Indonesian Journal of Society Development (IJSD)
Vol.5, No.1, 2026: 49-56

Introducing Green Chemistry–Based Slow-Release Fertilizer Technology to Farmers Using Zeolite and Biomass-Derived Carbon in Lempake, Samarinda

Hajar Anuar[1], Noor Hindryawati[2*], Husna Syaima[3], Irfan Ashari Hiyahara[4], Aman Sentosa P[5], Bohari[6], Teguh Wirawan[7], Nanang Triwidodo[8], M. Syaiful Arif[9], Ika Yekti Lianasari[10], Alimuddin[11], Soerja Koesnarpadi[12]
Mulawarman University
Corresponding Author: Noor Hindryawati hindryawati@gmail.com

A R T I C L E I N F O

Keywords: Green Chemistry, Slow-Release Fertilizer, Zeolite, Biochar, Farmer Empowerment

Received : 3 December
Revised : 23 January
Accepted: 24 February

A B S T R A C T

Excessive use of chemical fertilizers in agriculture often leads to various environmental problems, including soil degradation, water pollution, and low nutrient-use efficiency. Therefore, alternative environmentally friendly and sustainable fertilizers are urgently needed. This community service program aimed to improve farmers' knowledge and skills in producing slow-release fertilizers based on green chemistry principles using natural zeolite, activated carbon derived from lai (Durio kutejensis) peel, compost, and manure. The program was conducted with members of the Karya Mandiri and Sedap Malam farmer groups in Lempake, Samarinda, involving 30 participants. The implementation methods included preparation, training, demonstration of fertilizer production, mentoring, and evaluation using pre-test, post-test, and participant satisfaction questionnaires. The results indicated a significant increase in farmers' understanding, with average pre-test scores ranging from 30–40% and increasing to 80–90% in the post-test. Participant satisfaction levels ranged from 88–95%. The fertilizer formulation consisted of 30% zeolite, 20% activated carbon from lai peel, 40% compost, and 10% manure, which functioned as a slow-release fertilizer capable of storing and gradually releasing nutrients. This activity demonstrates that the application of green chemistry approaches in fertilizer development can enhance farmers' knowledge, reduce dependence on chemical fertilizers, and support sustainable agricultural practices within the community.

DOI: https://doi.org/10.55927/ijsd.v5i1.5
ISSN-E: 2964-6006
https://journalijsd.my.id/index.php/ijsd/index

INTRODUCTION

Agriculture plays a crucial role in supporting food security and the economic sustainability of rural communities, particularly in agrarian regions such as Samarinda. However, modern agricultural practices that heavily depend on chemical fertilizers have led to various environmental challenges, including soil degradation, groundwater contamination, and reduced fertilizer-use efficiency due to nutrient losses through leaching and volatilization (Mahmudha et al., 2025). These conditions highlight the need for innovative fertilization technologies that are more environmentally friendly and sustainable.

One promising approach in sustainable agriculture is the use of green chemistry–based materials in the development of slow-release fertilizers. Slow-release fertilizers are designed to gradually release nutrients into the soil, ensuring a more consistent nutrient supply for plants and improving nutrient-use efficiency (Bakshi et al., 2023).

Natural zeolite has attracted significant attention in slow-release fertilizer development due to its porous crystalline structure and high cation exchange capacity. These properties enable zeolite to adsorb nutrient ions such as ammonium and potassium and release them gradually according to plant requirements (Mahmudha et al., 2025). In addition to zeolite, carbon-based materials such as biochar or activated carbon are widely recognized for their ability to improve soil fertility due to their large surface area, high porosity, and strong adsorption capacity for nutrients and water (Farha et al., 2023).

Compost also plays an essential role in improving soil quality by increasing organic matter content and stimulating soil microbial activity. Previous studies have demonstrated that the combined application of biochar and compost can enhance nutrient availability and plant growth in soils with low organic matter content (Herhandini et al., 2021). Furthermore, the integration of biochar and compost has been shown to improve soil structure and increase horticultural crop productivity (Sukmawati et al., 2023).

