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Improving Maize Yield Through Locally Organic Resources: A Community-Based Strategy in Kaleke Village, Central Sulawesi

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Abstract

The utilization of locally available organic materials as liquid organic fertilizer (LOF) represents an eco-friendly biofertilizer alternative that supports sustainable agriculture and environmentally responsible farming practices. This community service program aimed to improve farmers' knowledge and technical skills in producing and applying liquid organic fertilizer derived from local organic resources, including moringa leaves (Moringa oleifera), aged coconut water waste, a weed-based biostimulant (BIOSAKA), and photosynthetic bacteria (PSB)to promote plant growth and enhance maize production. The program was implemented using a two-way interactive learning approach that combined educational sessions and hands-on practice on the utilization of organic liquid fertilizer (LOF) in maize cultivation. The program's effectiveness was primarily evaluated based on farmers' level of understanding after the training activities. Evaluation was conducted using a structured questionnaire administered at the end of the program, which assessed participants' comprehension of LOF materials, production principles, and application methods. The collected responses were used to determine changes in participants' knowledge and overall learning outcomes resulting from the program. The evaluation results revealed clear quantitative improvements in farmers' knowledge, technical understanding, and readiness to adopt locally derived organic fertilizers. Prior to the intervention, only 10–30% of participants were familiar with the concepts, raw materials, and production methods of liquid organic fertilizer (LOF), photosynthetic bacteria (PSB), and BIOSAKA. Post-training assessments showed a substantial increase, with 87–100% of farmers demonstrating an understanding of production procedures and application methods. In addition, 85% of participants recognized the functional roles of PSB, LOF, and BIOSAKA in supporting maize growth and soil fertility, while 95% expressed willingness to apply these organic inputs in their future farming practices. These quantitative shifts indicate that the community-based training effectively strengthened farmers' capacity and confidence to utilize locally sourced organic resources independently.

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INTRODUCTION

Maize (*Zea mays* L.) is a strategic staple crop that plays a critical role in national food security, rural economic development, and improved farmer incomes in Indonesia (Syahruddin et al., 2022). According to the data of the National Bureau of Statistics (BPS), maize productivity in Central Sulawesi from 2022 to 2024 was 4. 20-ton ha^{-1}, 4. 30-ton ha^{-1}, and 4. 45 ton ha^{-1}, respectively (Badan Pusat Statistik Provinsi Sulawesi Tengah, 2024). These productivity levels are considered low and have not reached the potential yield benchmark of 7.00-ton ha^{-1} (Lapates,

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2024). One of the main maize productions centers in Central Sulawesi is the Sigi Regency, particularly in Kaleke Village (Badan Pusat Statistik Provinsi Sulawesi Tengah, 2024).

A principal factor contributing to low maize productivity is the limited availability of inorganic fertilizers, both in terms of supply instability and high market costs (Zuhri et al., 2024). This condition restricts farmers in Kaleke Village from applying fertilizers according to agronomic recommendations, resulting in insufficient nutrient uptake and suboptimal plant growth during both the vegetative and generative phases (Ariningsih et al., 2021; Gezahegn 2021). Consequently, the provisioning of nitrogen, phosphorus, potassium, and essential micronutrients remains inadequate, hindering optimal biomass accumulation and grain filling.

The challenge of inorganic fertilizer scarcity can be mitigated through a community-based approach that emphasizes the utilization of locally available organic resources as sustainable, cost-efficient, and environmentally friendly fertilizer alternatives (Budiastuti et al., 2023). This approach is grounded in the theories of community empowerment and asset-based community development, which views local resources, indigenous knowledge, and farmer participation as core assets for achieving long-term agricultural resilience.

Fertilizers and bio stimulants derived from local organic materials not only contribute to soil fertility restoration and crop productivity enhancement but also strengthen farmers' autonomy by enabling them to independently produce nutrient inputs using resources accessible within their own farming landscape. Therefore, a community-based approach was chosen to ensure that technological innovations are socially acceptable, economically feasible, and contextually relevant, while fostering collective learning and capacity building among farmers.

Several organic fertilizer formulations and bio stimulants with strong potential to support plant growth and maize production include photosynthetic bacteria (PSB) (Rizqi et al., 2023), liquid organic fertilizer derived from aged coconut water waste (Sari et al., 2021), LOF derived from *Moringa oleifera* leaf extract (Praditya et al., 2024), and a weed-based antioxidant-rich bio stimulant known as BIOSAKA (Aprilia & Wahidah, 2024). PSB are metabolically versatile phototrophic bacteria capable of synthesizing phytohormones, such as auxins, cytokinin's, and gibberellins, while also facilitating atmospheric nitrogen fixation, enhancing nutrient availability, and improving maize tolerance to both abiotic stress and biotic pressures, including pathogens and insect pests (Maulana, 2023; Ardiansyah et al., 2025). Moreover, PSB stimulates beneficial soil microbial communities, thereby improving biological soil quality through increased enzymatic activity (Rizal & Barokah, 2024).

Liquid organic fertilizer produced from aged coconut water waste contains readily available macro- and micronutrients (Nasution et al., 2025), as well as active organic compounds that support vegetative development, strengthen root architecture, and increase plant metabolic efficiency (Haryanta et al., 2022). In parallel, LOF derived from *M. oleifera* leaves are rich in nitrogen, phosphorus, potassium, and bioactive secondary metabolites including flavonoids, saponins, tannins, and antioxidants which contribute to improved plant biomass, stronger defense responses against pathogens and herbivory, and enhanced grain quality and yield (Rachmawatie et al., 2022; Siahaan et al., 2023; AL-Marsoumi and Mustafa, 2025). BIOSAKA, a weed-based plant elicitor extract, enhances soil biological activity, supports organic matter decomposition, improves soil structure, accelerates nutrient cycling, and contributes to long-term soil sustainability and continuous maize growth (Umam et al., 2025).

