2021). Moreover, it can diminish soil microorganisms and increase soil degradation (Savci, 2012). One alternative to mitigate IF usage is substituting it with local wisdom biofertilizer.

LWB, also known as local microorganisms, is a fermentation solution derived from various sources, including plants and animals, containing carbohydrates (sugar), proteins, minerals, and vitamins. Utilizable materials include rice, fruits, eggs, milk, snails, fish waste, shrimp waste, among others (Mursalim et al., 2018). Bacteria like snails and fruits contain carbohydrates such as rice washing water, coconut water, and glucose sources like molasses or sugar water (Dewilda et al., 2021). LWB, as a liquid organic fertilizer, is beneficial for the environment as it mitigates environmental pollution and provides soil microorganisms useful for decomposing organic matter into plant-absorbable fertilizers. LWB contains macro and micronutrients and bacteria capable of stimulating plant growth, decomposing organic matter, and controlling plant diseases (Tulung et al., 2023).

LWB can substitute the role of IF and other commercial fertilizers, its production is not difficult and is more cost-effective since it utilizes readily available materials (Soebandiono et al., 2021). LWB can serve as a raw material for fertilizers. Microbial technology utilization is not only essential for plants but also beneficial for decomposing organic materials, unused agricultural materials, household waste disposal, and industrial waste (Manullang et al., 2018). Thus, LWB utilization can reduce heavy reliance on IF, enhance profit income by reducing production costs, and improve yields (Soebandiono et al., 2021).

Systematic Literature Review. A literature search conducted on the Scopus database using "local AND wisdom AND biofertilizer" OR

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"biofertilizer" OR "local AND microorganism" OR "soil AND health OR crop AND productivity OR sustainable agriculture" resulted in 704 research articles. After data cleaning of duplicates and ineligible entries, 644 articles remained. When exclusion and inclusion criteria were applied to relevant articles based on title and abstract screening, 26 were excluded. The final list of 11 research articles analyzed systematically is presented in Table 2.

Seaweed Waste. Seaweed waste is generated from seaweed processing plants. This material can be utilized as organic fertilizer and soil conditioner. The application of seaweed extract on plants can affect germination, increase resistance to stresses (biotic and abiotic stresses), and enhance yields (Prithiviraj, 2009). Seaweed extract consists of water (27.8%), ash (22.25%), protein (5.4%), fat (8.6%), carbohydrates (33.3%), and crude fiber (3%). Additionally, seaweed extract contains various enzymes, amino acids, nucleic acids, vitamins (A, B, C, D, E, and K), macro minerals (oxygen, nitrogen, selenium, and calcium), and micro minerals (iron, sodium, and magnesium) (Arfarita et al., 2022).

Bamboo Roots. Bamboo roots have the potential as an alternative material for use in LWB production because they contain numerous beneficial bacteria such as *Lactobacillus, Streptococcus, Azotobacter,* and *Azospirillum* (Walida et al., 2019). These bacteria produce secondary metabolites that can support plant growth in the form of phytohormones. The secreted phytohormones can stimulate enzymatic processes, biologically enhancing seed germination and accelerating the synthesis of organic nitrogen compounds in roots (Sodiq et al., 2021).

Table 2. Local potential materials as LWB formula.

Local Material	Crop	Result	Referensi
Fish waste	Cowpea	- Increased the height, root length and yield of cowpea - increased the growth and yield of aerial biomass increased the microbial fertility	Maquén-Perleche et al., 2023
Seaweed	Wheat, lettuce, date palm	- Improves growth parameters and grain yield in wheat - Improve the qualitative and quantitative traits of the lettuce crop - enhancement in growth and phytochemicals of plants Improve growth and development of date palm	Vafa et al., 2021; Rasouli et al., 2022; Parab & Shankhadarwar, 2022;
Azolla	Soybean, rice	- Increases soybean plant growth - Increase rice grain yield, nitrogen uptake and agronomic efficiency of N	Pauline et al., 2022; Marzouk et al., 2024
Fruit waste	*Capsicum frutescens*	- Increase growth and yield of *Capsicum frutescens*	Akpan et al., 2020
Moringa oleifera	Mustard spinach	- Promoted the growth and yield of mustard spinach	Chanthanousone et al., 2022
Microalga	Onion	- Promoted plant growth and increases in bulb caliber and yield of both onion cultivars.	Cordeiro et al., 2022
Indigenous microorganisms, mangoo, and longan	Okra	- Enhance the yeast community in IMO inoculants, indirectly improving okra growth and benefiting the agriculture field in the future	Selvarajoo, 2023
Soaked coconut fiber with cow urine	Rice	- increase fill grain of rice	Yassi et al., 2023

Phytohormones play a crucial role in plant growth and developmental regulation. They are vital regulators of plant growth that control various processes such as cell division, cell differentiation, organogenesis, and morphogenesis (Bielach et al., 2012). Walida et al. (2019) found that applying LWB from bamboo shoots to Jenggo F1 red chili plants affected plant height, stem diameter, leaf number, flowering age, and initial production weight.