Lempake Village in Samarinda possesses considerable potential for horticultural farming due to its favorable agroecological conditions and the active participation of local farmer groups. However, farmers in this region continue to face several challenges that limit agricultural productivity and sustainability. One of the major issues is the gradual decline in soil fertility caused by the long-term and intensive use of chemical fertilizers, which may lead to soil structure degradation, nutrient imbalance, and reduced microbial activity in the soil.

In addition to environmental concerns, economic constraints also represent a significant obstacle for local farmers. Based on discussions and interviews conducted with members of the Karya Mandiri and Sedap Malam farmer groups during the preliminary survey, farmers reported that the increasing price of chemical fertilizers has become a major burden in agricultural production. The fluctuating availability and relatively high cost of fertilizers often force farmers to reduce fertilizer application rates, which consequently affects crop productivity. These conditions highlight the urgent need for

alternative fertilization strategies that are both cost-effective and environmentally sustainable.

One promising approach to address these challenges is the development of fertilizers derived from locally available biomass resources. Biomass-based fertilizers not only reduce dependency on commercial chemical fertilizers but also provide an opportunity to utilize agricultural and organic waste materials that are abundant in the local environment. In this context, the use of natural zeolite, activated carbon derived from lai (Durio kutejensis) peel, compost, and manure represents a potential solution for producing environmentally friendly slow-release fertilizers. Natural zeolite functions as a nutrient carrier and reservoir due to its high cation exchange capacity, while biomass-derived carbon materials contribute to improved nutrient retention and soil structure.

Therefore, this community service program was designed to enhance farmers' knowledge and practical skills in producing slow-release fertilizers based on green chemistry principles using natural zeolite, activated carbon from lai peel biomass, compost, and manure. The novelty of this program lies in the integration of locally available biomass waste, particularly lai peel, with mineral-based materials such as natural zeolite to produce a green chemistry–based slow-release fertilizer that can be prepared directly by farmers through simple and low-cost methods. This approach not only introduces sustainable fertilization technology but also promotes the valorization of local biomass waste into value-added agricultural inputs.

It is expected that this initiative will contribute to improving farmers' knowledge, reducing dependence on expensive chemical fertilizers, and promoting sustainable agricultural practices that support long-term soil fertility and local agricultural productivity.

METHODS

Location and Participants

The community service activity was conducted in Lempake Village, Samarinda, East Kalimantan, Indonesia. The participants were members of the Karya Mandiri and Sedap Malam farmer groups, consisting of 30 farmers aged between 25 and 73 years.

Implementation Stages

The implementation of the program consisted of three main stages: preparation, implementation, and evaluation.

Preparation Stage

This stage involved an initial field survey to identify the main agricultural problems faced by farmers, preparation of training materials, procurement of tools and materials for fertilizer production, and coordination with local farmer groups.

Implementation Stage

The implementation stage included training sessions on the preparation of green chemistry–based slow-release fertilizers composed of natural zeolite, activated carbon derived from lai peel, compost, and manure. Demonstrations of fertilizer preparation were conducted, followed by hands-on practice sessions

where farmers were guided in mixing the materials and forming fertilizer granules.
The fertilizer formulation used in this activity consisted of:

Table 1. Implementation Stage

Material	**Composition**
Natural zeolite	30%
Activated carbon (lai peel biochar)	20%
Compost	40%
Manure	10%

Evaluation Stage

Program evaluation was conducted using pre-test and post-test assessments to measure improvements in participants' knowledge. Additionally, participant satisfaction was assessed through structured questionnaires to evaluate the perceived usefulness and effectiveness of the training activities.

RESULTS AND DISCUSSION

Improvement in Participants' Knowledge

The results of the pre-test indicated that most farmers had limited knowledge regarding the concept of slow-release fertilizers and the roles of materials such as zeolite and activated carbon in fertilizer systems. The average pre-test score ranged from approximately 30–40%. After participating in the training sessions and practical demonstrations, the post-test results showed a substantial increase, with average scores reaching 80–90% (Fig 1).