Previous studies have demonstrated that liquid organic fertilizers and plant growth-promoting microbes can substantially enhance maize growth performance, nutrient use efficiency, and yield. For example, Ginting et al. (2023) reported that LOF derived from aged coconut water improved plant height, leaf number, and kernel weight in maize. Chan-Keb et al. (2024) further documented that *M. oleifera*-based LOF increased maize growth traits and crop productivity. In addition, Sinuhaji et al. (2024) observed that PSB application improved soil nitrogen availability and activated enzymatic processes that support maize plant development.

Despite these advances, most studies remain confined to laboratory or controlled experimental scales, and research focusing on village-level farmer empowerment for independent, community-based LOF production remains limited. This creates a gap in practical knowledge of sustainable, group-based strategies for the long-term use of local organic fertilizer resources.

Therefore, this community service initiative aimed to enhance farmers' knowledge and technical capacity to produce and apply LOF derived from local organic resources, including M. oleifera leaves, coconut water waste, BIOSAKA biostimulant from wild weeds, and PSB inoculation, to support sustainable maize cultivation and production in the area.

This approach is expected not only to increase maize productivity and nutrient use efficiency but also to promote farmer self-reliance, strengthen farmer group capacity, and support long-term, environmentally sustainable agricultural practices in the Kaleke village, Sigi Regency, Indonesia.

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MATERIALS AND METHODS

Materials

Plastic containers, 1.500 mL plastic bottles, tablespoons, packaged 250 mL mineral water cups, chicken eggs (commercial layer breed), instant MSG (monosodium glutamate), pond water (as a source of natural microbial inoculum), and EM4 agricultural microbial inoculant; aged coconut water waste, fresh moringa leaves (*Moringa oleifera*), a blender, filter cloth, hand sprayer, foliar sprayer, compression sprayer, sprayer, sprayer, and sprayer; as well as *Ageratum conyzoides* (billygoat weed), *Euphorbia hirta* (asthma plant), and *Phyllanthus niruri* (stonebreaker plant).

Methods

Research Design and Community-Based Approach

The community service program was designed using a community-based participatory approach that emphasizes the active involvement of farmers in the learning, implementation, and evaluation processes. This approach was selected based on the theoretical assumption that farmer participation enhances the relevance, acceptance, and sustainability of agricultural innovation. By positioning farmers as active participants rather than passive recipients, the program aimed to foster knowledge co-creation, strengthen self-efficacy, and encourage the long-term adoption of locally sourced organic fertilizer technologies. The overall implementation stages of the community service activities are illustrated in Fig. 1.

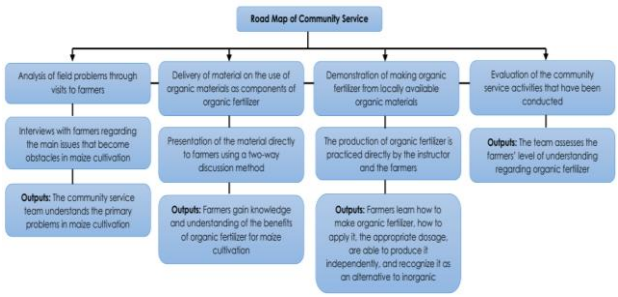


Fig. 1. Road map of community service

Educational Training on Organic Fertilizer Production

The community service program was implemented using a community-based participatory approach, with training materials on organic fertilizer production from locally available organic resources delivered at the Kaleke Village Hall. The materials were delivered using a two-way interactive learning method, beginning with an explanation of the utilization of local organic materials as fertilizer alternatives to reduce dependency on inorganic fertilizers. The session continued with detailed discussions on the nutrient composition and essential macro- and micronutrient elements contained in organic fertilizers, the step-by-step process for producing liquid and solid organic fertilizers from local feedstocks, and practical guidelines for field application on maize crops (Fig. 1).

The community service program introduced locally derived organic fertilizers and biostimulant inputs, including photosynthetic bacteria (PSB), liquid organic fertilizer (LOF) based on aged coconut water waste, LOF extracted from fresh moringa leaves (*M. oleifera*), and BIOSAKA, a natural elicitor biostimulant derived from wild weeds. The educational delivery session conducted at the Kaleke Village Hall applied a two-way interactive learning model, emphasizing the role of local organic resources as sustainable alternatives to reduce farmers' dependency on inorganic fertilizers. The session also covered nutrient composition, contributions of plant growth hormones, formulation procedures, and field-level foliar application strategies for maize production systems (Fig. 2).

The material presentation was followed by an interactive discussion session designed to verify that farmers understood the topics covered. Farmers who needed further clarification were encouraged to ask follow-up questions, and key concepts were subsequently re-explained in detail using simplified, accessible language without compromising the technical accuracy of the content. This educational stage corresponds to the interactive education session (90 minutes) within the training strategy framework.



Fig. 2. Two-way interactive educational delivery on locally sourced organic fertilizers to maize farmers in Kaleke Village, Sigi Regency

Demonstration of Organic Fertilizer Production

The organic fertilizer production demonstration aimed to strengthen farmers' capacity to independently produce and apply organic fertilizers, thereby enhancing maize yields. The activity was conducted through direct, hands-on engagement with farmers, allowing them to understand and practice the production processes. The fertilizers included photosynthetic bacteria (PSB), liquid organic fertilizer (LOF) from aged coconut water waste, LOF from fresh moringa (*M. oleifera*) leaves, and BIOSAKA, a weed-based plant biostimulant.

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This demonstration stage served as the practical training component (120 minutes), during which farmers actively participated in the preparation. Direct involvement was intended to improve procedural knowledge, reduce technical barriers, and increase farmers' confidence in independently replicating the technology under field conditions.

