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Substitution of Chemical Fertilizer with Organic MOL Fertilizer to Increase Crop Productivity

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ABSTRACT: Agriculture in Indonesia faces major challenges in terms of sustainability and productivity, especially with the high dependence on chemical fertilizers that can damage the soil in the long run. This study aims to determine the impact of chemical fertilizer substitution with MOL organic fertilizer on rice productivity in Village X, East Java. This research used a quantitative approach with a comparative case study. Data were collected during one rice growing season from two treatment groups using different fertilizers. Primary data were obtained through field observation, direct measurement, and sample analysis, while secondary data were collected from village reports and previous studies. Data analysis was conducted using descriptive statistics and Structural Equation Modeling (SEM). The results showed that chemical fertilizer increased rice productivity higher in the short term than MOL organic fertilizer. Independent T-test results showed significant differences, with chemical fertilizers producing significantly higher yields (t-value 12.45, p-value 2.306). However, the use of chemical fertilizers negatively impacts soil quality and the environment in the long run. In contrast, MOL organic fertilizer improved soil quality despite lower yields. SEM analysis showed that the substitution of chemical fertilizer with MOL organic fertilizer had a significant effect but with a smaller estimated coefficient compared to the use of chemical fertilizer. MOL organic fertilizer provides long-term benefits by improving soil fertility so that to achieve high production and protect the environment, a combination of using chemical fertilizers at optimal doses and gradually using organic fertilizers is highly recommended to support sustainable agriculture.

Keywords: Plant Productivity, MOL Organic Fertilizer, Chemical Fertilizer, Plant Growth

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INTRODUCTION

In this modern era, agricultural sustainability is becoming an increasingly urgent issue to address. One effective approach to achieving such sustainability is to optimize crop productivity through the substitution of chemical fertilizers with organic fertilizers. Chemical fertilizers, while providing quick results, often have long-term negative impacts on the environment and soil health. In contrast, organic fertilizers offer a more environmentally friendly and sustainable solution (Gamage et al., 2023). In this context, the importance of transitioning from chemical fertilizers to MOL organic fertilizers is becoming increasingly relevant, given the need to maintain soil health, the environment, and crop productivity in the long term. Optimizing the use of organic fertilizers is not just an option, but a strategic step towards healthier and more sustainable agriculture. As the world pays increasing attention to environmental and sustainability issues, the agricultural sector faces a major challenge in maintaining productivity while reducing negative impacts on ecosystems (Nhemachena et al., 2020). The rapid increase in the global population and the growing need for food are forcing farmers and researchers to look for more environmentally friendly farming methods. One solution that is increasingly being considered is the use of MOL organic fertilizers as an alternative to chemical fertilizers (Mansyur et al., 2021). The solution is expected to not only increase crop productivity but also maintain soil health and reduce environmental pollution.

Based on data from Sarwani (2023), world fertilizer consumption continues to increase, in 2021 reaching 199.88 million tons and subsidized fertilizer consumption in Indonesia for the 2018-2021 period is 8.73 million tons/year, for urea fertilizer 3.89 million, NPK 2.60 million, ZA 0.88 million, SP-36 0.69 million, and organic 0.66 million tons. The minimum need for subsidized fertilizers in Indonesia is around 8-9 million tons/year. This increase in the amount of fertilizer use is certainly accompanied by various negative impacts on the environment. Chemical fertilizers have long been a mainstay in increasing agricultural yields. However, their excessive use often causes various environmental problems such as soil degradation, water pollution, and greenhouse gas emissions. On the other hand, the global organic fertilizer market is expected to grow at a CAGR of 7.6% from 2021 to 2028 (Exactitude Consultancy, 2023). This reflects the growing interest in sustainable agricultural practices. Research in various countries, including India, Brazil, and several countries in Europe, shows that the use of organic fertilizers can increase crop yields by up to 30% compared to conventional methods while reducing greenhouse gas emissions and improving soil health. MOL organic fertilizers offer more sustainable benefits (Ayilara et al., 2020). In addition to increasing soil fertility, MOL organic fertilizers also play a role in improving soil structure and increasing water retention capacity (Aulia et al., 2024). Thus, the substitution of chemical fertilizers with organic fertilizers is a very relevant topic to achieve sustainable agriculture.

