



Research

Reducing chemical fertilizer dependency in cauliflower farming for economic sustainability

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ARTICLE HISTORY

Received:
06 September 2025

Revised:
28 November 2025

Accepted:
10 December 2025

Published:
15 December 2025

KEYWORDS

Chemical fertilizer;
Cost reduction;
Fertilizer efficiency;
Horticultural crops

ABSTRACT

The Fertilizer application is a crucial aspect of agricultural practices, especially for horticultural crops like cauliflower. Humbang Hasundutan Regency, a key horticultural hub in North Sumatra Province, has been significantly affected by rising chemical fertilizer costs, placing a financial strain on farmers. This study aimed to evaluate three fertilization strategies in terms of cost-efficiency, effectiveness, and their potential to reduce chemical fertilizer expenses. Using an experimental method, primary data were collected over one growing season to assess the efficiency and effectiveness of each experiment. Results showed that combining chemical and organic fertilizers improved cost-efficiency but did not enhance production effectiveness. Specifically, a 50:50 blend of chemical and organic fertilizers reduced fertilizer costs by IDR 1,468,400 per hectare. These findings indicate that incorporating organic fertilizers can be a viable approach for farmers to lower input costs and potentially improve farm sustainability.

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Citation (APA Style):

Juhandi, D., Elisabeth, J., Sumanto, N. L., Mabur, M., Nofriadi, N., Dithisari, I., Yunita, A., & Hutapea, W. Y. (2025). Reducing Chemical Fertilizer Dependency In Cauliflower Farming For Economic Sustainability. *Jambura Agribus. J.*, 7(1), 35-51.

DOI: <http://dx.doi.org/10.37046/jai.v7i1.34303>

INTRODUCTION

Farming is a comprehensive agricultural enterprise encompassing both on-farm and off-farm activities. This undertaking requires substantial input resources to generate outputs in the form of harvests. However, the cost of inputs required by farmers tends to be relatively high. In fact, input costs can account for approximately 60% to 80% of total farming expenses. Worldwide, fertilizer prices rose sharply in 2021 – 2022 (Balistreri et al., 2022). Therefore, the increase in

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fertilizer cost has led to a significant increase in farming cost (Alexander et al., 2022). Significant increases in fertilizer prices have resulted in higher production costs for farms, thereby reducing farmers' profit margins. Consequently, farmers have been compelled to curtail the application of fertilizer or defer its use, a practice that exerts a deleterious effect on both agricultural productivity and the quality of the produce. Moreover, the economic vulnerability of smallholder farmers is exacerbated by their inability to access affordable fertilizers, which has the potential to disrupt the sustainability of agricultural production systems.

Among input components, fertilizer represents a major share, contributing approximately 30% to 36% of total farm expenditures (J. Wang et al., 2024). Fertilizer is critical in ensuring optimal production and crop productivity. There are two main types of fertilizer commonly used by farmers: chemical fertilizers and organic fertilizers. Farmers tend to overuse chemical fertilizers relative to organic alternatives (Mutiarasari et al., 2022). This preference stems from the fact that chemical fertilizers often yield quicker results and provide more predictable returns (Liao et al., 2025). Farmers have a marked preference for chemical fertilizers, as evidenced by their rapid effect on plant growth and the fact that the results are more easily quantifiable. Furthermore, chemical fertilizers are regarded as more pragmatic due to their ease of application and accessibility. Additionally, they are characterized by precise dosages, which contributes to a reduction in the probability of production failure.