Production of Photosynthetic Bacteria (PSB)

The production of photosynthetic bacteria (PSB) was performed as described by Suyana et al. (2023), involving the preparation of the necessary equipment and materials, including plastic containers, 1.500 mL plastic bottles, tablespoons, 250 mL mineral water cups, one chicken egg (commercial layer breed), one sachet of instant MSG, pond water, and EM4 agricultural microbial inoculant.

PSB was prepared by cracking one egg into a plastic container, adding 1 tablespoon of instant MSG, 4 tablespoons of EM4 inoculant, and 250 mL of mineral water, and stirring until all ingredients were evenly mixed. Five tablespoons of the thoroughly mixed solution were then transferred into a 1.500 mL plastic bottle containing 1.200 mL of pond water, and the mixture was stirred thoroughly until homogeneous.

The bottles containing the mixture were placed in an area exposed to direct sunlight daily. The sun-drying process for PSB was conducted each day for 8 hours under direct sunlight. The mixture in the plastic bottle was stirred once daily to ensure even mixing, and the bottle cap was opened for 1 min daily to allow oxygen exchange. The sun-drying process for PSB lasted for 14 days. PSB was successfully produced and was ready for use when the color of the solution changed from cream to brick red or green, accompanied by a foul odor. A demonstration of PSB production conducted with maize farmers is shown in Fig. 3.



Fig. 3. Demonstration of PSB production attended by maize farmers

Production of Liquid Organic Fertilizer (LOF) Based on Aged Coconut Water Waste

The production of LOF from aged coconut water waste followed the method of Alfonsius et al. (2024) and was carried out by preparing the equipment and materials, including 1.500 mL plastic bottles, plastic strainers, tablespoons, aged coconut water waste, MSG sachets, and EM4 agricultural microbial inoculant.

LOF was produced by pouring 1.200 mL of filtered aged coconut water waste into a 1.500 mL plastic bottle, followed by the addition of one tablespoon of MSG and five tablespoons of EM4 solution. The mixture was stirred thoroughly until homogeneous and then incubated for 7 days in a room not exposed to direct sunlight. The mixture was stirred every morning and evening to accelerate fermentation, and the bottle cap was opened to release fermentation gases. LOF that was successfully fermented and ready for use was indicated by an acidic odor and effervescence resulting from fermentation. The demonstration of LOF production from aged coconut water waste can be seen in Fig. 4.



Fig. 4. Demonstration of liquid organic fertilizer (LOF) production from aged coconut water waste

Production of Liquid Organic Fertilizer (LOF) Based on Moringa Leaves

LOF was produced from *Moringa oleifera* leaves according to the method described by Azzahra et al. (2022) by preparing the required equipment and materials, including 1500 mL plastic bottles, plastic strainers, tablespoons, 100 g of fresh Moringa leaves, MSG sachets, and EM4 agricultural microbial inoculant.

The procedure involved blending 100 g of fresh moringa leaves with 100 mL of clean water until smooth. The leaf extract solution was then filtered using a strainer to separate the leaf pulp from the liquid extract. A total of 1,200 mL of the leaf extract was poured into a 1.500 mL plastic bottle, followed by the addition of one tablespoon of MSG and five tablespoons of EM4 solution, and the mixture was stirred until homogeneous. The LOF was incubated for 7 days in a room not exposed to direct sunlight. The mixture was stirred every morning and evening to accelerate fermentation, and the bottle cap was opened to release fermentation gases. LOF that was successfully fermented and ready for use was indicated by an acidic odor and effervescence due to fermentation. The demonstration of LOF production from moringa leaves can be seen in Fig. 5.

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Fig. 5. Demonstration of liquid organic fertilizer (LOF) production from moringa (*M. oleifera*) leaves

Production of BIOSAKA Elicitor from Wild Weed Plants

The production of BIOSAKA, as described by Abror & Azmi (2023), began with the careful selection of appropriate materials, including at least five types of healthy wild weeds free from pests and diseases. The weeds used included billygoat weed (*Ageratum conyzoides*), asthma plant (*Euphorbia hirta*), and stonebreaker (*Phyllanthus niruri*).

Subsequently, the equipment and materials were prepared, including plastic containers, clean water, and cloths, and all equipment was sanitized to prevent contamination. The crushing process was conducted by placing the plant materials into a plastic container containing 2–5 litres of clean water, then gently massaging and rotating the mixture for 10–15 minutes until the solution turned brown or dark green, with slight frothing. This stage was essential for extracting bioactive compounds from the wild weeds.



Fig. 6. Demonstration of BIOSAKA elicitor production from wild weed plants

The solution was then filtered to separate the plant residue from the liquid to be used. The liquid extract was poured into a closed bottle and stored in a location protected from direct sunlight, with an optimal usage period of 1–2 days after preparation. BIOSAKA application was carried out by mixing 40 mL of BIOSAKA solution with 15 L of clean water, which was then sprayed over the entire maize plant using a sprayer. Applications were conducted at weekly intervals using the same dosage. The demonstration of BIOSAKA elicitor production is shown in Fig. 6.

Application of Organic Fertilizers on Maize Plants (Field Trials)

The field trials component was designed as a guided field application stage to evaluate the practical feasibility and initial agronomic response of maize plants to locally produced organic fertilizers under farmer field conditions. Organic fertilizers were applied to maize plants to enhance vegetative growth, physiological quality, and yield performance. Treatments were initiated 7 days after planting (DAP), which represents a critical early growth phase associated with root establishment and initial leaf development. The organic fertilizers applied during the field trials included photosynthetic bacteria (PSB), liquid organic fertilizer (LOF) derived from aged coconut water waste, LOF derived from moringa leaves (*M. oleifera*), and the BIOSAKA elicitor.