According to data from the Indonesian Fertilizer Producers Association (APPI), from 2017 to 2022 the use of fertilizers in Indonesia ranged from 10 to 11

million tons per year, which was dominated by urea, SP-36, ZA, and NPK fertilizers, but the use of organic fertilizers was only about 5% of the total fertilizer use. A principal expert researcher from the Horticulture and Plantation Research Center of the National Research and Innovation Agency (BRIN) pointed out that organic fertilizers can be used to restore agricultural land with declining organic matter content. However, only about 29 percent of agricultural land has an organic matter content of two to three percent and only six percent of agricultural land contains organic matter above three percent. So farmers need to understand related to optimizing crop productivity through the substitution of chemical fertilizers with organic fertilizers which will have a direct impact on plant growth (Verma et al., 2020). To increase plant productivity through the substitution of chemical fertilizers with MOL organic fertilizers, several problems need to be identified and analyzed in depth. In Indonesia itself, the availability of raw materials for making organic fertilizers is often a challenge and obstacle, especially on a large scale. In addition, switching from the use of chemical fertilizers to organic fertilizers can have significant economic implications for farmers. The higher initial cost of organic fertilizers, as well as potential changes in crop yields, require in-depth economic analysis to determine the feasibility and long-term benefits to farmers, and farmers' acceptance and knowledge of organic fertilizer use are key factors in successful implementation. The use of organic fertilizers must be integrated with other sustainable agricultural practices to maximize their benefits (Selim, 2020).

Research on the substitution of chemical fertilizers with organic fertilizers to optimize crop productivity has grown rapidly in recent years. Recent studies have shown that organic fertilizers are not only able to match the yields achieved by chemical fertilizers but can also improve soil quality and overall plant health. Research by Chivenge et al (2020) found that organic fertilizer application significantly improved soil microbial activity and long-term fertility. In addition, a meta-analysis by Liu et al (2021) revealed that the combination of organic and chemical fertilizers provided higher crop yields than the use of chemical fertilizers alone which reflects the great potential of the integrative approach of these two fertilizers. Organic fertilizers are widely recognized to have a lower environmental impact than chemical fertilizers. Research by Gattinger et al (2020) found that the use of organic fertilizers can reduce greenhouse gas emissions by up to 20% compared to chemical fertilizers. However, research on optimizing crop productivity through the substitution of chemical fertilizers with organic fertilizers that have an impact on plant growth has not been widely carried out so this study aims to assess the effectiveness of substituting chemical fertilizers with organic fertilizers to increase crop productivity and agricultural sustainability through the identification of optimal types and methods of organic fertilizers, evaluation of economic impacts that include costs, benefits, and the role of government subsidies and incentives, and assessment of environmental impacts on greenhouse gas emissions, soil biodiversity, and water and soil quality. In addition, the research focuses on measuring farmers' acceptance and knowledge of organic fertilizers and barriers to adoption, while identifying the need for effective training and

extension programs. This research offers a comprehensive and sustainable solution to the challenges of modern agriculture by reducing reliance on chemical fertilizers that have negative environmental impacts, such as soil and water pollution, and greenhouse gas emissions. The use of organic fertilizers is expected to improve soil structure and fertility, increase microbial activity, and maintain long-term soil health while providing economic benefits through increased crop yields and reduced production costs.

THEORITICAL REVIEW

Corp Productivity

Crop productivity is the result of efforts to optimize the ability of plants to produce maximum yields under given conditions (Kapoor et al., 2020). Optimizing crop productivity involves strategies such as the use of appropriate fertilizers, efficient water management, and the selection of crop varieties that are suitable for the environmental conditions in which the crop grows. In addition, good cultivation techniques, effective pest and disease control, and the implementation of sustainable agricultural practices also play an important role in increasing crop productivity (Siregar, 2023). In the context of modern agriculture, attention to these factors helps farmers not only increase crop yields quantitatively but also improve the quality of the products produced (Hanani et al., 2023). To optimize crop productivity, the use of chemical fertilizer substitution with organic fertilizer is one of the attractive strategies. Organic fertilizers not only improve soil structure and nutrient balance but also reduce negative impacts on the environment and human health (Sagitarini et al., 2023). By integrating this approach, farmers can stimulate plant growth naturally and minimize dependence on synthetic chemicals that tend to have short-term effects.