Chemical fertilizers offer readily available nutrients for plant absorption, have stable availability, and are convenient to apply (Velayudhan et al., 2021). Conversely, organic fertilizers take longer to deliver visible results (Tian et al., 2025). Despite the short-term benefits, the use of chemical fertilizers has been associated with environmental degradation. Intensive chemical fertilization has been shown to reduce soil quality (Apoorva & Kundlas, 2024), increase greenhouse gas emissions (Yan et al., 2023) and cause water pollution (Madjar et al., 2024). The improper use of chemical fertilizers has been demonstrated to have deleterious effects on soil quality and water quality due to the accumulation of nutrient residues that are not absorbed by plants. These impacts possess the potential to reduce biodiversity and disrupt the balance of the surrounding agricultural and aquatic ecosystems. In the long term, this condition poses a threat to the sustainability of agricultural production systems by reducing environmental carrying capacity and increasing dependence on external inputs.

Efforts to mitigate environmental damage from excessive chemical fertilizer use have been underway since the 1960s–1980s, particularly following the publication of *Silent Spring* by Rachel Carson in 1962. The use of organic fertilizers derived from plant residues and animal manure is one such effort to reduce dependence on chemical inputs. Nonetheless, completely

replacing chemical fertilizers with organic ones has not yet proven to be a viable option for achieving optimal crop yields.

Recent studies investigating the application of 100% organic fertilizers in farming have found that such experiments did not significantly differ from chemical fertilizers in terms of productivity, while also improving vegetable quality (Liu et al., 2025). However, those findings are limited by the challenge of scaling up to larger production systems, which would require localized optimization strategies. An earlier study conducted in 2020 found that fully organic fertilization significantly improved yields (Cen et al., 2020). However, that study focused exclusively on organic fertilizer use and did not offer a comparative analysis with chemical fertilizer use. Research comparing the use of chemical and organic fertilizers in farming is necessary to determine the effectiveness and efficiency of each fertilization system in terms of production and costs. This comparison provides a scientific basis for determining fertilization strategies that can reduce input costs without decreasing crop productivity. Moreover, the findings of this study contribute to the development of sustainable agricultural practices by taking into account the environmental impact and farmers' reliance on chemical fertilizers. Consequently, this comparative study serves as a pivotal reference for farmers and policymakers in formulating more economical and sustainable fertilization systems.

Humbang Hasundutan Regency, located in North Sumatra, is a key center of horticultural production because of based on Juhandi & Purba (2021) stated this regency is the region specializes in high-value horticultural commodities such as chili and shallots. Furthermore, the region has been targeted for the national *Food Estate* program, which emphasizes horticultural development, reinforcing the area's strategic potential for farming (Azhar & Hasnanda, 2022). Horticultural farming generally requires more fertilizer than other types of crops, such as food staples or plantation crops. On average, horticultural crops require between 500 and 1,000 kg/ha of NPK fertilizer (Hochmuth et al., 2018; Kusum et al., 2024). This highlights the intensive dependence of horticultural yields on fertilizer application. The cost burden has further increased due to significant fertilizer price hikes beginning in 2021 and peaking in 2022 (Vos et al., 2025). These rising costs have made it increasingly difficult for farmers to procure sufficient fertilizer. Moreover, access to subsidized chemical fertilizers remains limited to a select group of farmers, forcing others to forego fertilization altogether (Muluneh et al., 2022).

Several studies on the use of the latest chemical fertilizer show that their use can be reduced by using a combination of fertilizers. Hanifa et al. (2025) state that the use of chemical fertilizers can be significantly reduced through a combination of biochar and chemical fertilizers. In experiments on vegetable crops, the combination of these tow fertilizers was able

to improve soil fertility, yield and crop quality (Zhao et al., 2024). Previous studies conducted fertilization combination experiments to measure their effectiveness based on soil fertility, production, and crop quality alone. They did not discuss further how fertilization combinations could potentially reduce farming costs.

This study offers several novel contributions (a) applying experimental analysis to economic evaluation, which is typically used only for plant growth measurements, and (b) utilizing efficiency and effectiveness analyses to measure the potential for reducing chemical fertilizer use. Three fertilization experiments were tested: a single application of chemical fertilizer (CF), a combination of 75% chemical and 25% organic fertilizer (M1), and a 50:50 combination of chemical and organic fertilizers (M2). This study makes a significant contribution to the fields of agricultural science and agricultural economics by offering empirical evidence on the effectiveness and efficiency of integrated fertilization (a combination of chemical and organic fertilizers) in reducing farm production costs without compromising productivity.