Banana Hump. Banana hump is one of the materials used as the main ingredient in LWB due to its content of phytohormones, such as gibberellins and cytokinins, which are beneficial for plant growth (Astuti, 2014). Banana hump contains carbohydrates (66%), starch (45.4%), protein (4.35%), water, and essential minerals (Sitinjak et al., 2018). LWB based on banana hump contains numerous microbes involved in the decomposition of organic materials (Sri et al., 2022). Microbes present in banana hump-based LWB include *Bacillus, Azospirillum, Aspergillus, Azotobacter, Aeromonas*, cellulolytic microbes, and phosphate-solubilizing microbes (Sitinjak et al., 2018). The high level of phenolic acids in banana hump organic liquid provides several elements, such as Al, Ca, and Fe, which are beneficial in the flowering process and seed formation (Soebandiono et al., 2021).

Golden Snail. Golden snail serves as a local resource that can be utilized as an ingredient in LWB. Utilizing golden snails can be a sustainable agricultural management effort as their presence in rice fields represents a pest. LWB from golden snails contains various beneficial microorganisms that support plant growth and development, including *Aspergillus niger, Azotobacter, Azospirillium, Pseudomonas*, and *Staphylococcus* sp. Additionally, it contains phytohormones and essential macro and micronutrients (N, P, K, Ca, Mg, Cu, Zn, Mn, and Fe). Spraying golden snail-based LWB every 1-2 weeks can enhance plant tolerance to drought and increase the average fruit weight per plant by 32% compared to the average fruit weight per tomato plant under optimum conditions (Eliyanti et al., 2022).

Mangrove Leaves. The use of LWB in agriculture can improve plant growth, soil fertility, and pathogen control (Kumar & Gopal, 2015). Fermented LWB can inhibit pathogenic bacteria, antimycotoxins, and antifungals. Antimicrobial substances (such as lactic acid) produced by bacteria are used to inhibit the growth of pathogenic microorganisms (Wang et al., 2015). Mangrove leaf-based LWB contains eight *Bacillus* species (Rahman & Ekasari, 2020). These bacteria can produce several bioactive compounds with broad-spectrum inhibitory activity against pathogens (Sandi & Salasia, 2016). LWB can be used as probiotic and biocontrol agents to suppress the growth of pathogenic bacteria through various mechanisms, one of which is the production of metabolites (Widanarni et al., 2015). Mangrove leaf-based LWB contains alkaloids, saponins, tannins, phenolics, flavonoids, and glycosides (Rahman & Ekasari, 2020). Additionally, it contains flavonoids, phenolics, and tannins that play a crucial role as antioxidant sources (Hamli et al., 2017). Glycosides present in LWB are involved in catalytic or anabolic destruction of microbial cell walls (Rijai, 2016).

Fruit and Vegetable Waste. Waste fruits processed into LWB can stimulate generative plant growth and contain several microorganisms acting as probiotic components (Roeswitawati & Ningsih, 2018). Microorganisms in the fermentation process of vegetable waste LWB include genera such as *Obesumbacterium, Megasphaera, Synthropococcus*, and one identified fungus, *Aspergillus* sp. Cellulolytic bacteria in LWB produce enzymes that can hydrolyze cellulose and cellobiose bonds, including species such as *Syntrophococcus, Sucromutans*, and *Ruminicoccus* (Widyastuti et al., 2021).

The quality of vegetable waste-based LWB, as assessed by physical parameters such as odor and color, shows favorable results. Chemical parameters of vegetable waste LWB tested include pH (3.75), organic matter (2.29%), C (1.33%), total N (0.08%), total P_2O_5 (0.04%), total K_2O (0.10%), and C/N ratio (16.63%) (Indrajaya & Suhartini, 2018). Application of vegetable waste LWB affects stem diameter and plant height. Fermented fruit and vegetable waste-based LWB result in increased guava plant height (Widyastuti et al., 2021). Application of fruit waste LWB on broccoli plants affects flower diameter, wet flower weight, and wet broccoli plant weight, as fruit waste LWB contains higher total nitrogen (Roeswitawati & Ningsih, 2018). Research by Yuliana (2021) shows that LWB based on white cabbage and cabbage waste with a 15% LWB concentration significantly affects soil pH, dry weight, and dry weight of Ipomea reptans Poir shoots.

The addition of other substances such as urine, rice water, fish and shrimp waste, and

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molasses in LWB formulations can enhance the effectiveness of LWB in supporting plant growth, development, and soil health. Urine serves as a source of N, K, and plant growth hormones. Urine can boost plant productivity due to its content of plant growth hormones such as auxin-a, auxin-b, and Indole Acetic Acid (IAA). The presence of auxins can stimulate root formation and promote cell division in the cambial vessels, supporting stem growth (Mudhita et al., 2016). Rice water, or "leri," contains numerous vitamins and minerals commonly utilized by plants. Molasses is a sugar mill waste that can be utilized by microbes as a carbohydrate source (Roeswitawati & Ningsih, 2018). Tuna and shrimp waste have high potassium (K) content, thus their utilization can enhance K levels. Potassium plays a crucial role in photosynthesis and aids in the formation of proteins and cellulose in plant stems (Dewilda et al., 2021).