Chemical Fertilizers

Chemical fertilizers are artificial products created to provide essential nutrients to plants quickly and efficiently (Pahalvi et al., 2021) which usually consist of a mixture of chemical compounds containing nitrogen (N), phosphorus (P), potassium (K), and other nutrients such as magnesium, sulfur, and other important microelements. Chemical fertilizers are designed to be easily soluble in water so that the nutrients can be directly absorbed by the plant through the roots and immediately used for plant growth and development. The main advantage of chemical fertilizers is their ability to provide a rapid response in increasing the availability of plant nutrients, which are often indispensable to support optimal growth, increased crop yields, and efficient management of planting time (Suntari et al., 2021). While providing significant benefits in increasing agricultural productivity, the use of chemical fertilizers also has some considerations. Excessive use or inappropriate types can cause environmental problems, such as groundwater pollution and soil degradation. Therefore, wise use of chemical fertilizers involves careful monitoring of crop needs as well as selection of the right dosage according to soil conditions and the type of crop being grown (Sundram et al., 2019). In addition, to achieve sustainable agriculture, the combination of

environmentally friendly cultivation techniques and the application of good crop rotation are also important factors to consider (Wardiman et al., 2024).

MOL Organic Fertilizers

Local microorganism organic fertilizer (MOL) is a natural and sustainable solution used in agriculture to improve soil fertility and plant health. MOL is a liquid fertilizer made from natural ingredients that contain beneficial local microorganisms (Durán-Lara et al., 2020). These microorganisms play an important role in the decomposition of organic matter in the soil, helping to improve nutrient content and soil structure. MOL is usually made from ingredients such as coconut water, stale rice, brown sugar, and rotten fruits that are fermented together to produce a liquid fertilizer rich in microorganisms. The process of making MOL involves anaerobic fermentation, where the ingredients are left to ferment in a closed container for several weeks. During the fermentation process, local microorganisms multiply and produce enzymes that help break down organic matter into nutrients that are more easily absorbed by plants. One of the main advantages of MOL is its ability to increase soil biological activity. The microorganisms in MOL help accelerate the decomposition process of organic matter, thereby increasing the availability of nutrients for plants. In addition, these microorganisms also help in the absorption of nutrients by plant roots, increase plant resistance to disease, and improve crop quality (Timsina, 2018). Regular use of MOL can improve damaged soil structure, increase the soil's capacity to hold water and reduce the need for synthetic chemical fertilizers that can damage the environment. MOL is also environmentally friendly because it uses natural ingredients that are easily available and cheap, making it a more sustainable option compared to chemical fertilizers.

Local microorganism organic fertilizer (MOL) plays an important role in increasing crop productivity through several key mechanisms. MOL contains a variety of beneficial microorganisms, such as bacteria, fungi, and actinomycetes, which play a role in improving soil fertility and plant health (Parwito et al., 2024). These microorganisms work synergistically to improve soil structure, increase nutrient availability, and protect plants from pathogens. Microorganisms in MOL help accelerate the decomposition of organic matter into simpler forms that are easily absorbed by plants. This process produces humus that is rich in essential nutrients such as nitrogen, phosphorus, and potassium, all of which are essential for plant growth (Maghfoer et al., 2018). Thus, the soil becomes more fertile and can provide the nutrients needed for plants to grow properly. This increased nutrient availability directly impacts the increase in crop productivity. The application of MOL in agriculture also supports a sustainable agriculture approach that reduces dependence on synthetic chemical fertilizers. Chemical fertilizers often only provide macronutrients such as nitrogen, phosphorus, and potassium, but do not improve soil structure or enhance soil biological activity. In contrast, MOLs offer a holistic solution by improving overall soil health. With the reduced use

of chemical fertilizers, the risk of environmental pollution can be minimized, and the balance of the ecosystem can be maintained.

Plant Growth

Plant growth is a complex process that includes an increase in the size and number of plant cells and the formation of new tissues that support overall plant growth and development. This process is influenced by several key factors such as nutrients, water, sunlight, temperature, and other environmental conditions. Nutrients that include essential elements such as nitrogen, phosphorus, and potassium are essential in providing raw materials for the formation of proteins, DNA, and energy metabolism in plants. Water is needed for nutrient transportation and photosynthesis, while sunlight is needed as an energy source for the photosynthesis process that produces glucose as fuel for growth (Ginting, 2019). In addition to these factors, plant hormones such as auxin, gibberellin, cytokinin, ethylene, and abscisic acid also play an important role in regulating plant growth (Ali et al., 2020). These hormones control processes such as cell elongation, cell division, flowering, fertilization, as well as responses to environmental stress. Environmental conditions such as air humidity, soil pH, and the presence of pathogens and pests can also significantly affect plant growth. In agricultural practice, an in-depth understanding of all these factors is required to optimize growing conditions that support healthy and productive plant growth (Hanani et al, 2023).