Each organic input was applied independently following standardized dosage and application procedures to ensure consistency across treatments. PSB functions as a photosynthetic microorganism that improves nitrogen and phosphate availability through biological fixation and nutrient mobilization, thereby promoting root and shoot development. LOF derived from aged coconut water waste supplies essential macro- and micronutrients, particularly potassium and phosphorus, which support stem strengthening and improve plant tolerance to abiotic stress and biotic disturbances.

LOF derived from moringa leaves contains natural plant growth regulators, nitrogen, proteins, and essential minerals that accelerate vegetative growth and enhance leaf development, which is the primary photosynthetic organ. BIOSAKA, a fermented extract of wild weeds, provides bioactive compounds and beneficial microorganisms that stimulate plant defense mechanisms against pests and diseases while enhancing soil biological activity.

For field application, PSB, LOF from aged coconut water, and LOF from moringa leaves were each diluted to 250 mL per 15 L of clean water, whereas BIOSAKA was applied at 40 mL per 15 L of water. The diluted solutions were uniformly applied to the entire leaf surface using a sprayer to facilitate the efficient absorption of nutrients and bioactive compounds through the stomata and cuticle. Applications were conducted once per week to allow for the cumulative effects of microbial activity and nutrient availability on plant growth and development. Application timing was scheduled during periods of low solar radiation, specifically in the morning or late afternoon, to minimize evaporation losses and degradation of active compounds.

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The parameters of success for the field trials were defined qualitatively and operationally as follows: (1) farmers' ability to correctly prepare and apply the organic fertilizers according to the recommended dosage and frequency, (2) observable improvements in maize vegetative vigor, such as leaf color uniformity and plant robustness, and (3) farmers' willingness to continue applying the organic fertilizers independently after the guided session. This field application stage functioned as a guided field application session (60 minutes) and served as an essential bridge between training activities and independent farmer adoption. The application of organic fertilizers to maize plants is shown in Fig. 7.



Fig. 7. Application of organic fertilizers on maize plants

Activity Evaluation

An activity evaluation was conducted to assess farmers' understanding, technical competence, and independence in applying locally sourced organic fertilizer technologies following the implementation of the empowerment program. The evaluation focused on the cognitive, psychomotor, and attitudinal aspects related to the adoption of organic fertilizer production and application practices. Data were collected using a structured questionnaire developed by the community service team to ensure consistent and comparable responses.

The first evaluation component assessed farmers' conceptual understanding of organic fertilizer production, including knowledge of the basic principles, functions, and benefits of organic fertilizers in maize cultivation systems. This assessment aimed to determine the extent to which farmers understood the rationale for using locally available materials as inputs for sustainable agriculture. Understanding of nutrient availability, soil health improvement, and the role of organic fertilizers in reducing dependency on synthetic inputs was also evaluated.

The second component evaluated farmers' practical abilities in preparing raw materials, producing, and applying various types of organic fertilizers introduced during the activity, including phosphate-solubilizing bacteria (PSB), liquid organic fertilizer (LOF) derived from aged coconut water, LOF formulated from *M. oleifera* leaves and BIOSAKA. This aspect emphasized farmers' capacity to independently carry out each production stage, from material selection and processing to field application techniques, reflecting the effectiveness of hands-on training and field practice.

The third evaluation aspect focused on farmers' knowledge regarding the appropriate dosage, application frequency, and intended use of each type of organic fertilizer. This component was essential to assess farmers' understanding of correct application strategies to optimize fertilizer effectiveness while minimizing potential misuse. Accurate knowledge of dosage and application timing is considered a critical factor influencing the successful adoption and sustainability of organic fertilizer technologies in maize farming systems.

The fourth component assessed farmers' perceptions, attitudes, and motivation to independently apply the introduced organic fertilizer technologies in their maize fields. This assessment aimed to capture farmers' readiness for technology adoption, perceived benefits, and willingness to continue using locally produced organic fertilizers beyond the program's duration. Positive perceptions and strong motivation are indicators of long-term adoption potential.

The questionnaire was completed at the end of the activity after all training sessions and field practices had been fully implemented. Farmers were encouraged to provide honest and comprehensive responses, with assistance from the team when necessary to ensure the clarity and accuracy of responses, thereby supporting data validity and reliability. The collected data were analyzed using both quantitative and qualitative approaches to evaluate the effectiveness of the empowerment program, determine the level of technology adoption among farmers, and formulate recommendations for improving and scaling up locally based organic agriculture development programs in the region.

Data Analysis

To evaluate the effectiveness of the training program, changes in farmers' responses between the preliminary and final questionnaires were statistically analyzed using the McNemar test. This test was selected because the questionnaire responses were dichotomous (yes/no) and collected from the same participants before and after the intervention. The McNemar test is appropriate for assessing significant changes in paired nominal data.

Results of the McNemar test for farmers' knowledge and skills across all evaluated indicators. The most pronounced changes were observed in indicators related to awareness and understanding of PSB, utilization of aged coconut water waste and

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moringa leaves for LOF production, and the use of wild weeds for BIOSAKA formulation. These indicators showed a substantial shift from "No" responses in the preliminary questionnaire to "Yes" responses in the final questionnaire. The statistically significant improvement confirms that the observed increases were not merely descriptive changes but were directly attributable to the training intervention.

RESULTS AND DISCUSSION

Delivery of Material on Organic Fertilizer Production

The delivery of instructional material on the production of locally sourced organic fertilizers contributed to demonstrable improvements in farmers' knowledge and conceptual understanding of sustainable nutrient management in maize cultivation systems. The material emphasized the principles of organic fertilization, the ecological role of organic inputs in maintaining soil health, and their potential to support maize growth and productivity under conditions of limited availability of inorganic fertilizers. The focus on locally available raw materials strengthened the material's contextual relevance and enhanced its applicability in smallholder farming systems.

