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Maggot Frass Fertilizer: Effects on Productivity and Economic Efficiency in Organic Vegetable Farming

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Abstract. Maggot frass fertilizer derived from larvae waste processing represents an innovative organic fertilizer with significant potential for supporting sustainable agriculture implementation, particularly in organic vegetable commodities. This study aimed to analyze the technical effectiveness of maggot frass fertilizer application in organic vegetable cultivation and examine the economic efficiency of farming systems in Panji Village, Buleleng, Bali. Results demonstrated that maggot frass fertilizer application technically increased crop productivity by 15%. The study design has been clarified as a cross-sectional descriptive field study. Quantitative methods are used for effectiveness evaluation and business feasibility analysis, employing the R/C ratio. an average effectiveness value of 76.33% based on criteria including yield achievement, cost planning, and application dose appropriateness. Regarding economic efficiency, maggot frass reduced fertilizer costs by 29.73% with R/C ratios of 2.6 (non-organic) and 3.7 (organic), indicating high business feasibility. These findings suggest that maggot frass represents not only an effective agronomic innovation but also constitutes part of a sustainable agricultural approach based on local resources and principles of the circular economy. Therefore, institutional strengthening and policy support are required to enhance broader and more sustainable adoption of maggot frass technology.

Keywords: maggot frass; circular economy; effectiveness; efficiency; organic agriculture

INTRODUCTION

The growing global population increases pressure on agriculture, especially for sustainable protein sources (Poveda, 2021). Insect farming, particularly using the Black Soldier Fly (Hermetia illucens), offers a solution by converting organic waste into two valuable products: protein-rich larvae for feed and frass as an organic fertilizer (Tanga et al., 2021; Beesigamukama et al., 2021; Terfa, 2021). Conventional farming in developing countries like Indonesia faces sustainability issues due to heavy reliance on inorganic fertilizers and high production costs. Around 73% of smallholder farmers struggle to access subsidized fertilizers, reducing land productivity (BPS, 2021). Therefore, BSF frass presents a promising, sustainable, and affordable alternative for local agricultural systems.

In addition to helpful macromolecules and microorganisms that can increase plant development and resilience to abiotic stress and disease, BSF frass includes macronutrients, including nitrogen (N), phosphorus (P), and potassium (K) (Beesigamukama et al., 2021; Tanga et al., 2021). In comparison to chemical fertilizers and traditional compost, it has been demonstrated that applying BSF frass to horticultural crops, maize, and tomatoes increases yield and nitrogen usage efficiency. (Terfa, 2021; Chavez et al., 2023).

The circular economy is promoted through the use of BSF frass, which turns organic waste into useful resources. A Cameroonian investigation by Tambeayuk et al. (2024) indicated that BSF frass can serve as a cost-effective alternative to inorganic fertilizers such as NPK and urea and is socially acceptable to urban farmers. Frass utilization supports food security and sustainable agriculture while boosting farmers' income—up to fifteen times higher than selling BSF larvae alone—especially when combined with inorganic fertilizers to

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improve yield and reduce costs (Beesigamukama et al., 2021; Tanga et al., 2021). Studies also show that BSF by-products enhance soil nutrient cycling and crop productivity (Ahuja et al., 2020).

In addition to being used as fertilizer, maggot feed from BSF farming also represents a potential alternative protein source for poultry and fish, with high nutritional content and competitive economic value (Batool et al., 2024; Nurindra et al., 2024). Rearing maggots using organic waste such as kitchen scraps and livestock manure has proven to be an efficient bioconversion pathway in a circular economy system that reduces waste volume and strengthens local feed self-sufficiency (Nurindra et al., 2024). In Indonesia, BSF farming provides significant ecological and socio-economic benefits, particularly in household waste management and microenterprise empowerment. Hanim et al. (2021) reported that BSF business development plays an important role in enhancing community economic resilience during the COVID-19 pandemic through job creation, waste reduction, and increased added value of local products.

BSF farming produces two valuable outputs: frass as organic fertilizer and maggot feed as an alternative protein source for livestock and fish, while efficiently converting organic waste into useful resources. This circular economy system enhances resource efficiency, reduces waste, and supports local economic empowerment (Hanim et al., 2021; Jupesta et al., 2025). It also contributes to food security, environmental sustainability, and several UN Sustainable Development Goals, including SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production) (Adamtey et al., 2020; Gram et al., 2020).

This study aims to evaluate the impact of maggot frass fertilizer on productivity and economic efficiency in organic farming systems by (1) assessing its effect on crop yield, (2) comparing its economic performance with organic and inorganic fertilizers, and (3) identifying the best application techniques to improve the sustainability and productivity of organic vegetable farming.