Furthermore, this research contributes to the existing literature by employing a contextual approach that draws upon local resources, particularly the utilization of palm oil waste as a raw material for organic fertilizers. This subject is under-explored in the context of horticultural farming in Indonesia. Another significant contribution of this study is the integration of agricultural economic analysis with the technical aspects of fertilization. This integration provides a more comprehensive conceptual framework for the development of sustainable fertilization systems and decision-making at the farmer and policy-maker levels. The study aims to compare the cost-efficiency of each farming method, assess the effectiveness of each fertilization experiment, and calculate the potential cost savings from reduced chemical fertilizer usage.

METHOD

This study was conducted in Lintong Nihuta Subdistrict, Humbang Hasundutan Regency, North Sumatra Province. The selection of this location was based on previous research, which identified the area as a major horticultural production base Juhandi & Purba (2021). According to the recent data from BPS, this subdistrict is a central production area for cauliflower (BPS, 2024). The basic research method employed was experimental, comparing three fertilization experiments on cauliflower crops. The three fertilization experiments were: single application of chemical fertilizer (CF), a combination of 75% chemical fertilizer + 25% organic fertilizer (M1), and 50% chemical fertilizer + 50% organic fertilizer (M2). This fertilizer combination refers (Xiong & Zhao, 2024), because this combination can increase crop production by 20 – 30%. The trial was carried out from March to May 2025. During this period, the farming

activity yielded four harvests within a single growing season for cauliflower. Fertilization experiments used an area of 20 x 20 meters for each treatment with a plant spacing of 60 x 40 cm and rainfall of ~178 mm/day. The land area used in this study was 400 m² for each experiment. The potential yield for cauliflower is 17.23 tons/ha¹.

The data used consisted of primary data, including land area, production yield, fertilizer costs, labor costs, equipment costs, seed costs, and crop selling prices. Data were collected directly from farmers who participated in the experimental trials at the study site. The variables observed in this study included land area, production, productivity, cost efficiency, and fertilization effectiveness. The analyzed data was processed using Microsoft Excel software.

A preliminary survey was conducted in Lintong Nihuta Subdistrict at the study site, and consultations were held local farmers and village officials to assess fertilizer-related challenges. Based on the findings, an experimental design was established to evaluate various fertilizer application combinations on cauliflower crops. This study employs an experimental approach to analyze and compare the effectiveness and efficiency of different fertilization strategies. The research is designed to directly benefit farmers who have partnered with the research team since 2023. The expected contribution includes a balanced fertilization recommendation that supports both optimal yields and increased income.

Data Analysis

1) Cost efficiency

Cost efficiency was analyzed using the *Net Farm Income Percent* by dividing the total farm revenue by the total farm cost and multiplying by 100 percent, resulting in the following equation (Dartt et al., 1999):

$$NFI = \frac{TR}{TC} \times 100\%$$

Where:

NFI = Net Farm Income

TR = Total Revenue

TC = Total Cost

2) Fertilization effectiveness

Fertilization effectiveness was calculated using the *Capacity Utilization Rate* by dividing actual production by potential production and multiplying by 100 percent, resulting in the following equation (Lei et al., 2025):

¹ Based on product specification of seed brand

$$Ec = \frac{Qa}{Qp} \times 100\%$$

Where:

Ec = Effectiveness of production

Qa = Actual Production

Qp = Potential Production

The potential production of cauliflower used in this study was 17.23 tons/ha², while actual production was based on the harvest yields from the cultivation trials of the three fertilization experiments. The effectiveness criteria used were as follows: > 90% = very effective, 75–90% = effective, 50–75% = moderately effective, and < 50% = ineffective (L. Wang et al., 2024).