Following the instructional session, farmers exhibited improved comprehension of the characteristics, functional mechanisms, and production procedures of four organic fertilizer technologies, namely Photosynthetic Bacteria (PSB), liquid organic fertilizer (LOF) derived from aged coconut water waste, LOF formulated from *M. oleifera* leaf extract, and BIOSAKA produced from wild weed biomass. In addition, farmers demonstrated increased understanding of the appropriate application methods of organic fertilizers in maize cultivation, including considerations related to dosage, application timing, and frequency. This improvement indicates that the instructional material effectively addressed both the conceptual and practical dimensions of organic fertilizer utilization.

The learning process incorporated systematic explanations supported by visual materials and structured descriptions of fermentation and biological transformation processes. These instructional elements facilitated farmers' understanding of the underlying biological mechanisms, including nutrient mobilization, microbial activity, and plant physiological responses to organic inputs. Consequently, farmers were better able to link organic fertilizer production techniques with their functional roles in enhancing nutrient availability, promoting vegetative growth, and supporting plant resilience.

Overall, the delivery of materials increased farmers' awareness of the strategic importance of utilizing locally sourced organic resources as sustainable alternatives to inorganic fertilizers. This outcome reflects the effectiveness of the instructional component in strengthening farmers' cognitive readiness to adopt organic fertilizer technologies and supports the broader objective of promoting environmentally sustainable and economically resilient agricultural practices within maize-based farming systems.

Demonstration of Organic Fertilizer Production

Demonstration of Photosynthetic Bacteria (PSB) Production

Demonstrations of Photosynthetic Bacteria (PSB) production contributed to measurable improvements in farmers' technical understanding of microbial fermentation processes and the functional role of photosynthetic microorganisms in supporting maize growth. Farmers actively participated in all production stages, including material preparation, inoculation, and sunlight-based incubation, thereby facilitating experiential learning and strengthening procedural knowledge. The explanation of material functions, such as eggs as a source of protein and amino acids, monosodium glutamate (MSG) as a nitrogen source, and EM4 as a microbial inoculum, enabled farmers to understand the biological rationale underlying PSB formulation rather than merely following technical instructions.

The effectiveness of the PSB production process was evaluated using observable fermentation indicators, particularly changes in color and odor of the fermentation medium (Fig. 8). During the initial fermentation phase, the solution exhibited a cream-colored appearance, reflecting limited microbial activity and incomplete substrate utilization. As fermentation progressed, the solution gradually changed to a characteristic brick-red color, indicating increased metabolic activity of PSB and the synthesis of photosynthetic pigments such as bacteriochlorophyll and carotenoids. These pigments are essential components of anoxygenic photosynthesis, allowing PSB to efficiently utilize light energy under low-oxygen conditions.

The development of brick-red coloration reflects active microbial growth and the successful conversion of organic substrates into microbial biomass and secondary metabolites. This visual indicator suggests that the PSB population reached an active growth phase, characterized by optimal pigment synthesis and metabolic efficiency. In addition to color transformation, the emergence of a distinctive fermentation odor further confirmed successful microbial activity. This odor is a result of volatile organic compounds, including organic acids, alcohols, and esters, produced during enzymatic degradation of organic materials by PSB-associated extracellular enzymes, such as proteases and lipases.

These observations are consistent with previous findings reported by Brahmana et al. (2022), who

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identified brick-red coloration and characteristic fermentation odor as reliable indicators of successful PSB fermentation driven by high microbial activity and secondary metabolite production. Similarly, Sutejo et al. (2025) emphasized that visual and olfactory indicators provide a practical and low-cost method for assessing PSB fermentation success under non-laboratory conditions. The alignment between the observed outcomes and established literature strengthens the validity of the fermentation indicators used in this activity.

The demonstration results indicate that farmers were able to acquire practical competence in producing PSB using simple techniques and locally available materials without reliance on laboratory equipment. This increased capacity has direct practical implications, as PSB application is known to enhance nitrogen and phosphate availability, improve soil quality, increase leaf photosynthetic efficiency, and ultimately support maize growth and productivity. Post-demonstration observations showed that farmers were confident in replicating the PSB production process independently, suggesting that the activity effectively translated technical knowledge into applicable skills and supported the broader goal of promoting sustainable, farmer-led biofertilizer adoption.



Fig. 8. PSB after 14 days of fermentation under direct sunlight

Demonstration of Liquid Organic Fertilizer (LOF) Production from Aged Coconut Water Waste

The demonstration of liquid organic fertilizer (LOF) production from aged coconut water waste resulted in a clear improvement in farmers' understanding of organic waste valorization and microbial fermentation. Through direct involvement in the preparation and fermentation stages, farmers recognized aged coconut water as a nutrient-rich substrate suitable for LOF production. This recognition was based on its relatively high macro- and micronutrient content, particularly potassium (K) and phosphorus (P), as well as essential micronutrients such as magnesium (Mg) and zinc (Zn), which support microbial growth and nutrient transformation during the fermentation process.

The effectiveness of the LOF fermentation process was evaluated using observable physical and sensory indicators, including changes in aromatic, gas formation, and solution appearance (Fig. 9). Successful fermentation was characterized by the emergence of a distinctive acidic odor and gas accumulation within the container, both of which indicate active metabolic processes of fermentative microorganisms. After seven days of fermentation, the solution changed to a cloudy cream color, reflecting the degradation of organic compounds and the formation of microbial metabolites. These changes indicate that the fermentation process proceeded optimally and resulted in a biologically stable liquid fertilizer.

