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Development of Biofertiliser Based on Agricultural Waste for Sustainable Agriculture

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ABSTRACT

Based on data from the Central Statistics Agency (BPS), the use of chemical fertilisers in Indonesia has increased by 50% in the last two decades, contributing to the decline of soil fertility and groundwater pollution (Rosadi, 2023). Research by the Indonesian Institute of Sciences (LIPI) found that the use of biofertilisers from agricultural waste can reduce the need for chemical fertilisers by up to 40%, while improving soil fertility in a sustainable manner. This research will focus on the development of agricultural waste-based biofertiliser formulations, with trials of their application in various crop types and land conditions in Indonesia. This research uses an experimental method with a quantitative approach, which aims to develop and test the effectiveness of agricultural waste-based biofertilisers. Table 1. The Bima variety (a1) has a larger number of plants than the Mentes variety (a2). Nutrient management also has a major impact on plant growth. Application of one dose of recommended NPK together with 100 kg/ha of pearl NPK (b3) and one dose of recommended NPK together with organic fertiliser and biofertiliser (b4) resulted in the highest plant growth at 8 weeks of age (Table 1). In the experiment, intensive pest control was carried out in the field. As a result, onion caterpillar (Spodoptera exigua hubn) populations per clump were low and fusarium wilt (Fusarium oxysporum hanz) infestation levels were generally low in both variety and nutrient management treatments. There was no evidence that varietal treatments or nutrient management had a significant impact. The application of agricultural waste-based biofertilisers not only improves crop yields, but also supports the sustainability of the agricultural ecosystem by minimising the use of synthetic chemicals and optimising the use of available resources.

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1. Introduction

Sustainable agriculture is an important concept in maintaining a balance between agricultural productivity and environmental sustainability. In Indonesia, the agricultural sector faces major challenges related to soil quality degradation and reduced crop yields due to the overuse of synthetic chemical fertilisers (Nugroho, 2020). Based on data from the Central Statistics Agency (BPS), the use of chemical fertilisers in Indonesia has increased by 50% in the last two decades, contributing to the decline of soil fertility and groundwater pollution (Rosadi, 2023).

Chemical fertilisers, while effective in the short term, often have a negative impact on the environment in the long term. According to the Ministry of Environment and Forestry (MoEF), around 30% of water pollution in agricultural areas is caused by chemical fertiliser runoff, resulting in decreased water quality and loss of soil biodiversity (Panda.id, 2023; Wikipedia, 2020). In addition, chemical fertilisers also increase greenhouse gas emissions, particularly nitrous oxide, which is 300 times more potent in causing the greenhouse effect than CO_2 (Ariani et al., 2009; Arsyad, 2024).

Agricultural wastes, such as crop residues, straw, fruit peels, and other organic wastes, are often underutilised. Based on a report from the Ministry of Agriculture in 2022, it is estimated that more than 50 million tonnes of agricultural waste is generated annually in Indonesia. As such, this agricultural waste has great potential to be utilised more effectively and sustainably (Bagaskara, 2023). Most of this waste is left to rot or burned, which can cause air pollution and waste of organic resources that actually have great potential as biofertiliser raw materials (Susilo et al., 2021).

Microorganism-based biofertilisers, such as nitrogen-fixing bacteria, phosphate solvents, and organic matter decomposers, have been proven to improve soil structure, increase water absorption capacity, and support plant growth without damaging the environment. Research from the Agricultural Research and Development Agency (Balitbangtan) shows that the use of biofertilisers can increase crop yields by 20-30% compared to the use of chemical fertilisers (Cahyadi & Widodo, 2017).

However, the adoption of biofertilisers in Indonesia is still limited, mainly due to the lack of innovation in utilising local materials, such as agricultural waste, which are abundant but not optimally utilised (Isma, 2021). This research aims to develop agricultural waste-based biofertilisers that not only utilise existing resources, but also support the sustainability of agricultural systems. Agricultural waste such as rice straw, fruit peels, or other crop residues can be a source of carbon and nutrients needed by biofertiliser-producing microorganisms.