Fermentation Process of LWB. The fermentation process of LWB can be influenced by several factors such as the type of organic material, pH, temperature, types of microbes, and specific substances that enhance microbial activity, thus facilitating a rapid fermentation process (Roeswitawati & Ningsih, 2018). During the fermentation of LWB, several processes occur, including a decrease in pH. The decrease in pH during fermentation is caused by the activity of microorganisms present in the fermentation solution (Yuliana et al., 2019). During the fermentation process, the pH decreases by 3.4-5.2. The decomposition of organic matter leads to an increase in acidity levels and the production of CO_2 gas. This CO_2 gas forms carbonic acid (H_2CO_3), which readily decomposes into H^+ and H_2CO_3 ions. The H^+ ions affect acidity, resulting in a decrease in pH (an increase in acidity) in the LWB solution (Hunaefi et al., 2013). Furthermore, increased acidity can occur due to the nitrification process, which releases ammonium and hydrogen ions (Ma et al., 2022). Subsequently, microorganisms decompose nitrogen into ammonia (NH_2 or NH_2^+). The ammonification process leads to an increase in pH (Grzyb et al., 2021). At the end of the fermentation process, the solution will reach a neutral pH range, indicating a decrease in nitrogen decomposition due to microbial activity (Ramadhani et al., 2022). Addition of stabilizing agents such as PEG (Polyethylene Glycol) and glycerol can be performed to stabilize the microorganisms present in the solution (Simonin et al., 2015). PEG and glycerol, as additive substrates for biofertilizer formulations, are still limited, especially when combined with extracted solid waste materials. Additionally, glycerol can also prolong the shelf life of biofertilizers (Arfarita et al., 2022).

Local Wisdom Biofertilizer as a Concept of Bio-cycling Farming. Indonesia faces challenges in achieving the Sustainable Development Goals (SDGs) for 2030, particularly in waste management and food security. An innovation addressing waste management while enhancing food security simultaneously is the application of the concept of biocycling farming. Biocycling farming is an agricultural method that integrates and utilizes waste to support farming activities. The development of zero-waste farming concepts aims to optimize household and agricultural waste. Implementation involves leveraging the presence of both plant and animal waste to produce LWB. The environmental impact of this program is derived from the total volume of liquid organic waste processed into LWB, resulting in a reduction in organic waste. A decrease of 750 kg of organic waste has the potential to reduce methane gas (CH_4) emissions by 0.0004 Gg/year, equivalent to 7.88 tons of CO_2 equivalent per year (Firmansyah et al., 2023). Applying fish waste-based LWB to cowpea plants can increase height, root length, and yield by 1, 1.25, and 1.5%, respectively (Maquén-Perleche et al., 2023). Apart from that, the research results of Akpan et al. (2020) show that applying fruit waste-based LWB to hot peppers can increase the field of fresh fruit by 266.84% in the rainy season and 150.84% in the dry season.

Urgency and Challenges of Implementing LWB in Indonesia. Utilizing local resources as raw materials for LWB can foster the spirit of farmer self-sufficiency by enabling them to produce organic fertilizers independently. The use of LWB is a component of organic farming that can reduce the reliance on chemical fertilizers (Jasim et al., 2016). The development of organic agriculture has several benefits such as reducing external input costs, increasing farmer income, enhancing food security, and being more environmentally friendly (Jouzi et al., 2017). Developing LWB is a strategy to realize sustainable agricultural systems in Indonesia through a local wisdom approach. This can be achieved through various efforts such as intensive utilization of local resources (energy and nutrients), enhancing farmer skills, and adopting local and environmentally friendly approaches (Srivastava et al., 2016).

Continued innovation is necessary for the development of LWB with a sustainable and environmentally friendly agricultural approach. These innovations are not only related to the utilization of local resources but also to micro and macro fauna that support plant growth. Addition of beneficial microbes can also be carried out to enhance the effectiveness of LWB in supporting plant growth (Soebandiono et al., 2021). Several challenges in the implementation and development of new fertilizer technologies include lack of regulation, lack of public trust, lack of awareness among farmers, inadequate promotion, and shortage of raw material availability (Naveed et al., 2015). The availability of LWB raw materials must be ensured and supported by the entire community and government. Additionally, the promotion of LWB technology that can influence plant growth and increase productivity is essential (Soebandiono et al., 2021).

Conclusion

Many potential local resources can be utilized as LWB to enhance soil fertility and improve plant growth, such as fish waste, seaweed, Azolla, fruit waste, *Moringa oleifera*, microalga, bamboo roots, banana hump, golden snail, mangrove leaves, fruit, and vegetable waste. Utilizing waste as LWB material can reduce the presence of organic waste in the environment. The challenges of implementing LWB in Indonesia include the availability of raw materials and raising awareness among Indonesian farmers to use LWB to achieve sustainable agriculture need to be addressed. Moreover, further research on adding compatible and efficient microorganisms to LWB formulas to enhance growth and yield is an interesting avenue for future research.

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