METHODOLOGY

This research used a quantitative method with a comparative case study approach on farmland in one of the villages in East Java Province, which is one of the largest rice production areas in Indonesia (Data Box, 2023). Data collection was conducted during one rice growing season. Data collected included fertilizer use (type, amount), crop productivity, and yield. The researcher compared two fields with the same planting period and seedlings but with different fertilizers. This research uses a comprehensive approach by combining primary and secondary data to analyze the impact of chemical fertilizer substitution with organic fertilizer on rice plant growth in X Village. Primary data was obtained directly from the field through a series of methods that included observation, direct measurement, and sample analysis. Field observations were conducted to monitor the growth conditions of rice plants in detail, including plant height, and seed weight per hectare. Secondary data were collected from various credible sources to complement and strengthen the analysis. Data from village offices provided basic information on the total number of farmers, farm size, amount of subsidized fertilizer use, and rice productivity statistics. Previous reports and studies were important references for understanding previous trends and findings related to fertilizer use. Data analysis was conducted using quantitative methods with the help of Structural Equation Modeling (SEM). This approach was chosen to capture complex models with multiple variables and relationship pathways between variables.

RESULTS

Based on the research conducted during the cropping period, the distribution of yield data in Table 1 illustrates the main descriptive statistics for each treatment group on the fertilizer used. Table 1 provides a comprehensive picture of the distribution and variation of yield between MOL organic fertilizer and chemical fertilizer, and provides important information for further analysis of performance differences between the two types of fertilizers in the context of crop productivity.

Table 1. Yield Data Distribution Table

Lands	Fertilizer Type	Yield (Ton/Hectare)	Description
1	Chemistry	5.6	High productivity, declining soil quality
2	Chemistry	5.4	
3	Chemistry	5.5	
4	Chemistry	5.3	
5	Chemistry	5.7	
6	MOL Organic	4.1	Improvements in soil quality seen, low yields
7	MOL Organic	4.3	
8	MOL Organic	4.2	
9	MOL Organic	4.0	
10	MOL Organic	4.4	

Source: Data Processing Results (2024)

Based on the data in Table 1, it was found that the substitution of chemical fertilizers with MOL organic fertilizers has not been able to significantly increase rice plant production beyond the use of chemical fertilizers. The results of observations during one growing season showed that the productivity of rice plants using MOL organic fertilizer was slightly lower than that of land using chemical fertilizers.

Table 1. Average Yield

Fertilizer Type	Average Yield (tons/hectare)	Standard Deviation	Sample Quantity
Chemical	5.5	0.16	5
MOL Organic	4.2	0.17	5

Source: Data Processing Results (2024)

Based on Table 2, it can be seen that the descriptive statistics show that the average yield of chemical fertilizer is 5.5 tons/ha, higher than that of MOL organic fertilizer (4.2 tons/ha). However, the continuous use of chemical fertilizers can degrade soil quality in the long run. On the other hand, the use of MOL organic fertilizer showed better improvement in soil quality, although the yield was relatively lower in the short term. However, this difference was not statistically significant given the relatively similar range of standard deviations

between the two treatment groups (0.16 for chemical fertilizer and 0.17 for MOL organic fertilizer).

To determine whether there is a significant difference in average yield between the organic fertilizer and chemical fertilizer treatment groups, a Mean difference test (Independent T-test) was conducted with the results in Table 3.

Table 3. Independent T-test

Statistical Test	Value
t-value	12.45
Degree of Freedom	8
p-value	2.306

Source: Data Processing Results (2024)

Table 3. shows the results of the independent t-test analysis conducted to compare the average yields between the organic fertilizer and chemical fertilizer treatment groups. The t value (12.45) indicates that there is a significant difference between yields using chemical fertilizer and MOL organic fertilizer, with chemical fertilizer providing significantly higher yields. The degrees of freedom (df = 8) indicate the number of samples used in this analysis. The p-value (2.306) indicates that the observed difference was statistically significant at the 5% level of significance, so it can be seen that chemical fertilizer gave significantly higher yields compared to organic fertilizer in this study. However, it should be kept in mind that continuous use of chemical fertilizers can lead to environmental damage and sloping productivity in the long run, while MOL organic fertilizers provide long-term benefits for soil health and agricultural sustainability. These results can provide a strong basis for farmers or policymakers to consider the use of organic fertilizers as a more profitable alternative for sustainably increasing crop productivity.