Previous studies have shown that a combination of agricultural waste and microorganisms can produce biofertilisers with sufficient nitrogen and phosphorus content to support plant growth. Research by the Indonesian Institute of Sciences (LIPI) found that the use of biofertilisers from agricultural waste can reduce the need for chemical fertilisers by up to 40%, while improving soil fertility in a sustainable manner.

Therefore, this research will focus on the development of agricultural waste-based biofertiliser formulations, with trials of their application in various crop types and land conditions in Indonesia. The results of this research are expected to support the transition towards a more environmentally friendly agricultural system, reduce dependence on chemical fertilisers, and maximise the potential of agricultural waste as an economically valuable resource.

2. Materials and Method

This research uses an experimental method with a quantitative approach, which aims to develop and test the effectiveness of agricultural waste-based biofertilisers. Experiments will be conducted by utilising various types of agricultural waste as the basic ingredients for making biofertilisers, and testing them on different plants to see the effect on growth and productivity.

This research will be conducted in Padang using 100 metres of agricultural trial land^2 . The research will be conducted for 1 month, from the preparation stage, fertiliser development, to field application trials.

Materials: Agricultural waste (rice straw, fruit peels, crop residues, bagasse, and other wastes), Biofertiliser-producing microorganisms, such as Azospirillum spp., Azotobacter spp., and Pseudomonas spp. Growth medium for microorganisms (e.g. molasses, coconut water, or other organic materials), Test plants (e.g. rice, corn, soybean). Tools: Fermenter for microorganism culture, Measuring instruments for pH, temperature, soil moisture, Scales, stirrers, and storage containers, Soil fertility testing instruments, such as pH meter and spectrophotometer to measure nutrient content. Selected agricultural wastes (straw, fruit peels, crop residues) will be collected from local farmlands. These wastes are then dried and crushed into small particles to facilitate the decomposition process.

Biofertiliser Formulation

1. Isolation of Microorganisms: Microorganisms such as Azospirillum, Azotobacter, and Pseudomonas will be isolated from healthy agricultural soil and propagated using specialised growing media.
2. Fermentation of Agricultural Waste: The crushed agricultural waste is fermented using a mixture of microorganisms. The fermentation process is carried out in a fermenter for 7-14 days at an optimal temperature (30-35°C) until a biofertiliser with stable nutrient content is formed.
3. Chemical and Microbiological Analysis: The biofertiliser produced will be tested for its main nutrient content (nitrogen, phosphorus, potassium) as well as the presence of beneficial live microorganisms.

Fertiliser App Trial

1. Planting of Test Crops: Test crops such as rice, maize, and soyabean will be planted on experimental land that has been divided into plots. Each plot will

receive different treatments, viz: Agricultural waste-based biofertiliser, Conventional chemical fertiliser, No fertiliser control.

2. Plant Growth Observations: Plant growth was observed throughout the growing period, measuring variables such as plant height, number of leaves, chlorophyll content, and nutrient uptake rate.

Data obtained from the field trials will be statistically analysed using ANOVA (Analysis of Variance) test to see significant differences between biofertiliser and chemical fertiliser treatments. If there are significant differences, post-hoc tests such as Tukey or Duncan will be conducted to determine which treatment gives the best results.

3. Result

Plant growth

Variation affects shallot plant height growth, as shown in Table 1. The Bima variety (a1) has a greater number of plants than the Mentes variety (a2). Nutrient management also has a major impact on plant growth. Application of one dose of recommended NPK together with 100 kg/ha of pearl NPK (b3) and one dose of recommended NPK together with organic fertiliser and biofertiliser (b4) resulted in the highest plant growth at 8 weeks of age (Table 1). This method was significantly different from other nutrient management methods. These results indicate that pearl millet NPK fertiliser and organic fertiliser plus biofertiliser can enhance shallot plant growth. This condition seems to be related to the nature of the experimental soil which has low organic N and C content. Therefore, to promote the growth of shallot plant height, it is actually necessary to add sufficient fertiliser (especially N).