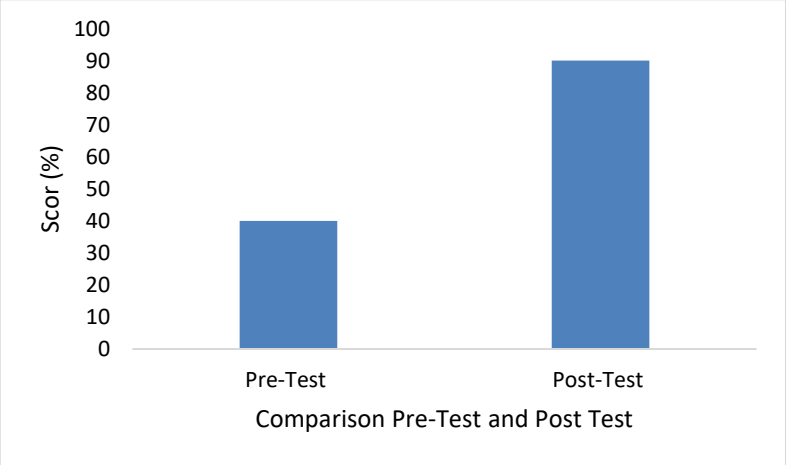

Figure 1. Pre-Test and Pot-Test From the Participant's Knowledge

This improvement indicates that the training approach, which combined theoretical explanations with hands-on practice, was highly effective in enhancing participants' understanding of environmentally friendly fertilizer technologies.

Analysis of Slow-Release Fertilizer Composition

The fertilizer formulation developed in this program consists of a combination of zeolite, activated carbon, compost, and manure. Each component contributes to the overall performance of the slow-release fertilizer system.

Zeolite acts as a nutrient reservoir through cation exchange mechanisms, allowing nutrients to be stored and gradually released into the soil. Activated carbon or biochar provides a highly porous structure that enhances water retention and nutrient adsorption within the soil matrix. Meanwhile, compost and manure serve as primary sources of organic nutrients essential for plant growth. The synergistic combination of these materials improves soil fertility while providing a steady supply of nutrients for plant uptake.

Participant Satisfaction

The evaluation of the training program was conducted using a participant satisfaction questionnaire covering four key aspects: material quality, training benefits, material relevance, and instructor performance. The results indicate a high level of satisfaction among participants, with scores ranging from 88% to 95%, reflecting the overall effectiveness of the training program (Fig 2).

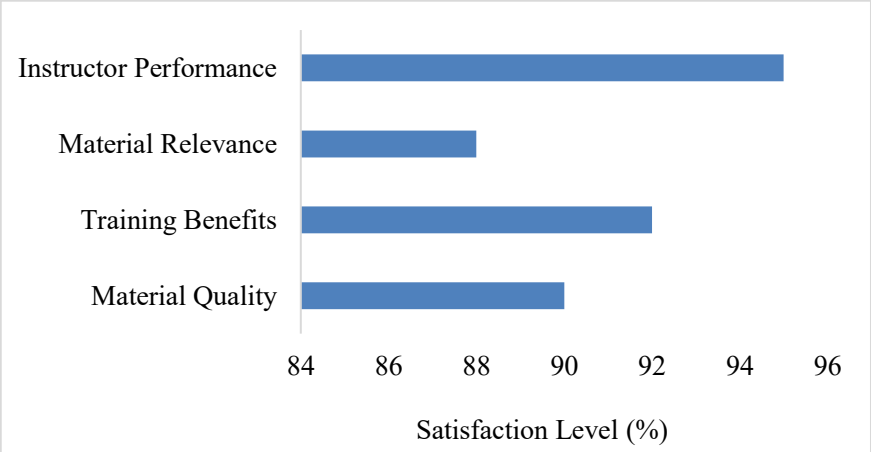

Figure 2. Training Participant Questionnaire Results

The highest score was obtained for instructor performance, reaching approximately 95%. This result indicates that participants perceived the facilitator's ability to deliver the material as highly effective. The instructor was able to explain complex concepts related to green chemistry and slow-release fertilizer production in a clear and understandable manner. Effective communication, practical demonstrations, and interactive discussions during the training sessions likely contributed to the high level of satisfaction in this aspect. Previous studies have shown that facilitator competence plays a crucial role in determining the success of community-based training programs because it influences participants' motivation and engagement during learning activities.