METHODS

The research was conducted in Panji Village, Sukasada District, Buleleng Regency, from November 2024 to January 2025. The research site was determined using a purposive sampling method with the following considerations: (1) Panji Village cultivates Black Soldier Fly (BSF) maggots by utilizing village organic waste; (2) the village has been certified as an organic farming area; and (3) no previous research has specifically examined the effectiveness of maggot frass fertilizer in supporting organic agriculture. This study employed a descriptive research design using both qualitative and quantitative data. Data were collected through structured interviews and questionnaires distributed to farmers actively involved in organic vegetable cultivation using maggot frass fertilizer. The sample was determined using a census approach, where all 30 farmers who met the criteria were included as respondents. The relatively small sample size was justified by the limited number of active organic farmers applying maggot frass in the study area, ensuring full population coverage and representativeness. Data were analyzed using descriptive quantitative analysis to measure effectiveness indicators and income analysis to assess the economic feasibility of maggot frass fertilizer application.

Effectiveness Analysis

An evaluation approach aimed at assessing the extent to which a program, policy, activity, or system successfully achieves predetermined targets or objectives. The effectiveness analysis formula is presented below:

% Effectiveness = (Average Score /

Classification criteria:

Effective: 67% – 100.00%

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Less Effective : 34% – 66.66%
Ineffective : 0% – 33.33%

Business Efficiency Analysis

A calculation method used to evaluate whether a business or project is financially viable by comparing total revenue with total costs incurred.

- Total Cost (TC)

$$TC = FC + VC$$

Where:
TC = Total Cost (Rp)
FC = Fixed Cost (Rp)
VC = Variable Cost (Rp)

- Total Revenue (TR)

$$TR = Q \times P$$

Where:
TR = Total Revenue (Rp)
Q = Production quantity (kg/unit)
P = Selling price per unit (Rp/kg)

- Business Income (π)

$$\pi = TR - TC$$

Where:
π = Net income (Rp)
TR = Total Revenue (Rp)
TC = Total Cost (Rp)

- B/C Ratio

$$B/C \text{ Ratio} = \pi/TC$$

Where:
$\pi/C > 1 \rightarrow$ Business is efficient and profitable (revenue exceeds costs)
$\pi/C = 1 \rightarrow$ Business breaks even (revenue equals costs, no profit or loss)
$\pi/C < 1 \rightarrow$ Business is inefficient and unprofitable (revenue is less than costs)

RESULTS AND DISCUSSION

Productivity Level Through Maggot Frass Fertilizer Effectiveness

Maggot frass fertilizer, as an innovation in organic agriculture, provides solutions to reduce dependence on chemical fertilizers and maximize organic waste management. Technical evaluation encompassing output achievement, such as increased crop productivity and improved soil physical properties, serves as a success indicator for this fertilizer application. Through program success indicators, targets, and satisfaction levels, this study aims to assess the actual impact of maggot frass fertilizer use on sustainable agricultural practices under various environmental conditions. The effectiveness of maggot frass fertilizer in Panji Village is presented in **Table 1**.

The overall effectiveness of 76.33% demonstrates that maggot frass fertilizer substantially contributes to organic agriculture goals in Panji Village. Farmers reported tangible benefits in yield improvement and soil quality, confirming findings by Susilowati & Purnamasari (2022) and Zahra et al., 2021 that maggot frass enhances soil fertility through its rich nutrient and microbial content. Technical efficiency indicators show farmers apply inputs according to cost planning and recommended dosages (Wardhana, 2023), aligning with agronomic principles emphasizing balanced input use for optimal productivity (Mahesti et al., 2025).

Despite high adoption rates exceeding 80%, program dissemination remains limited (43%), highlighting the need for institutional strengthening and broader access to technology (Yudiarini et al., 2024). These findings highlight the need for strengthened extension services and streamlined production systems to maximize technology adoption. Nevertheless, maggot frass embodies Low External Input Sustainable Agriculture (LEISA) principles and circular economy approaches (Handayani et al., 2022.,Nuryati and Supadi, 2015), positioning it as a strategic component for agricultural transformation toward greater farmer independence and climate resilience (Kurniawan & Dewi, 2021).