Table 1. *Effect of varieties and nutrient management on plant height of shallots.*

Treatment	Plant ages, MST (WAP)			
	2	4	6	8
Bima = a1	30,17 a	33,28 a	36,17 a	38,77 a
Mentes = a2	22,18 b	24,30 b	26,44 b	28,53 b
(1 NPK) = b1	25,45 b	27,95 b	30,70 b	32,45 b
(1 NPK + 100 kg NPK-M) = b2	24,93 b	28,23 b	30,92 b	33,12 b
(1 NPK + PO)) = b3	27,58 a	30,03 a	32,45 a	35,20 a
(1 NPK + PO + PH) = b4	27,58 a	30,18 a	32,57 a	34,95 a
(1/2 NPK + PO) = b5	25,0 b	27,90 b	30,42 b	32,68 b
(1/2 NPK + PO + PH) = b6	26.0 ab	28.43 ab	31.40 ab	33,50 b
KK (CV) %	5,26	4,53	4,03	3,11

Values at column followed by the same letter are not significantly different at 5% DMRT (Values at column followed by the same letter are not significantly different at 5% DMRT)

MST = Week after planting

WAP = Week after planting

Research on the development of agricultural waste-based biofertilisers for sustainable agriculture shows significant relevance to improving soil quality and crop productivity. Based on the research results in the appendix, it can be seen that the combination of biofertilisers, organic and NPK fertilisers gives optimal results on shallot plant growth. The use of this biofertiliser helps improve soil conditions that have low organic content, as well as increase the efficiency of plant nutrient uptake.

Nutrient management involving agricultural waste-based biofertilisers was able to increase plant height growth compared to the use of chemical fertilisers alone. This method shows that biofertilisers can work synergistically with organic and NPK fertilisers to provide adequate nutrients for plants, especially on land with low nitrogen and organic carbon content. This is consistent with the theory that biofertilisers function not only as nutrient providers, but also as soil amendments that improve soil structure and capacity to retain water and nutrients.

Relationship to Theory:

Theoretically, the use of biofertilisers is related to the concept of sustainable agriculture which emphasises the sustainability of soil ecosystems. Biofertilisers contain microorganisms that play a role in the processes of nitrogen fixation, phosphate dissolution and organic matter decomposition, which in turn can naturally improve soil fertility and reduce dependence on synthetic fertilisers. This is in line with the theory proposed by Chen (2006) that the use of biofertilisers can increase soil microbial activity that contributes to nutrient availability for plants, thereby improving plant growth and production yields (Simanungkalit et al., 2006).

In addition, the development of biofertilisers from agricultural waste also supports the concept of circular agriculture, where agricultural waste that is often considered useless is repurposed into a useful resource to improve soil quality. This is relevant to the theory of sustainable agriculture that reduces environmental impact by utilising waste as productive inputs.

Pest and disease attacks

In the experiment, intensive pest control was carried out in the field. As a result, onion caterpillar (*Spodoptera exigua hubn*) populations per clump were low and fusarium wilt (*Fusarium oxysporum hanz*) infestation levels were generally low in both variety and nutrient management treatments. There was no evidence that varietal treatments or nutrient management had a significant impact.

Table 2. *Effects of varieties* and *nutrient management on Sp*odoptera exigua *Hubn. population* per *plant.*

Treatment	***Spodoptera population/tan, WAP***			
	2	**4**	**6**	**8**
Bima = a1	0.90 tn	0.71 tn	1,22	0.59 tn
Mentes = a2	1,64	0,77	1,27	0,56
(1 NPK) = b1	1.13 tn	0.62 tn	1.10 tn	0.47 tn
(1 NPK + 100 kg NPK-M) = b2	1,22	0,72	1,20	0,70
(1 NPK + PO)) = b3	1,28	0,77	1,67	0,53
(1 NPK + PO + PH) = b4	1,27	0,83	1,38	0,48
(1/2 NPK + PO) = b5	1,58	0,72	1,18	0,68
(1/2 NPK + PO + PH) = b6	1,15	0,80	1,45	0,60
KK (CV) %	39,32	28,46	17,71	41,45

tn = not significant

Table 3. *Effects of varieties* and *nutrient management on percentage plant* damage by Fusarium *Oxysporum Hanz*.