The second highest score was observed in the training benefits aspect, with a satisfaction level of approximately 92%. This finding suggests that participants considered the training highly useful for their agricultural practices. The knowledge gained during the program, particularly regarding the production of slow-release fertilizers using locally available materials such as

zeolite, biomass-derived carbon, compost, and manure, was perceived as directly applicable to their farming activities. The high score in this category indicates that the training program successfully addressed the practical needs of farmers and provided solutions to the challenges they face in fertilizer management.

The material quality aspect obtained a satisfaction level of around 90%, indicating that the training materials were well-prepared and sufficiently comprehensive. The materials included explanations of the basic principles of green chemistry, the functions of each fertilizer component, and step-by-step guidance on fertilizer preparation. Clear visual aids and demonstrations helped participants better understand the production process, thereby enhancing their learning experience.

Meanwhile, the material relevance aspect received a score of approximately 88%, which, although slightly lower than the other aspects, still indicates a high level of satisfaction. This result may reflect variations in the farming conditions and experiences of the participants. Some farmers may require more specific examples or further adaptation of the fertilizer formulation to suit different crop types or soil conditions. Nevertheless, the relatively high score suggests that the training content was generally aligned with the needs and expectations of the participants.

Overall, the results demonstrate that the training program was well-received by the farmer participants and successfully achieved its objectives. The high satisfaction scores across all aspects indicate that the training not only provided valuable knowledge but also delivered practical skills that can be applied in agricultural practices. Furthermore, the strong positive response from participants suggests that similar community empowerment programs focusing on sustainable fertilizer technologies should be continued and expanded to other agricultural communities.

The implementation of such programs is particularly important in promoting environmentally friendly agricultural practices while simultaneously addressing economic challenges faced by farmers, such as the rising cost of chemical fertilizers. By introducing locally sourced materials and simple production techniques, farmers can potentially reduce production costs while maintaining soil fertility and crop productivity.

Impact of the Program on the Community

The community service program generated several positive impacts for the local community. Farmers gained new knowledge regarding environmentally friendly fertilizers, developed practical skills in producing fertilizers independently, and increased their awareness of sustainable agricultural practices.

Moreover, the utilization of local biomass waste such as lai peel as a raw material for activated carbon production provides additional economic and environmental benefits by promoting biomass waste valorisation. The documentation of the activity is presented in Figure 3, which shows the presentation session as well as examples of the products produced during the training program.

Figure 3. Presentation session and examples of slow-release fertilizer products produced during the training activity.

CONCLUSION

The community service program focusing on training farmers to produce slow-release fertilizers based on green chemistry principles in Lempake Village successfully improved farmers' knowledge and skills in producing environmentally friendly fertilizers. Evaluation results showed a significant increase in participant understanding based on pre-test and post-test comparisons, along with very high levels of participant satisfaction.

The fertilizer formulation consisting of natural zeolite, activated carbon derived from lai peel, compost, and manure demonstrates strong potential as a slow-release fertilizer capable of improving nutrient-use efficiency and supporting sustainable agricultural practices. Therefore, similar programs

should be expanded to reach a broader farming community to further promote environmentally friendly fertilization technologies.

REFERENCES

Bakshi, S., He, Z., Harris, W., & Sarkar, B. (2023). Biochar in agriculture: Impacts on soil fertility and nutrient management. *Science of the Total Environment*, 865, 161234.

Farha, N., Rahman, M., & Islam, M. (2023). Development of biochar–zeolite composite fertilizer for improving nitrogen use efficiency in vegetable crops. *Journal of Cleaner Production*, 382, 135285.

Herhandini, R., Suryanto, A., & Widyastuti, R. (2021). Effects of biochar and compost on soil fertility and maize growth in Ultisol soils. *Jurnal Tanah dan Sumberdaya Lahan*, 8(2), 347–356.

Mahmudha, N., Rahman, A., & Prasetyo, B. (2025). Natural zeolite as a slow-release fertilizer matrix to improve nutrient efficiency in agricultural systems. *Environmental Technology & Innovation*, 29, 103021.

Sukmawati, N., Lestari, T., & Wulandari, D. (2023). Utilization of compost and biochar for improving soil structure and crop productivity in sustainable agriculture. *International Journal of Agricultural Sustainability*, 21(2), 145–156.