To see the impact of chemical fertilizer use on growth, crop quality, and crop productivity, SEM tests were conducted with the results in Table 4 below.

Table 4. SEM Analysis on the Use of Chemical Fertilizers

Path	Estimate	p-value
Chemical Fertilizer -> Plant Height	0.50	< 0.01
Chemical Fertilizer -> Seed Weight per Hectare	0.60	< 0.01
Chemical Fertilizer -> Seed Yield Quality	0.45	< 0.01
Chemical Fertilizer -> Plant Productivity	0.55	< 0.01

Source: Data Processing Results (2024)

The analysis showed that the use of chemical fertilizers had a significant impact on plant growth and yield. The estimated coefficient of chemical fertilizer on plant height was 0.50 with a p-value < 0.01, indicating that any increase in chemical fertilizer use was associated with an increase in plant

height. In addition, the use of chemical fertilizers also increased seed weight per hectare with an estimated coefficient of 0.60 and p-value < 0.01, and improved seed yield quality with an estimated coefficient of 0.45 and p-value < 0.01, and the use of chemical fertilizers also had a significant effect on crop productivity with an estimated coefficient of 0.55 and p-value < 0.01. These results indicate that chemical fertilizers have a significant positive impact on plant height, seed weight per hectare, seed yield quality, and crop productivity.

To see the impact of chemical fertilizer substitution with organic fertilizer on plant growth and yield quality, SEM testing was conducted with the results in Table 5. The results of the analysis show that the substitution of chemical fertilizers with organic fertilizers has a significant impact on plant growth and yield. Path coefficient (β) analysis showed that the use of organic fertilizer had a positive effect on various crop yield variables. The path coefficient of organic fertilizer on plant height is 0.45 with a standard error of 0.08, which indicates that any increase in the use of organic fertilizer is associated with an increase in plant height. In addition, the use of organic fertilizer also increased seed weight per hectare with a path coefficient of 0.30 and a standard error of 0.06 and improved the quality of seed yield with a path coefficient of 0.25 and a standard error of 0.07. Overall, these results suggest that organic fertilizers are not only capable of replacing chemical fertilizers but also have the potential to significantly increase crop productivity and yield quality, supporting sustainable agriculture and soil ecosystem health.

Table 5. SEM Analysis of Chemical Fertilizer Substitution with Organic Fertilizer

Path	Estimate	p-value
Use of Organic Fertilizer -> Plant Height	0.30	< 0.05
Use of Organic Fertilizer -> Seed Weight per Hectare	0.25	< 0.05
Use of Organic Fertilizer -> Quality of Seed Yield	0.40	< 0.01
Use of Organic Fertilizer -> Plant Productivity	0.20	< 0.05

Source: Data Processing Results (2024)

These results provide a comprehensive picture of the complexity of the interaction between fertilizer types in increasing agricultural yields. It shows that the substitution of chemical fertilizer with organic fertilizer has a significant, but lower effect on increasing plant height than chemical fertilizer with an estimated coefficient of 0.30 and a p-value <0.05. In addition, the use of organic fertilizers also has a significant effect on seed weight per hectare and seed yield quality, but lower than chemical fertilizers with an estimated coefficient of 0.25, p-value < 0.05, and an estimate of 0.40, p-value < 0.01. The results of substituting chemical fertilizers with organic fertilizers also have a significant effect on overall plant productivity, but the effect is lower than chemical fertilizers with an estimated coefficient of 0.20 and p-value <0.05. These results indicate that organic fertilizers have not been able to increase crop production beyond chemical fertilizers in the short term. However, the continuous use of chemical fertilizers can cause damage to the environment,

such as soil degradation and water pollution. While chemical fertilizers show higher yields in terms of crop production in the short term, organic fertilizers offer significant long-term benefits for soil fertility and agricultural sustainability. Organic fertilizers can improve the physical, chemical, and biological properties of the soil, thereby increasing soil fertility. However, these positive results only become apparent over a relatively long period (more than 1 year), making them suitable for sustainable agriculture. Therefore, combining and rotating the use of chemical and organic fertilizers can be the best solution to achieve high production while maintaining environmental and soil health in the long run.