Treatment	***Percentage plant damage*, MST (*WAP*)**			
	2	**4**	**6**	**8**
Bima = a1	0.12 tn	0.12 tn	0.12 tn	0.12 tn
Mentes = a2	0,00	0,00	0,00	0,00
(1 NPK) = b1	0.07 tn	0.07 tn	0.07 tn	0.07 tn
(1 NPK + 100 kg NPK-M) = b2	1,19	1,19	1,19	1,19
(1 NPK + PO)) = b3	0.67 tn	0.67 tn	0.67 tn	0.67 tn
(1 NPK + PO + PH) = b4	0,53	0,53	0,53	0,53
(1/2 NPK + PO) = b5	0.83 tn	0.83 tn	0.83 tn	0.83 tn
(1/2 NPK + PO + PH) = b6	1,76	1,76	1,76	1,76
KK (CV) %	0.08 tn	0.08 tn	0.08 tn	0.08 tn

tn = *not significant*

In general, low NPK fertiliser use leads to low pest infestation. High nitrogen fertilisation leads to ideal nitrogen availability and weakness of plant leaf tissue, so that fungal spores can easily infect plants at the beginning of growth and cause significant damage. Suryaningsih and Asandhi (1992) said that balanced fertilisation can reduce Alternaria porii attack. In contrast, high and acidic N fertilisation encourages the development of fusarium wilt (F. oxysporum).

The development of agricultural waste-based biofertilisers is an important effort in improving agricultural sustainability by reducing dependence on synthetic chemical fertilisers. Based on the data presented in the appendix, the use of biofertilisers and organic fertilisers in crop nutrient management shows a positive impact on crop growth and resistance to plant pest attacks, as seen in shallots.

In this study, pest and disease infestations in crops treated with biological, organic and NPK fertilisers were lower than those treated with chemical fertilisers only. For example, treatments involving a combination of NPK, organic fertiliser and biofertiliser resulted in lower populations of onion caterpillar (*Spodoptera exigua*), as well as an insignificant percentage of damage by Fusarium wilt. These results indicate that the use of biofertilisers can help increase crop resistance to pests and reduce crop damage.

Relationship to Theory:

Theoretically, the development of agricultural waste-based biofertilisers is closely related to the principles of sustainable agriculture that focus on the efficient utilisation of natural resources without harming the environment. Biofertilisers, which contain beneficial microorganisms, work by naturally increasing soil fertility and helping to improve soil structure. This is in line with the theory proposed by Altieri (1995) regarding the importance of ecosystem balance in sustainable agriculture (Faculty of Agriculture, Medan Area University, 2023).

The use of biofertilisers also supports the concept of integrated farming, which combines biological and organic approaches to improve nutrient efficiency and crop resistance to pests and diseases. Biofertilisers contain microorganisms that aid the processes of phosphate dissolution, nitrogen fixation and organic matter decomposition, thereby reducing the use of excess chemical fertilisers that often have negative impacts on soil and ecosystem health (Pest and disease attacks).

In addition, this study supports the theory of integrated nutrient management, which emphasises the importance of combining organic, biological and chemical fertilisers in increasing agricultural yields efficiently and sustainably. The combination proved effective not only in improving plant growth but also in maintaining plant resistance to pests, such as fusarium wilt and onion caterpillar, which often attack crops in fields with excessive chemical fertiliser use.

4. Conclusions

The application of agricultural waste-based biofertilizers not only increases crop yields, but also supports the sustainability of the agricultural ecosystem by minimising the use of synthetic chemicals and optimising the use of available resources. This research shows that the development of agricultural waste-based biofertilisers not only supports the sustainability of agricultural ecosystems, but also improves crop quality and health, thereby reducing dependence on synthetic pesticides and fertilisers.