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Table 1 Effectiveness of Maggot Frass Fertilizer in Panji Village

No	Indicator	N	Mean Score (Scale 0–5)	SD	Percent of Maximum (%)	Classification
A. Overall Goal Achievement						**92.22**
1	Maggot frass fertilizer provides positive impact on farmers in organic agriculture	20	4.50	0.52	90.00	Effective
2	Maggot frass fertilizer use in organic agriculture aligns with planned objectives	20	4.58	0.51	91.67	Effective
3	Maggot frass fertilizer used by farmers improves agricultural effectiveness	20	4.75	0.44	95.00	Effective
B. Input and Output Level						**84.44**
1	Maggot frass fertilizer helps solve problems in organic agriculture	20	3.67	0.68	73.33	Effective
2	Maggot frass fertilizer produces good results in organic agriculture	20	4.75	0.44	95.00	Effective
3	Maggot frass fertilizer use aligns with cost calculations	20	4.25	0.55	85.00	Effective
C. Target Achievement						**83.89**
1	Maggot frass fertilizer is used by all farmers	20	3.58	0.69	71.67	Effective
2	Maggot frass fertilizer use fits its intended purpose	20	4.42	0.51	88.33	Effective
3	Maggot frass fertilizer increases farmer participation in organic agriculture	20	4.58	0.51	91.67	Effective
D. Program Success						**67.78**
1	Maggot frass fertilizer use continues sustainably	20	4.17	0.62	83.33	Effective
2	Maggot frass fertilizer use has been disseminated to the community	20	2.17	0.83	43.33	Less Effective
3	Maggot frass fertilizer use maximizes farmer income in organic agriculture	20	3.83	0.68	76.67	Effective
E. Program Satisfaction						**53.33**
1	Maggot frass fertilizer improves farmer satisfaction with results	20	3.75	0.64	75.00	Effective
2	Maggot frass fertilizer production is improved for easier use	20	2.17	0.83	43.33	Less Effective
3	Constraints during maggot frass fertilizer use	20	2.08	0.76	41.67	Less Effective
Average			**3.82**		**76.33**	

Source: Primary Data Processed, 2025

Notes:

- **N** = Number of respondents or observations (n = 20 in this study)
- **Mean Score (0–5)** derived from Likert-scale responses converted to average per indicator

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- **Percent of Maximum (%)** calculated as:
  Percent=Mean5×100\text{Percent} = \frac{\text{Mean}}{5} \times 100Percent=5Mean×100
- **SD** = Standard Deviation of individual indicator responses
- **Classification** based on percentage range (e.g., >80% = Effective; 60–80% = Moderate; <60% = Less Effective)

Table 2 Presents Economic Efficiency Comparisons Between Organic and Non-Organic Mustard Cultivation in Panji Village

Cost Component	Quantity	Unit	Price (Rp/Unit)	Organic Mustard (Maggot Frass)	Non-Organic Mustard
1. Fixed Costs					
a. Hoe depreciation	5	units	145,000	145,000	145,000
b. Rake depreciation	3	units	85,000	51,000	51,000
c. Trowel depreciation	3	units	55,000	33,000	33,000
d. Knife depreciation	5	units	35,000	35,000	35,000
e. Scale depreciation	2	units	200,000	80,000	80,000
Total Fixed Costs				344,000	344,000
2. Variable Costs					
a. Mustard seeds	200	grams	150	30,000	30,000
b. Fertilizers					
1. Maggot frass	800	kg	10,000	8,000,000	-
2. Urea	30	kg	5,200	-	156,000
3. ZA	30	kg	3,600	-	108,000
4. KCl	20	kg	6,000	-	120,000
c. Pesticides					
Organic pesticides (garlic extract, neem leaves, lemongrass, tobacco, coconut oil)	4	bottles	50,000	200,000	-
Insecticides	3	bottles	65,000	-	195,000
Fungicides	3	bottles	55,000	-	165,000
d. Labor					
1. Land preparation	2	HOK	100,000	200,000	200,000
2. Planting	3	HOK	100,000	300,000	300,000
3. Fertilizing	3	HOK	100,000	300,000	300,000
4. Spraying	2	HOK	100,000	200,000	200,000
5. Maintenance	4	HOK	100,000	400,000	400,000
6. Harvesting	4	HOK	100,000	400,000	400,000
f. Harvest baskets	10	units	20,000	150,000	150,000
Total Variable Costs				2,200,000	2,480,000
3. Total Production Costs				2,544,000	2,824,000
4. Total Revenue - Organic Mustard	755	kg	16,000	12,080,000	
Total Revenue - Non-Organic Mustard	775	kg	12,000		9,300,000
5. Income				9,536,000	6,476,000
6. B/C Ratio (Efficiency)				3.7	2.6

Source: Primary Data Processed, 2025

Economic Efficiency

Organic agriculture demands solutions to reduce dependence on chemical fertilizers and maintain soil fertility. Maggot frass fertilizer, derived from organic waste compost and maggot frass, offers agronomic benefits while reducing production costs. Economic efficiency evaluation is essential to

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ensure its use is financially beneficial. Economic efficiency is measured through revenue-to-cost ratios, expressed as Benefit Cost Ratio. B/C Ratio indicates feasible and profitable operations. Maggot frass fertilizer is expected to improve B/C Ratio by reducing chemical fertilizer costs and enhancing harvest yields sustainably. The following **Table 2** presents economic efficiency comparisons between organic and non-organic mustard cultivation in Panji Village.