The observed fermentation characteristics were consistent with the findings of Nada et al. (2025), who reported that color transformation and acidic aroma are reliable indicators of successful fermentation of aged coconut water waste. Properly controlled fermentation enhances the availability of essential nutrients, including carbon (C), nitrogen (N), phosphorus (P), and potassium (K), and accelerates the formation of organic compounds that are readily absorbed by plants. The cloudy cream appearance and acidic odor reflect effective microbial activity and the production of high-quality LOF.

Beyond technical outcomes, the demonstration significantly strengthened farmers' practical capacity to convert organic waste into agronomically valuable inputs. Farmers gained a functional understanding of how locally available waste materials can be transformed into liquid fertilizers capable of enhancing vegetative growth, improving crop productivity, and increasing plant tolerance to biotic stress, such as pest and pathogen attacks. This outcome supports the broader objective of reducing dependency on chemical fertilizers while promoting environmentally sustainable and economically efficient nutrient management practices at the farm level.



Fig. 9. LOF from aged coconut water waste after 7 days of fermentation

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Demonstration of Liquid Organic Fertilizer (LOF) Production from Moringa Leaves

The demonstration of liquid organic fertilizer (LOF) production from moringa (*M. oleifera*) leaves was designed as a capacity-building intervention to improve farmers' technical competence in utilizing locally available plant resources as raw materials for biofertilizers. The participants were actively engaged in all procedural stages, including leaf homogenization, filtration, and incorporation of fermentation additives, such as molasses and bio activators. This participatory approach was intentionally implemented to facilitate experiential learning and strengthen farmers' ability to replicate the technology independently using local resources.

M. oleifera leaves possess a high nutritional profile, including nitrogen, proteins, vitamins, essential minerals, and natural phytohormones such as auxins and cytokinins, which provides a strong scientific basis for their selection as LOF raw materials. These compounds play a critical role in promoting vegetative growth, cell division, and new tissue formation (Samarakoon et al., 2020; Brockman et al., 2020). In addition, Moringa leaves contain antioxidants and phenolic compounds that support microbial proliferation and metabolic activity during fermentation, thereby improving the quality of the resulting liquid fertilizer.

Fermentation was conducted over a seven-day period with daily observation of changes in aromatic, color, and gas formation as indicators of microbial activity (Fig. 10). Changes in the physical characteristics of the solution to a cloudy suspension indicated increased microbial biomass and the formation of soluble organic matter, reflecting successful fermentation and biological stabilization of the LOF. Changes in the physical characteristics of the solution to a cloudy suspension indicated increased microbial biomass and the formation of soluble organic matter, reflecting successful fermentation and biological stabilization of the LOF.

The outcomes of this activity demonstrated that farmers achieved a functional understanding of both the procedural steps and the scientific rationale underlying the production of moringa-based LOF. Participants were able to explain the role of each component, including molasses as a carbon and energy source for fermentative microorganisms and bio activators as microbial inoculants that accelerate the decomposition of organic matter. This level of understanding indicates that the intervention effectively transitioned farmers from basic awareness to practical competence.

Overall, the demonstration contributed to increased farmer autonomy in producing affordable and environmentally friendly biofertilizers, thereby supporting sustainable nutrient management practices. The utilization of moringa leaves as a locally sourced input reduces dependency on synthetic fertilizers and reinforces community-based agricultural innovation grounded in local resource optimization and sustainability.



Fig. 10. LOF from moringa leaves after 7 days of fermentation

Demonstration of BIOSAKA Production from Wild Weed Plants

The demonstration of BIOSAKA production from wild weed plants was implemented as a practical intervention to enhance farmers' understanding of the role of naturally occurring bioactive compounds in strengthening plant defense mechanisms. Farmers were introduced to several locally abundant weed species, including babadotan (*A. conyzoides*), patikan kebo (*E. hirta*), and meniran (*P. niruri*), which were selected based on their known bioactive and elicitor properties. The kneading process of plant materials in water was conducted gently to facilitate the release of intracellular bioactive compounds and indigenous microorganisms from the weed tissues. The resulting extract was subsequently filtered and stored in sealed containers prior to application to maize plants. Participants recognized that BIOSAKA quality is influenced by critical factors, such as raw material freshness, kneading duration, and equipment sanitation, indicating an improved understanding of process control. The activity demonstrated that farmers were capable of producing an effective BIOSAKA formulation using materials readily available in their surrounding environment. This knowledge is particularly important, as BIOSAKA functions as a natural elicitor capable of inducing plant resistance against pests and diseases through non-chemical pathways.

The resulting BIOSAKA solution exhibited a cloudy appearance accompanied by a characteristic plant extract aroma (Fig. 11). The greenish cloudy coloration reflects the presence of finely dispersed organic particles derived from the dissolution of plant cellular components. The greenish cloudy coloration reflects the presence of finely dispersed organic particles derived from the dissolution of plant cellular components. This condition indicates the breakdown of complex

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biomolecules such as chlorophyll, proteins, and phenolic compounds into simpler, soluble forms that are more readily assimilated by plants.

The distinctive aroma of the plant extract indicates the presence of volatile secondary metabolites produced during fermentation, including organic acids, alcohols, and esters. The formation of these metabolites signifies the occurrence of active fermentative microbial processes within the BIOSAKA system. Such microbial activity plays a crucial role in generating bioactive substances, including natural phytohormones, amino acids, and growth-regulating compounds, which collectively contribute to enhanced plant vigor and increased tolerance to biotic and abiotic stress.

Overall, the observed changes in color and aroma confirm the successful biochemical transformation of weed biomass into a functional BIOSAKA solution. Consequently, the produced BIOSAKA demonstrates strong potential as an environmentally friendly liquid organic input enriched with bioactive compounds. This finding is consistent with Elmiati et al. (2024), who reported that physical characteristics, such as cloudy appearance and distinctive plant aroma, are reliable indicators of BIOSAKA quality, reflecting intensive biochemical and microbial activity during the extraction process.



