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Effect of Combination of Manure and Mycorrhiza on Fruit Quality and Storability of Tomato in Organic Farming Lembang

Farida Arinie Soelistianto[1], Yana Priyana[2], Ilham Akbar Bunyamin[3]
[1] Politeknik Negeri Malang and farida.arinie@polinema.ac.id
[2] STAI Al-Andina and mrpyana@gmail.com
[3] Nusa Putra University and ilhamakb14@gmail.com

ABSTRACT

This study investigates the effect of a combination of manure and mycorrhiza on the quality and storability of tomatoes from the perspective of organic farmers in Lembang, utilizing a quantitative analysis with 140 samples. Data were collected using a Likert scale (1-5), and the analysis was performed using Structural Equation Modeling-Partial Least Squares (SEM-PLS). The results show that manure positively impacts fruit quality and storability, with a stronger effect on storability. Mycorrhiza had a more significant effect on fruit quality and also positively influenced storability. The study found that mycorrhiza is the more dominant factor in improving fruit quality, while manure plays a more significant role in enhancing storability. The findings provide important insights for organic farming practices in Lembang, suggesting that a combination of manure and mycorrhiza can effectively enhance both the quality and shelf life of tomatoes.

Keywords: *Manure, Mycorrhiza, Tomato Quality, Storability, Organic Farming.*

1. INTRODUCTION

The use of natural amendments such as manure and mycorrhiza in organic tomato farming plays a crucial role in enhancing tomato quality and shelf life. Organic farming practices, including organic fertilizers and beneficial microorganisms, have been proven effective in improving yield, soil fertility, and the nutritional and economic value of tomatoes. Organic manures like goat manure, poultry dung, and vermicompost enhance soil structure, water retention, and nutrient availability, supporting plant health and stress resilience [1]. The application of poultry manure and vermicompost with mulching significantly boosts plant height and root length, leading to higher yields [2]. Trichoderma, a bio-fungicide, enhances plant resistance by inducing systemic resistance and improving nutrient uptake, especially under heat stress [1]. The combined use of Trichoderma and organic manures helps mitigate the negative effects of heat stress, preserving tomato quality and yield [1]. Additionally, organic fertilizers containing fulvic and humic acids enrich the biochemical composition of tomatoes, increasing lycopene, phenol, and vitamin C levels, particularly through root and foliar applications [3]. Organic NPK granules further enhance soil fertility and microbial populations, which are essential for sustainable tomato production [4]. Integrated nutrient management, combining organic and inorganic fertilizers, provides optimal crop yield and soil health benefits [5].

The use of organic methods, such as manure and mycorrhiza, in Lembang's tomato farming enhances soil fertility and post-harvest quality, with organic fertilizers playing a crucial role in sustainable agriculture by improving soil health and crop productivity. Integrating organic fertilizers with sustainable practices optimizes tomato quality, shelf life, and economic and environmental sustainability. Compost and biofertilizers improve soil structure, water retention, and microbial activity essential for healthy tomato growth [6]. Liquid organic fertilizers, such as those from maja fruit and NASA, supply key nutrients, boosting plant growth and yield [7]. The use of organic fertilizers in Lembang maintains soil quality and enhances crop fertility, benefiting various crops [8]. Additionally, reducing reliance on inorganic fertilizers mitigates soil pollution and economic burdens [8]. The Indonesian government supports organic farming to promote agricultural sustainability [6], while Lembang farmers gain economic benefits through higher yields and lower input costs [9]. Despite challenges like limited awareness and labor intensity [9], opportunities exist through government programs, cooperative farming, and rising demand for organic produce [9].