DISCUSSION

Based on the results of research conducted during the cropping period, data were obtained describing the comparison between the use of chemical fertilizers and MOL organic fertilizers on rice crop productivity in Village X, East Java with a focus on plant height, seed weight per hectare, seed yield quality, and crop productivity. The data analysis of various aspects of crop growth and yield provided in-depth insights into the impact of each type of fertilizer and its implications in the short and long term. Independent T-test results showed that there was a significant difference in yield between the two fertilizer types. The t-value of 12.45 and p-value of 2.306 (above the 5% significance level) indicates that chemical fertilizers gave significantly higher yields than MOL organic fertilizer. The use of chemical fertilizers does show a significant increase in productivity in the short term, however, it should be noted that soil quality degrades over time with continued use of chemical fertilizers. In contrast, MOL organic fertilizer showed an improvement in soil quality, despite lower yields in the short term.

In addition, the SEM analysis results of chemical fertilizer use had significant effects on plant height, seed weight per hectare, seed yield quality, and crop productivity with highly significant p-values (<0.01). The results of SEM analysis of the substitution of chemical fertilizers with organic fertilizers showed that the substitution of chemical fertilizers with organic fertilizers also had a significant effect on growth and yield variables where based on the estimated coefficient of 0.30 with a p-value <0.01, showed that the use of MOL organic fertilizer had a significant positive impact on plant height. The increase in plant height resulting from the substitution of the use of MOL organic fertilizer indicates that the nutrients contained in this fertilizer can be absorbed more effectively by plants (Sharma & Chetani, 2017). This MOL organic fertilizer provides macro and micronutrients in a form that is more accessible to plants (Dhaliwal et al., 2024). In addition, MOL organic fertilizers increase the activity of beneficial soil microorganisms, such as bacteria and fungi, which play a role in the decomposition of organic matter and the gradual release of nutrients. This helps to maintain long-term nutrient availability, which in turn supports better plant growth (Bergstrand, 2022).

The use of MOL organic fertilizer on plants does have a significant impact on plant growth and productivity, but the effect is lower than that of chemical fertilizers. This can be interpreted that organic fertilizers have not been able to

increase plant production beyond chemical fertilizers because the results of data processing for organic fertilizers show a positive estimated coefficient, but with a smaller value so that it can be seen that the increase in plant yield with organic fertilizers is slower and smaller than with chemical fertilizers. This result shows that chemical fertilizers still have an advantage in increasing crop production in the short term compared to organic fertilizers (Verma et al., 2020). This is reflected in the results of SEM analysis which showed that the use of chemical fertilizers had a significant effect on plant height, seed weight per hectare, seed yield quality, and plant productivity. However, although chemical fertilizers show higher yields, their long-term negative impact on the environment cannot be ignored. Chemical fertilizers, when applied in low doses, have little impact on production while excessive use of chemical fertilizers (at high doses) can damage the environment and increase costs (Pahalvi et al., 2021). In addition, it can also cause soil degradation and water pollution. Soil degradation occurs because chemical fertilizers tend to cause a decrease in soil organic matter and disrupt the balance of soil microorganisms that are important for long-term soil fertility. Water pollution occurs when chemical fertilizers that are not absorbed by plants leach into waterways, causing eutrophication that is detrimental to aquatic ecosystems.

In contrast, organic fertilizers offer more sustainable benefits, although the results are not as fast as chemical fertilizers. Organic fertilizers can improve the physical, chemical, and biological properties of the soil, which in turn increases soil fertility in the long run (Singh et al., 2020). Microorganisms in organic fertilizers help improve soil structure, increase water retention capacity, and support natural nutrient cycling (Liu et al., 2021). This makes the soil more fertile and able to better support plant growth in the long run. In addition, the use of organic fertilizers also helps reduce dependence on chemical fertilizers, which in turn reduces the risk of environmental degradation. However, the benefits of organic fertilizers cannot be seen in a short period. It can take more than a year to see significant improvements in soil fertility and crop yields (Cen et al., 2020). This may be one of the reasons why many farmers are still reluctant to switch completely to organic fertilizers. They may feel that they are in a hurry to increase crop yields in the short term without considering the long-term impacts on the soil and environment, making the use of organic fertilizers suitable for sustainable agriculture (Zhang et al., 2023). Sustainable agriculture aims to minimize negative impacts on the environment while still maintaining high productivity. In the long run, the use of organic fertilizers can help achieve this goal by improving soil fertility and reducing environmental pollution. It can also help maintain the health of agricultural ecosystems and support food security.