Fig. 11. BIOSAKA solution extracted from wild weed plants

Application of Organic Fertilizers on Maize Plants

The application of locally sourced organic fertilizers was associated with observable differences in vegetative growth appearance of maize plants under farmers' field conditions. Maize plants that received organic fertilizer inputs visually exhibited greener leaves, relatively wider leaf surfaces, and sturdier stem appearance compared to plants that did not receive organic fertilizer applications (Fig. 12). It is important to note that these observations were qualitative in nature and were not supported by quantitative growth measurements or statistical analysis. It is important to note that these observations were qualitative in nature and were not supported by quantitative growth measurements or statistical analysis.

The visually greener leaf appearance observed in the treated plants may be related to the functional role of photosynthetic bacteria (PSB) in supporting nutrient dynamics and photosynthetic processes. PSB are known to participate in nitrogen transformation and nutrient mobilization in the rhizosphere, which can contribute to chlorophyll formation and vegetative development. Salsabila (2024) reported that beneficial nutrient-mobilizing bacteria (PSB) can support vegetative growth in maize by improving plant physiological performance and nutrient use efficiency. In the present activity, PSB were applied through foliar spraying; therefore, their effects are more likely associated with enhanced photosynthetic activity and metabolic processes at the leaf level rather than rhizosphere-mediated mechanisms. Although physiological parameters such as chlorophyll content were not quantitatively measured, the visual improvements observed in leaf greenness are consistent with the general functional roles of foliar-applied PSB reported in previous studies. In addition, the use of organic inputs has been widely reported to improve soil fertility and crop performance through enhanced soil biological activity and nutrient cycling (Zhou et al., 2022), which may contribute to the plant responses observed descriptively in this activity.

Liquid organic fertilizer (LOF) derived from aged coconut water waste primarily functions as a source of macro- and micronutrients that support plant nutritional requirements during the vegetative phase. In this activity, nutrient uptake, biomass accumulation, and yield parameters were not quantitatively measured. However, farmers consistently reported visually improved plant vigor and more uniform growth following routine LOF application. Community-based studies have shown that coconut water-based LOF contains essential nutrients and fermentation-derived bioactive compounds that can support plant physiological processes and vegetative growth (Pane et al., 2023). Therefore, the observations recorded in the present activity can be interpreted as descriptive indications of potential nutritional support rather than confirmed agronomic effects.

Farmers perceived that LOF formulated from M. oleifera leaves contributed to improved leaf development and overall plant appearance. *M. oleifera* leaves are known to contain nitrogen, minerals, and naturally occurring bioactive compounds that are associated with vegetative growth support. Previous studies have reported that moringa-based liquid organic fertilizers can influence plant height, leaf number, and biomass accumulation in several crops (Rachmawatie et al., 2025; Zakria et al., 2025). In the present study, the

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effects of moringa-based LOF were evaluated qualitatively based on visual plant characteristics; therefore, the observations should be interpreted as indicative trends rather than measured responses.

The application of BIOSAKA, a liquid bioelicitor derived from mixed weed extracts, was associated with perceived improvements in plant vigor and physiological appearance. BIOSAKA has been applied in community-based organic agriculture systems as a plant elicitor intended to stimulate metabolic activity rather than serve as a direct nutrient source. Pebriyanto et al. (2025) demonstrated that the adoption of BIOSAKA in community farming systems increased farmers' capacity to utilize locally available biological inputs in crop management. Furthermore, Nurhijjah et al. (2024) reported that weed-based BIOSAKA applications were associated with improved vegetative parameters, such as plant height and leaf number, in shallot cultivation under field conditions. These findings support the interpretation that BIOSAKA may function as a bioelicitor, and the visual plant responses observed with this application are consistent with previous descriptive field reports.



Fig. 12. Effect of application organic fertilizers on maize plant. (a) Maize growth in vegetative stages (30 DAP), and (b)Maize yield (80 DAP)

Regular weekly application of PSB, LOF, and BIOSAKA was perceived by participating farmers to result in more uniform plant growth and improved vegetative appearance of maize plants. The combined use of these locally sourced organic inputs was also reported by farmers to contribute to better soil conditions and reduced reliance on chemical fertilizers. However, it should be emphasized that this activity did not employ a controlled experimental design, quantitative growth measurements, or statistical analysis. Consequently, the observed plant responses should be interpreted strictly as descriptive field-based observations rather than statistically validated treatment effects. Nonetheless, these findings provide preliminary field-level indications of the practical potential of locally sourced organic fertilizers in community-based agricultural systems and underscore the need for future studies that incorporate controlled field experiments, quantitative growth parameters, and statistical analysis to rigorously evaluate agronomic impacts.

Activity Evaluation

The evaluation results demonstrated substantial improvements in participants' knowledge, technical understanding, and intention to adopt organic fertilizer technologies following the implementation of the community service program. Based on the pre- and post-test questionnaire analysis summarized in Table 1, positive transitions (No to Yes) were consistently observed across all twenty evaluated parameters, indicating the effectiveness of the training and mentoring activities.

Prior to the intervention, the participants generally possessed a basic awareness of organic fertilizers. As shown in the pre-test results, 80.00% of farmers reported prior knowledge of organic fertilizers; however, their practical experience and applied understanding were still limited. Only 30.00% of the participants had previously used organic fertilizers for crop cultivation, and a similar proportion (30.00%) understood their advantages over chemical fertilizers. These findings suggest that initial awareness was not accompanied by sufficient confidence or technical comprehension to support its practical adoption.