3) Reduction in chemical fertilizer costs

Potential reduction in chemical fertilizer costs was assessed using the *Marginal Revenue of Cost Efficiency (MREc)* equation, which measures the additional cost incurred for each additional unit of revenue. The equation used was as follows (Tolno et al., 2016).

$$MREc = \frac{\Delta TC}{\Delta TR} = \frac{TC_1 - TC_0}{TR_1 - TR_0}$$

where :

MREc = Marginal Revenue of Cost Efficiency

TC₁ = Total Cost of Farming with M1 and M2 Fertilization Experiments

TC₀ = Total Cost of Farming with CF Fertilization Experiment

TR₁ = Total Revenue of Farming with M1 and M2 Fertilization Experiments

TR₀ = Total Revenue of Farming with CF Fertilization Experiment

The subscript 0 refers to the baseline farming condition that typically uses the CF fertilization experiment. Subscript 1 refers to the experimental condition with M1 and M2 fertilization experiments. If the MREc value is less than 1, the experiment yields greater additional income compared to the additional fertilization cost. However, if the MREc value exceeds 1, the experiment has not yet yielded additional income greater than the additional cost incurred (Tolno et al., 2016).

RESULTS AND DISCUSSION

Comparing Farm Cost Efficiency

The input costs of cauliflower farming include seeds, labor, equipment, pesticides, and fertilizers. Table 1 presents a comparison of input costs across the three fertilization experiments. Among the five production inputs, the only variation observed was in fertilizer

² Based on product specification of seed brand

costs. The M1 fertilization experiment incurred the highest fertilizer cost at IDR 90,069, whereas the M2 experiment recorded the lowest fertilizer cost at IDR 59,470. The higher cost of the M1 experiment was due to relatively high distribution expenses for both chemical and organic fertilizers. In contrast, the M2 experiment incurred lower distribution costs because both 25% and 50% organic fertilizer applications shared similar distribution expenses.

Farming with a combination of 75% chemical fertilizer and 25% organic fertilizer results in higher costs due to the preponderance of chemical fertilizer, which is characterized by its relatively high cost and tendency to fluctuate in price. The utilization of substantial quantities of chemical fertilizers also enhances the necessity to procure inputs from the market, thereby rendering production costs more susceptible to price escalations. Conversely, a combination of 50% chemical fertilizer and 50% organic fertilizer has been demonstrated to significantly reduce dependence on chemical fertilizer, thereby reducing input costs and enhancing cost structure efficiency.

Table 1. Comparison of cauliflower farm production cost

Cost	Fertilizer experiment		
	CF	M1	M2
Seed	500,000	500,000	500,000
Labour	540,000	540,000	540,000
Equipment	1,086,000	1,086,000	1,086,000
Pesticide	635,000	635,000	635,000
Fertilizer	70,149	90,069	59,470
Total Cost	2,831,149	2,851,069	2,820,470

Source: data processed, 2025

The proportion of fertilizer cost to total input cost was 2.48% for the CF experiment, 3.16% for the M1 experiment, and 2.11% for the M2 experiment. The M1 experiment had the highest fertilizer cost share, consistent with findings from Biovision (2024), which identified high distribution costs as a key barrier to accessing organic fertilizer. However, this contrasts with Martey (2018), who reported that organic fertilization reduces costs. This discrepancy may stem from the source of organic fertilizer: in one case, it was purchased from a fertilizer store, while in the other, it was self-produced. The cost of fertilizer purchased from fertilizer stores is often higher due to the inclusion of distribution and transportation expenses, as well as the retailer's profit margin, in the price paid by farmers. Furthermore, the volatility of fertilizer prices in the market imposes a financial risk on farmers, who must anticipate price escalations during the planting season, a period marked by heightened demand.