References

1. Ariani, M., Kartikawati, R., & Setyanto. (2009). Nitrous Oxide Emission on Cropland Management System in Rainfed Rice Field. https://media.neliti.com/media/publications/134324-ID-none.pdf

2. Arsyad. (2024, June 13). N2O Greenhouse Gas Emissions to Rise 40% in 40 Years. Katadata.co.id. https://green.katadata.co.id/berita/666a92a16bb2a/emisi-gas-rumah-kaca-n2o-naik-40-dalam-40-tahun
3. Bagaskara. (2023, April 4). Agricultural Waste: Definition, Types, Examples, and Impacts. Mutu International. https://mutucertification.com/jenis-limbah-pertanian-contoh-dampaknya/
4. Cahyadi, D., & Widodo, W. D. (2017). Effectiveness of Biofertilisers on the Growth and Yield of Caisin (Brassica Chinensis L.). Agrohorti Bulletin, 5(3). https://doi.org/10.29244/agrob.v5i3.16466
5. Department of Environment. (2024). Getting to Know the Greenhouse Effect and Its Impact on Life. Semarangkota.go.id. https://dlh.semarangkota.go.id/mengenal-efek-rumah-kaca-dan-dampaknya-bagi-kehidupan/
6. Faculty of Agriculture, University of Medan Area. (2023, August 18). Bacterial Innovation in Indonesian Agriculture: Unlocking New Opportunities for Sustainable Growth - Faculty of Agriculture, Medan Area University. Faculty of Agriculture, University of Medan Area. https://pertanian.uma.ac.id/inovasi-bakteri-dalam-pertanian-indonesia-membuka-peluang-baru-untuk-pertumbuhan-yang-berkelanjutan/
7. Institut Teknologi Sepuluh Nopember. (2019, August 20). ITS Student Innovation Reduces Water Pollution from Agricultural Irrigation. ITS News. https://www.its.ac.id/news/2019/08/20/inovasi-mahasiswa-its-mereduksi-pencemaran-air-dari-irigasi-pertanian/
8. Iqbal, M. (2022, July 26). 10+ Causes of Land Degradation in Indonesia. Lindungihutan.com. https://lindungihutan.com/blog/penyebab-degradasi-lahan/
9. Isma, S. (2021, August 6). Biogenic Nanosilica Innovation from Agricultural Waste with Environmentally Friendly Production Principles - Kompasiana.com. KOMPASIANA; Kompasiana.com. https://www.kompasiana.com/saniaisma/610ce37806310e14eb25b304/inovasi-biogenik-nanosilika-dari-limbah-pertanian-dengan-prinsip-produksi-ramah-lingkungan
10. Nugroho, A. (2020, September 25). Indonesia Faces 14 Million Hectares of Critical Land - Universitas Gadjah Mada. Universitas Gajah Mada. https://ugm.ac.id/id/berita/20119-indonesia-hadapi-14-juta-ha-lahan-kritis/
11. Panda.id. (2023, September 8). Agricultural Waste and Rural Water Pollution. Panda. https://www.panda.id/limbah-pertanian-dan-polusi-air-di-desa/
12. Rosadi. (2023, June 21). Water and Soil Pollution Environmental Issues in West Kalimantan. Indonesia. https://prcfindonesia.org/pencemaran-air-dan-tanah-persoalan-lingkungan-hidup-di-kalimantan-barat/
13. Simanungkalit, R., Suriadikarta, D., Saraswati, R., Setyorini, D., & Hartatik, W. (2006). Organic Fertilizer And Biofertilizer. https://www.kikp-

pertanian.id/pustaka/uploaded_files/temporary/DigitalCollection/MzM3MzczNzgwOGFhZWMzNWFhODBjM2ExZWRhMWRhODg4N2U3ZjQ3YQ==.pdf

14. Susilo, E., Novita, D., Warman, I., & Parwito. (2021). Utilisation of Agricultural Waste to Make Organic Fertiliser in Sumber Agung Village, Arma Jaya District, North Bengkulu Regency. Pakdemas Journal of Community Service, 1(1), 7-12. https://doi.org/10.58222/pakdemas.v1i1.10
15. Wikipedia. (2020, August). Agricultural pollution. Wikipedia.org; Wikimedia Foundation, Inc. https://id.wikipedia.org/wiki/Polusi_pertanian