Despite the well-documented benefits of organic fertilizers and biological soil amendments, there is limited empirical research on the combined effects of manure and mycorrhiza on tomato quality and shelf life in organic farming. Farmers in Lembang face challenges in improving tomato yields and reducing post-harvest losses, which could significantly benefit from evidence-based recommendations on the use of these organic inputs. Given the importance of quality and storability in the marketability of tomatoes, it is essential to understand how these amendments interact and their effects on tomato production. This study addresses the following research questions: (1) How does the combination of manure and mycorrhiza affect the quality of tomatoes in organic farming? (2) What impact do these inputs have on the shelf life of harvested tomatoes? (3) How do farmers perceive the effectiveness of manure and mycorrhiza in improving tomato production?

This study aims to evaluate the effect of manure and mycorrhiza on tomato quality, including factors such as size, texture, and nutritional content; analyze the impact of these organic amendments on the shelf life of harvested tomatoes, focusing on storage duration and quality retention; and assess farmers' perspectives on the effectiveness of manure and mycorrhiza through quantitative analysis, providing practical insights for improving organic farming practices in Lembang.

2. LITERATURE REVIEW

2.1 Organic Farming and Soil Fertility Management

Organic farming enhances soil health and crop productivity by avoiding synthetic inputs and relying on natural processes, improving soil structure, microbial activity, and nutrient cycling for better crop resilience. Maintaining soil fertility remains a challenge, addressed through organic amendments like manure and beneficial microorganisms such as mycorrhiza. Natural inputs like livestock manure and plant growth-promoting rhizobacteria (PGPR) sustain soil fertility [10], while cyanobacteria and biofertilizers improve nutrient availability and soil structure [10]. Sustainable Soil and Crop Management Practices (SS-CMP) further optimize soil properties and productivity [11]. Organic farming also reduces environmental degradation by eliminating synthetic chemicals, supporting biodiversity, and lowering greenhouse gas emissions [11], [12]. The rising demand for organic products is driven by their nutritional and environmental benefits [12]. However, challenges persist in maintaining soil fertility and addressing long-term ecological impacts [13], necessitating further research, policy integration, and collaboration among stakeholders to enhance the economic viability of organic farming [10].

2.2 The Role of Manure in Organic Farming

Manure is a valuable organic fertilizer that enhances soil fertility by supplying essential nutrients, improving soil organic matter, microbial diversity, and water retention, leading to better plant growth and fruit quality. In tomato cultivation, it boosts fruit size, flavor, and post-harvest quality, but excessive use can cause nutrient imbalances and contamination, requiring proper management. Manure enhances soil structure, microbial activity, and nutrient availability [14], [15], while organic fertilizers, including vermicompost, increase soil nutrient content and microbial diversity [16]. Manure processing also reduces energy consumption compared to synthetic fertilizers, making it a more sustainable alternative [17]. However, precise nutrient management is crucial to maximize benefits and minimize environmental risks, including contamination from antibiotic residues [16], [18].

2.3 *The Role of Mycorrhiza in Plant Growth and Crop Quality*

Mycorrhizal fungi enhance plant growth and resilience in organic farming by forming symbiotic relationships with roots, improving phosphorus uptake, and increasing stress resistance. This symbiosis supports sustainable agriculture by boosting soil health, crop productivity, and reducing reliance on chemical fertilizers. They also improve root surface area for better nutrient absorption, aiding plant resilience against drought, salinity, and heavy metals through osmotic regulation and antioxidant production [18]–[20]. Additionally, mycorrhizal inoculation enhances fruit quality, nutrient composition, and shelf life in tomatoes by strengthening cell walls and reducing oxidative stress [21]. Field studies confirm their role in increasing crop productivity, as seen in corn with improved root growth and physiological traits [22].

2.4 *Farmers' Perspectives and Adoption of Organic Inputs*

The adoption of organic inputs depends on farmers' perceptions, knowledge, and economic considerations. Research by [23], [24] indicates that farmers are more likely to adopt organic practices when they see tangible benefits in yield, quality, and marketability. However, challenges such as limited access to high-quality organic amendments and knowledge gaps in application techniques can hinder widespread adoption.

In Lembang, where organic farming is growing, understanding farmers' perspectives on manure and mycorrhiza is crucial for developing effective agricultural extension programs. By assessing farmer perceptions through quantitative analysis, this study aims to bridge the gap between scientific knowledge and practical application in the field.