Fertilization experiments also resulted in relatively different revenues. Revenues were based on the sale of four harvests during a single growing season, with the selling price set at IDR 3,500/kg. Based on revenue calculations from yield volume and price, Figure 1 illustrates the

comparison among the three experiments. The 50:50 combination experiment (M2) generated the highest revenue at IDR 281,575, while the CF experiment produced the lowest. The average land area owned by farmer is 800 – 1,200 m², therefore the potential income using the M2 experiment is IDR 563,150 – 844,725.

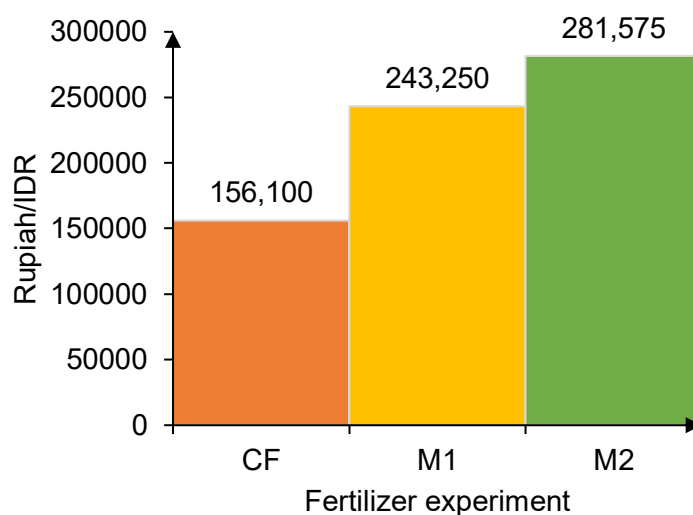


Figure 1. Comparison of revenue farming

Source: data processed, 2025

This revenue outcome aligns with previous research by Sahu et al. (2024), which found that organic farming yields 43.9% higher revenue compared to conventional (non-organic) farming. However, unlike this study, Sahu's research only compared two experiments (organic vs. non-organic), whereas this study compares three experiments. Additionally, Li et al. (2024) noted that organic fertilizers can significantly improve farmer revenue due to reduced input costs and enhanced efficiency (Kumar et al., 2024). The decrease in fertilizer cost stems from reduced dependence on chemical fertilizer (Wu et al., 2024). A reduction in the reliance on chemical fertilizers leads to a decrease in agricultural production costs, as costly inputs can be partially substituted by organic fertilizers derived from local resources. The substitution of chemical fertilizers with organic fertilizers has been demonstrated to enhance fertilization efficiency, thereby ensuring that the costs incurred by farmers are more aligned with the yields they obtain. A reduction in the proportion of chemical fertilizers has been demonstrated to reduce the risk of input price fluctuations, thereby increasing cost stability and agricultural sustainability.

Fertilizer costs and farming revenues were then used to calculate fertilization cost efficiency. This was determined by dividing revenue by total fertilizer cost. Figure 2 shows the results of this analysis. All experiments yielded efficiency values >100%, indicating that revenues

exceeded fertilizer costs (i.e., profitable). Among them, the M2 experiment yielded the highest fertilization cost efficiency.