Knowledge gaps were more pronounced in relation to specific organic fertilizer technologies introduced during the program. None of the participants (0.00%) had prior awareness of Photosynthetic Bacteria (PSB) and their role in plant growth. Likewise, knowledge regarding the utilization of mature coconut water waste and *Moringa oleifera* leaves as raw materials for liquid organic fertilizer (LOF) was limited to only 20.00% of the participants. Awareness of wild weeds as raw materials for BIOSAKA elicitor production was even lower, at 10.00%. These results indicate that although local resources were readily available, most farmers had not previously recognized their agronomic potential.

Following the training activities, the post-test results revealed marked improvements across all knowledge-related parameters. Participants demonstrated full understanding (100.00%) of the procedures for producing LOF from coconut water waste and *M. oleifera* leaves, as well as increased comprehension of BIOSAKA and PSB preparation techniques. In addition, 85.00%–89.00% of participants reported improved understanding of the functional roles of PSB, LOF, and BIOSAKA in supporting plant growth, plant health, and maize production systems.

In addition to enhancing conceptual knowledge, the program also enhanced participants' technical skills and confidence. Most farmers reported being able to independently replicate the preparation of PSB, LOF, and BIOSAKA using locally available materials. Improvements were also

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Table 1. Pre- and post-test evaluation of participants' knowledge, skills, and adoption intention toward PSB, LOF, and BIOSAKA

No	Evaluation Parameters	Pre-test Yes (%)	Post-test Yes (%)	Change (%)
1.	Prior knowledge of organic fertilizers	80.00	100.00	+20.00
2.	Experience using organic fertilizers in cultivation	30.00	95.00	+65.00
3.	Understanding advantages of organic fertilizers compared to chemical fertilizers	30.00	85.00	+55.00
4.	Awareness of Photosynthetic Bacteria (PSB) and their role in plant growth	00.00	89.00	+89.00
5.	Awareness that old coconut water waste can be utilized for LOF production	20.00	100.00	+80.00
6.	Awareness that moringa (*M. oleifera*) leaves can be used as LOF raw material	20.00	100.00	+80.00
7.	Awareness that wild weeds can serve as raw material for BIOSAKA production	10.00	87.00	+77.00
8.	Interest in learning and applying PSB, LOF, and BIOSAKA	50.00	95.00	+45.00
9.	Awareness that organic fertilizers contribute to soil fertility and environmental sustainability	50.00	85.00	+35.00
10.	Understanding basic PSB fermentation principles	5.00	88.00	+83.00
11.	Understanding foliar application of PSB	10.00	90.00	+80.00
12.	Understanding appropriate LOF dosage and application frequency	15.00	88.00	+73.00
13.	Ability to independently prepare LOF from old coconut water	10.00	100.00	+90.00
14.	Ability to independently prepare LOF from moringa leaves	10.00	100.00	+90.00
15.	Understanding BIOSAKA as a plant elicitor rather than a nutrient source	5.00	85.00	+80.00
16.	Confidence in producing BIOSAKA from locally available weed biomass	5.00	87.00	+82.00
17.	Perceived improvement in plant vigor after organic fertilizer application	20.00	90.00	+70.00
18.	Intention to reduce the use of chemical fertilizers	30.00	85.00	+55.00
19.	Perception that organic fertilizers can reduce production costs	25.00	80.00	+55.00
20.	Willingness to disseminate PSB, LOF, and BIOSAKA knowledge to other farmers	40.00	90.00	+50.00

*Pre- and post-test assessments were conducted using dichotomous (Yes/No) responses completed by the same participants. Parameters 1–9 represent the original questionnaire items, while parameters 10–20 were included to capture additional changes in technical understanding, skills, perception, and adoption intention following the training activities.

observed in participants' understanding of the appropriate dosage, application frequency, and application methods, including foliar application strategies for PSB and the use of BIOSAKA as a plant elicitor rather than a direct nutrient source.

Importantly, the intervention positively influenced farmers' attitudes and adoption intentions. While initial interest in learning and applying organic fertilizer technologies was moderate (50.00%), post-test results showed that 95.00% of participants expressed a willingness to apply PSB, LOF, and BIOSAKA in future cultivation practices. Furthermore, the recognition of the role of organic fertilizers in improving soil fertility and supporting environmental sustainability increased substantially, reflecting a shift from short-term productivity concerns toward more sustainable farming perspectives.

Overall, the pre- test and post-test evaluations (Table 1) demonstrate that the community service program effectively addressed existing knowledge gaps, strengthened technical capacity, and fostered positive attitudes toward the adoption of locally sourced organic fertilizers. Although the evaluation was based on qualitative Yes/No responses rather than quantitative agronomic measurements, the consistent positive transitions across all twenty parameters provide strong evidence of the program's impact and support the potential for wider adoption of PSB, LOF, and BIOSAKA technologies in maize-based farming systems.

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CONCLUSION

This community service activity successfully achieved its objectives by improving farmers' knowledge, skills, and adoption intention regarding the production and application of locally sourced organic fertilizers, including LOF, PSB, and BIOSAKA. The achievement of these objectives was demonstrated through measurable improvements in the pre- and post-test evaluation parameters, indicating an increased understanding of organic fertilizer concepts, preparation procedures, and application purposes.

The activity contributed to strengthening farmers' capacity to utilize locally available organic materials, such as *M. oleifera* leaves, mature coconut water waste, and wild weeds, as sustainable agricultural inputs. Farmers were able to independently reproduce the fertilizer preparation processes and demonstrated improved awareness of the role of organic fertilizers in supporting maize growth and environmentally friendly farming practices.

However, this activity was limited to descriptive evaluations based on questionnaire responses and visual field observations, without quantitative growth measurements or statistical field trials. Therefore, future activities are recommended to incorporate controlled experimental designs, quantitative agronomic parameters, and longer-term monitoring to more rigorously assess the effectiveness and sustainability of locally produced organic fertilizers

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