Therefore, there is a need to increase farmers' awareness and knowledge of the long-term benefits of organic fertilizers. In addition, to overcome this, it is necessary to apply a combination of chemical fertilizers and organic fertilizers so that crop productivity remains maximum with the application of chemical fertilizers at optimal doses (Iqbal et al., 2020), with the hope that the application of organic fertilizers can reduce the dose of chemical fertilizers without reducing production and preserving the environment so that farmers can use chemical

fertilizers at optimal doses while gradually switching to using organic fertilizers. The substitution of chemical fertilizers with organic fertilizers not only provides benefits in terms of increased crop yield and quality but also supports agricultural sustainability (Liu et al., 2021). Chemical fertilizers often have long-term negative impacts on the environment. In contrast, organic fertilizers support natural and sustainable nutrient cycling, increase soil biodiversity, and improve soil structure. By utilizing local resources such as crop residues and animal manure, farmers can reduce production costs and improve resource use efficiency. Integrated Nutrient Management (INM) theory supports this finding by emphasizing that the use of organic fertilizers can maximize nutrient use efficiency and increase crop yields in a sustainable manner (Nugroho et al., 2023). INM encompasses a holistic approach that incorporates multiple nutrient sources, both organic and inorganic, to meet crop nutrient requirements while maintaining soil and environmental health. Thus, the transition to organic fertilizer use is a strategic step that needs to be encouraged to achieve sustainable agriculture in the future.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the research conducted in Village X, East Java, it can be concluded that chemical fertilizer provides higher yields in the short term compared to MOL organic fertilizer. Independent T-test results showed a significant difference in yields between the two types of fertilizers, where chemical fertilizers had a t-value of 12.45 and a p-value of 2.306, indicating significantly higher yields than MOL organic fertilizers. However, the long-term use of chemical fertilizers has a negative impact on soil quality and the environment. Chemical fertilizers tend to cause a decrease in soil organic matter, disrupt the balance of soil microorganisms, and pollute water through fertilizer solutions that are not absorbed by plants. In contrast, MOL organic fertilizer improves soil quality despite lower yields in the short term. SEM analysis showed that chemical fertilizer use had a significant effect on plant height, seed weight per hectare, seed yield quality, and plant productivity. MOL organic fertilizer also showed significant positive effects on these variables but with smaller estimated coefficients. MOL organic fertilizer provides long-term benefits by improving soil fertility, supporting the activity of beneficial soil microorganisms, and maintaining long-term nutrient availability. Although their impact is slower and smaller compared to chemical fertilizers, organic fertilizers offer a sustainable solution for agriculture by improving the physical, chemical, and biological properties of the soil. So to achieve high crop production and maintain a healthy environment, a strategy that combines the use of chemical and organic fertilizers is needed. This approach allows the use of optimal doses of chemical fertilizers while gradually switching to organic fertilizers, which can help reduce dependence on chemical fertilizers and support sustainable agriculture.

So based on the results of this study, it is recommended to use a combination of chemical fertilizers at optimal doses and gradually replace them

with MOL organic fertilizers to achieve a balance between productivity and sustainability in rice farming in Indonesia.

FURTHER STUDY

The limitations of this study are that it was only conducted in one growing season and one location, namely Village X in East Java, so the results may not fully represent conditions in other locations or over a longer period. In addition, this study focused on several variables such as plant height, seed weight per hectare, seed yield quality, and crop productivity but did not consider other factors such as production costs, farmer revenue, and overall economic impact. In addition, measuring the long-term impact of organic fertilizer use on soil quality and productivity may require a longer period to provide more accurate results, so it is recommended for future research to conduct long-term studies that cover several growing seasons and in various locations to get a more comprehensive picture of the impact of chemical and organic fertilizer use. Research also needs to consider economic factors, such as cost and benefit analysis, as well as farmers' acceptance and perception of organic fertilizer use. In addition, further research can examine the interaction between organic fertilizers and soil microorganisms, and how the combination of chemical and organic fertilizers can be optimized to achieve sustainable production. Thus, the research results can be more useful for the development of efficient and environmentally friendly agricultural strategies.

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