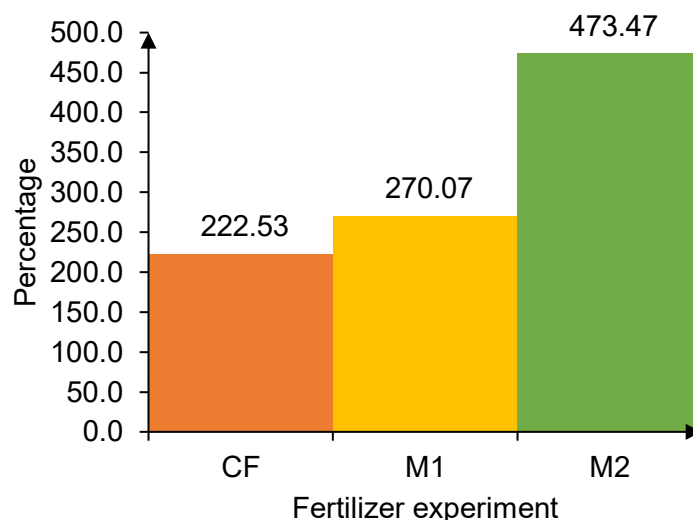


Figure 2. Comparison of fertilization cost efficiency

Source: data processed, 2025

These findings are consistent with Islam et al. (2019), who stated that organic fertilization improves efficiency due to a 50% reduction in input costs and a 30% increase in net profit. Similarly, Ederigbe et al. (2024) found that combining chemical and organic fertilizers yields higher economic efficiency. Several factors contribute to this improved efficiency, including increased soil fertility (Tian et al., 2025) and greater nutrient absorption (Wu et al., 2024). The utilization of organic fertilizers has been demonstrated to enhance agricultural efficiency by reducing production costs, thereby mitigating farmers' reliance on costly and subject to price volatility chemical fertilizers. Furthermore, the utilization of organic fertilizers derived from local resources can be accomplished at a reduced cost, thereby mitigating input expenses without compromising plant nutrient requirements. The application of organic fertilizers has been demonstrated to enhance the physical and chemical properties of soil, thereby increasing nutrient absorption efficiency. This, in turn, has a direct impact on production stability. The combination of reduced input costs and relatively stable production ultimately increases the profitability and sustainability of farming.

Comparing Fertilization Effectiveness

The potential yield for cauliflower is 17.23 tons/ha³. When converted to kg/m², the yield potential is 1.72–2.01 kg/m². Figure 3 shows the effectiveness of fertilization across the three experiments. The M2 experiment achieved the highest effectiveness rate at 11.55%, while the

³ Based on product specification of seed brand

CF experiment had the lowest at only 6.40%. However, none of the experiments met the effectiveness threshold of > 50% (L. Wang et al., 2024). The low productivity recorded at the study site was attributed to heavy rainfall during the harvest period. Rainfall in Lintong Nihuta ~178 mm/day⁴, which is classified as high rainfall. Weather played a significant role in suppressing production, highlighting the importance of using rain-tolerant cauliflower varieties (Rai & Kencho, 2024).

Rainfall exerts a direct influence on the yield and efficiency of cauliflower cultivation, as it determines the availability of water for vegetative growth and floral development. Excessive rainfall has been demonstrated to have deleterious effects on agricultural productivity, including the potential for increased incidence of flooding, which, in turn, can lead to an elevated risk of disease. These conditions have been shown to result in a decline in crop yields and a deterioration in cauliflower quality. Conversely, insufficient or uneven rainfall can induce water stress, which can impede crop formation and result in a reduction in yield weight. Consequently, the judicious balancing of rainfall with plant necessities emerges as a pivotal factor in sustaining optimal cauliflower productivity.

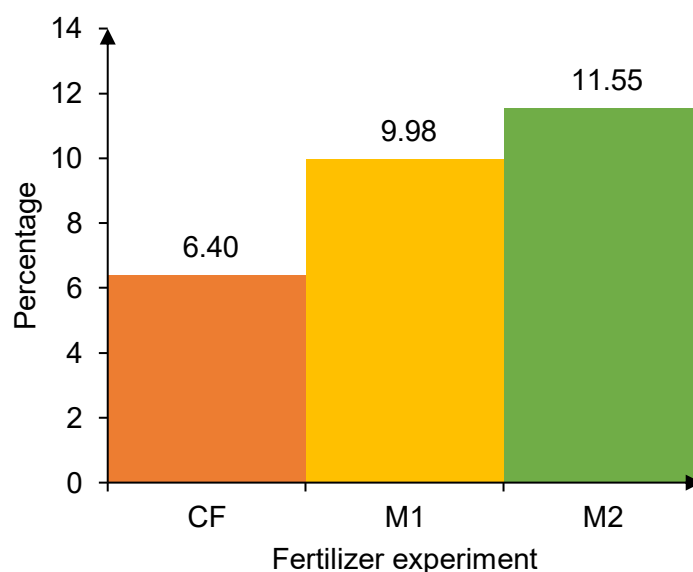


Figure 3. Comparison of farming effectiveness

Source: data processed, 2025

Fertilization effectiveness results correspond to cost efficiency results, with the M2 experiment achieving both the highest efficiency and effectiveness. These findings differ from those of J. Wang et al. (2024), who reported highest productivity and efficiency from a 20:80 ratio