Research results indicate that maggot frass fertilizer application in organic mustard cultivation affects production cost structures, making them higher compared to non-organic patterns (see **Table 2**, Total Production Costs row). This aligns with findings by Purba et al. (2019), who emphasized that organic inputs require larger application volumes to provide nutrients equivalent to chemical fertilizers, thus increasing variable costs. Variable cost components increase primarily due to large-scale maggot frass purchases and organic pesticide use, such as garlic extract, neem leaves, lemongrass, and tobacco, which are relatively expensive in local markets (Mahesti et al., 2025). Conversely, fixed costs for investment and equipment maintenance such as hoes, rakes, trowels, knives, and scales remain identical for both systems at Rp 344,000, supporting Susilowati & Purnamasari (2022) findings that fixed costs in small-scale horticultural farming tend to be stable. Total variable costs in organic cultivation with maggot frass recorded Rp 12,080,000, significantly higher than non-organic patterns at Rp 2,780,000, dominated by chemical fertilizer purchase costs. This finding aligns with Wardhana (2023) who noted that during initial organic input technology adoption phases, costs are indeed higher but balanced by long-term ecological benefits.

From revenue perspectives, organic mustard with maggot frass can be sold at higher prices (Rp 16,000/kg) compared to non-organic (Rp 12,000/kg), resulting in total organic revenue of Rp 12,080,000 exceeding non-organic revenue of Rp 9,300,000. This result supports Diyana et al.'s (2025) findings, demonstrating that organic products tend to have premium prices due to consumer perceptions regarding food safety and chemical residue-free products. Net income shows significant differences: organic cultivation with maggot frass generates margins of Rp 9,536,000, while non-organic generates Rp 6,476,000. These results support Hardjowigeno (2020), who identified high input costs and limited scale efficiency as key challenges in small-scale organic farming. The B/C Ratio values of 3.7 (organic) and 2.6 (non-organic) confirm both systems' financial viability (see **Table 2**, row 6) (Kurniawan & Dewi, 2021).

The linkage between effectiveness and efficiency becomes clearer when considering long-term sustainability. The high technical effectiveness scores for soil quality improvement (Dimension B: 84.44%) and alignment with cost planning (85%) indicate that maggot frass supports the Low External Input Sustainable Agriculture (LEISA) framework (Nuryati and Supadi, 2015). While current input costs are high, the circular economy model—utilizing village organic waste to produce fertilizer (Handayani et al., 2022)—suggests opportunities for cost reduction through local production systems. Furthermore, the 95% effectiveness score for goal achievement directly correlates with the premium market positioning that generates 33% higher prices, demonstrating how technical performance drives economic value.

However, relatively low values in organic systems indicate the need for cost control strategies and cultivation efficiency improvements. Thus, although short-term economic efficiency of maggot frass fertilizer is not yet optimal, its potential support for ecological sustainability, soil health improvement, and organic niche markets remains relevant for broader development. This research emphasizes the need for input cost reduction, production scale optimization, and market strengthening to make organic cultivation with maggot frass increasingly

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competitive and supportive of sustainable agriculture goals at local and national levels.

CONCLUSION

This study reveals that maggot frass application in organic vegetable cultivation demonstrates high technical effectiveness (76.33%), reflected in successful harvests, accurate dosage application, and efficient use of local inputs. Economically, farming systems utilizing maggot frass are viable, reducing input costs by up to 29.73% with R/C ratios of 2.6 (non-organic) and 3.7 (organic). Maggot frass thus serves as an efficient alternative fertilizer and a strategic product of organic waste bioconversion by Black Soldier Fly (BSF) larvae, promoting circular and sustainable agriculture. To strengthen applicability, future efforts should specify optimal dosage rates and timing for different crops and conditions. Overall, the study provides an integrative assessment linking technical, economic, and sustainability dimensions within a local agricultural transformation framework. Several recommendations can be proposed for farmers to enhance maggot frass production capacity independently through appropriate technical training, while local governments and agricultural extension services are expected to expand socialization and provide supporting infrastructure to ensure more equitable adoption of this technology. For academics, further research is needed to develop maggot frass formulations suited to local plant characteristics and agroecosystem conditions. For policymakers, it is essential to integrate maggot frass into organic fertilizer subsidy schemes or circular economy incentives to accelerate widespread implementation of this technology at the farm level.

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