⁴ Based on Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) Website <https://iklim.bmkg.go.id/id/food-estate-humbahas/>

experiment. The discrepancy likely stems from differences in crop types. Nonetheless, both studies support the conclusion that combining chemical and organic fertilizers offers greater effectiveness and efficiency than chemical fertilizers alone. Organic fertilizers also promote better early growth (Kai & Tamaki, 2020).

The combination of chemical and organic fertilizers provides a more balanced supply of nutrients, with chemical fertilizers meeting the need for readily available nutrients and organic fertilizers improving soil conditions and providing nutrients gradually. This approach has been demonstrated to enhance fertilizer use efficiency by mitigating nutrient loss and optimizing nutrient uptake by plants. Furthermore, the integration of organic fertilizers with chemical fertilizers has been demonstrated to curtail the reliance on chemical fertilizers, thereby effectuating a reduction in production costs. Maintaining or increasing production yields, coupled with reduced input costs, has led to the enhanced effectiveness and efficiency of integrated fertilization systems in comparison to the utilization of chemical fertilizers as a standalone practice.

While all three experiments demonstrated efficiency, none were effective, indicating that optimal farming conditions were not achieved. The effectiveness value of the M1 experiment is 6.4%, meaning that each IDR 100 spent only generates IDR 6.4 in revenue. The M2 experiment provides an effectiveness value of IDR 9.98 in revenue for each IDR 100 spent, and the M3 experiment provides an effectiveness value of IDR 11.55 in revenue for each IDR 100 spent. For farming to be considered optimal, it must reach an effectiveness level above 50%. Farmers can increase effectiveness by adopting Good Agricultural Practices (GAP), such as using appropriate technology (Saha et al., 2025), crop rotation (Jalli et al., 2021), and improved plant nutrition (Ren et al., 2020).

Good Agricultural Practices (GAP) are a system of cultivation principles and procedures aimed at producing safe, high-quality, and sustainable agricultural products. The implementation of GAP entails the judicious management of inputs, including the application of fertilizers and pesticides in accordance with recommended dosage and application time. Furthermore, GAP underscores the significance of soil, water, and environmental conservation to ensure the sustainability of agricultural resources. The implementation of GAP has been demonstrated to enhance agricultural productivity and efficiency, thereby ensuring adherence to food safety and environmental standards.

Calculating the Potential Reduction in Chemical Fertilizer Costs

The potential reduction in fertilizer costs was calculated using the Marginal Revenue of Cost Efficiency (MREc) approach, using CF experiment as the baseline. Table 2 shows that both

the M1 and M2 experiments had MREc values < 1, indicating that additional income from these experiments exceeded the additional fertilization costs. The M2 experiment had a higher MREc value of 0.085, meaning that every additional IDR 1 in cost yielded an additional IDR 1.085 in income, whereas M1 only yielded IDR 1,005.

Tabel 2. Comparing of MREc Values

Fertilizer experiment	MREc
M1	0.0005
M2	0.0851

Source: data processed, 2025

Both experiments met the efficiency criteria. A deeper analysis using CF as a baseline revealed that the M1 experiment reduced fertilization costs by IDR 49.19/m² (IDR 222.39 – IDR 173.21), while M2 reduced costs by IDR 26.37/m² (IDR 173.21 – IDR 146.84). When extrapolated to 1 hectare, M1 saves IDR 491,851.85/ha, and M2 saves IDR 263,679.01/ha. Farming efficiency in fertilization per unit of land area in cauliflower farming describes the ability of farmers to use fertilizer inputs optimally to produce maximum yields and income per hectare of land. Efficient fertilization is achieved when the dosage, type, and timing of fertilizer application are in line with crop requirements, so that each unit of fertilizer used can provide additional yields that are proportional to the costs incurred. In the context of cabbage cultivation, adequate fertilization per hectare is crucial for optimal crop formation and harvest weight. Conversely, excessive fertilizer use has been observed to increase costs without achieving substantial increases in yields. Consequently, fertilizer efficiency per unit of land area emerges as a pivotal metric for evaluating the efficacy of cabbage farming management in achieving cost reductions while sustaining productivity and profitability.

Table 1. Comparison of cauliflower farm production cost

Fertilizer experiment	Fertilizer cost	
	Per m ²	Per hectare
Seed	IDR 173.21	IDR 1,732,100
Labour	IDR 222.39	IDR 2,223,900
Equipment	IDR 146.84	IDR 1,468,400

Source: data processed, 2025

There are 472 farmers⁵ in the study area, each with an average land size of 0.5 ha⁶, totaling 236 ha in Desa Sipunjot. If all farmers adopt the M2 experiment, the total cost savings could reach IDR 346,542,400, or IDR 734,200 per farmer. Scaling this balanced fertilization model

⁵ Based on document of Desa Sipunjot Profile 2023

⁶ Based on average of land farmer in Indonesia 2023 (BPS Indonesia)

nationally, where there are 27,802,434 farmers⁷, could lead to savings of more than IDR 20.4 trillion. On a global trade scale, with Indonesia importing 5.37 million tons of fertilizer⁸, widespread adoption of balanced fertilization could reduce imports by nearly 50%. A reduction in the reliance on chemical fertilizers has the potential to diminish the necessity to import raw materials and finished fertilizers, which presently predominate in the national supply. The increased use of organic fertilizers derived from local resources has the potential to gradually mitigate the pressure on the trade balance, which is currently influenced by the importation of fertilizers. This contributes to foreign exchange savings and increases the resilience of the agricultural sector to global price fluctuations. Furthermore, the substitution of imported chemical fertilizers with domestic alternatives has been demonstrated to enhance the long-term autonomy of national agriculture.

CONCLUSION

Cauliflower farming using M1 and M2 fertilization experiments was found to be cost-efficient, though not yet effective in terms of production. However, the additional costs associated with both experiments generated greater increases in income. The M2 experiment demonstrated the highest efficiency and helped reduce dependence on chemical fertilizers by lowering input costs. It had the potential to reduce fertilizer expenses by IDR 1,468,400 per hectare. This study recommends that farmers adopt a balanced 50:50 chemical and organic fertilization approach to minimize input costs while maximizing yield. However, the study was limited to a single crop, and further research involving various horticultural crops is recommended for a more comprehensive analysis.

ACKNOWLEDGMENT

The authors express their gratitude to Politeknik Wilmar Bisnis Indonesia and Medan State Polytechnic for their collaboration in this research, sponsored by the Ministry of Education and Culture and the Ministry of Finance of the Republic of Indonesia. Special thanks also go to the local government of Humbang Hasundutan Regency, particularly the village of Siponjot, for serving as research partners. This study was funded by the Berdikari Partnership Catalyst Program – Strengthening Partnership Ecosystems for Innovation-Based Regional Development, under the Directorate General of Vocational Education, Ministry of Education and Culture, and the Indonesia Endowment Fund for Education (LPDP), Ministry of Finance, with contract numbers 3243/D6/DV.03.00/2024 and 3391/WBI/PP/12/2024.

⁷ Based on the number of farmers using agricultural land in Indonesia, 2023 (BPS Indonesia)

⁸ Based on Indonesia's fertilizer import data for 2023 (BPS Indonesia)

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