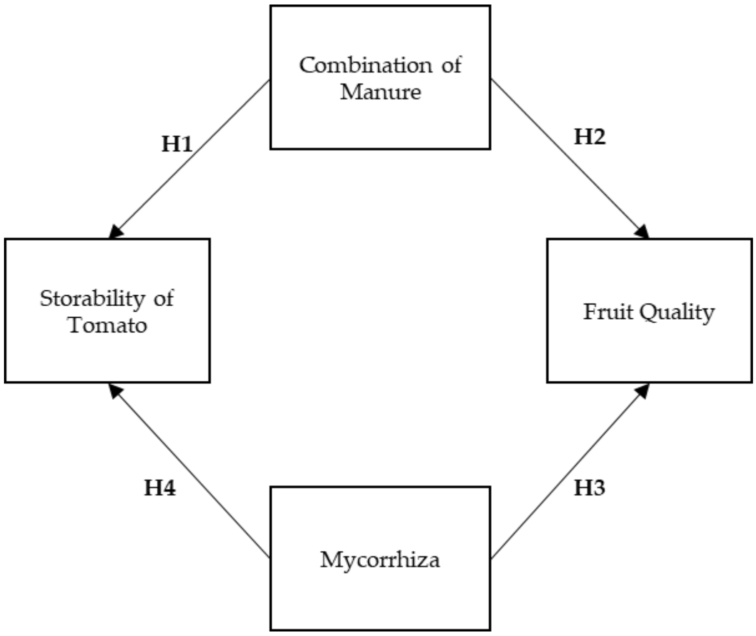

Figure 1. Conceptual Framework

3. METHODS

3.1 Research Design

This study employs a quantitative research approach to examine the effect of manure and mycorrhiza on the quality and shelf life of tomatoes in Lembang organic farming. A survey-based method was used to gather data from farmers, and Structural Equation Modeling-Partial Least Squares (SEM-PLS 3) was applied for data analysis. This approach allows for the evaluation of complex relationships between independent and dependent variables based on farmer perceptions.

3.2 Population and Sample

The target population for this study consists of organic tomato farmers in Lembang. A sample size of 140 respondents was selected using a purposive sampling technique, ensuring that all participants had direct experience with using manure and mycorrhiza in their farming practices. This sample size aligns with SEM-PLS 3 requirements, which recommend a minimum of 100–200 observations for robust analysis.

3.3 Data Collection Method

Data were collected through a structured questionnaire distributed to participating farmers, which was divided into several sections: Demographic Information (age, farming experience, education level), Tomato Farming Practices (use of manure, mycorrhiza, and other organic inputs), Perceived Tomato Quality (size, color, texture, taste), Perceived Shelf Life (days before spoilage, firmness over time), and General Satisfaction (effectiveness of manure and mycorrhiza in organic farming). Responses were recorded using a Likert scale (1-5), where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree.

3.4 Data Analysis Technique

The collected data were analyzed using Structural Equation Modeling-Partial Least Squares (SEM-PLS 3), a statistical method suitable for predictive modeling in small-to-medium sample sizes. The analysis followed these steps: Descriptive Analysis, which summarized respondent characteristics and key farming practices; Measurement Model Evaluation, assessing the reliability and validity of the questionnaire items; Structural Model Evaluation, testing relationships between manure, mycorrhiza, tomato quality, and shelf life; and Hypothesis Testing, evaluating the statistical significance of the proposed relationships.

4. RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Respondents

This study involved 140 organic tomato farmers in Lembang, and their demographic characteristics are summarized as follows. Age Distribution: The majority of respondents (57.8%) were between 41 and 60 years old, with the age distribution as follows: < 30 years (8.6%), 30-40 years (24.3%), 41-50 years (30.7%), 51-60 years (27.1%), and > 60 years (9.3%). Farming Experience: Most farmers (66.4%) had over 10 years of organic farming experience, with the following distribution: < 5 years (10.7%), 5-10 years (22.9%), 11-15 years (34.3%), and > 15 years (32.1%). Education Level: A majority of respondents (60.7%) had completed high school, while 26.4% had higher education, with the following breakdown: Primary School (12.9%), High School (60.7%), and Diploma/Bachelor's Degree (26.4%). Farm Size: Most farmers (71.4%) cultivated tomatoes on farms ranging from 0.5 to 2 hectares, with the following distribution: < 0.5 hectares (15.0%), 0.5-1 hectare (35.0%), 1-2 hectares (36.4%), and > 2 hectares (13.6%). Use of Organic Inputs: Nearly 48% of farmers used both manure and mycorrhiza, while 33.6% used manure only, and 18.6% used mycorrhiza only. Perception of Tomato Quality and Shelf Life: Farmers rated their perception of tomato quality and shelf life using a Likert scale (1-5), with the highest-rated attributes being taste (4.4), size (4.3), and firmness (4.2), followed by shelf life (4.0), indicating moderate satisfaction with post-harvest durability and significant improvements in tomato quality due to organic inputs.

4.2 Measurement Model Evaluation

The measurement model was assessed based on factor loadings, Cronbach's Alpha (α), Composite Reliability (CR), and Average Variance Extracted (AVE). These indicators help evaluate the reliability and validity of the constructs used in this study.

Table 1. Measurement Model

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Combination of Manure	CM.1	0.890	0.916	0.947	0.857
	CM.2	0.857			
	CM.3	0.728			
Mycorrhiza	MY.1	0.830	0.825	0.896	0.742
	MY.2	0.855			
	MY.3	0.897			
Fruit Quality	FQ.1	0.819	0.806	0.873	0.634
	FQ.2	0.722			
	FQ.3	0.876			
	FQ.4	0.760			
Storability of Tomato	ST.1	0.837	0.908	0.931	0.730
	ST.2	0.864			
	ST.3	0.845			
	ST.4	0.844			
	ST.5	0.880			

Source: Data Processing Results (2025)

The factor loadings indicate strong relationships between observed indicators and their respective latent variables, with values above 0.70 considered acceptable. The Combination of Manure (0.728 to 0.890), Mycorrhiza (0.830 to 0.897), Fruit Quality (0.722 to 0.876), and Storability of Tomato (0.837 to 0.880) all meet the threshold, ensuring adequate indicator reliability. Internal

Consistency Reliability is confirmed with Cronbach's Alpha and Composite Reliability values above 0.80 and 0.85, respectively, indicating excellent reliability across all constructs. For Convergent Validity, the Average Variance Extracted (AVE) values exceed the 0.50 threshold, with the Combination of Manure (0.857) and Mycorrhiza (0.742) showing excellent and strong validity, and Fruit Quality (0.634) and Storability of Tomato (0.730) demonstrating strong validity.

Discriminant validity assesses whether a construct is distinct from other constructs in the model. The Heterotrait-Monotrait Ratio (HTMT) is one of the most robust methods to evaluate discriminant validity. HTMT values should be below 0.90 to confirm that each construct is conceptually distinct.

Table 2. Discriminant Validity

	BI	NW	SS	ST
Combination of Manure				
Fruit Quality	0.744			
Mycorrhiza	0.769	0.817		
Storability of Tomato	0.789	0.758	0.804	

Source: Data Processing Results (2025)

All HTMT values are below 0.90, confirming strong discriminant validity between constructs. The highest HTMT value is 0.817 (between Mycorrhiza and Fruit Quality), which is still within the acceptable threshold, indicating that these constructs are related but distinct. The lowest HTMT value is 0.744 (between Combination of Manure and Fruit Quality), showing strong differentiation between these constructs. These results confirm discriminant validity, meaning that each construct measures a unique concept in the study. With all values below 0.90, there is no multicollinearity issue between constructs, supporting the robustness of the measurement model for further structural model evaluation.

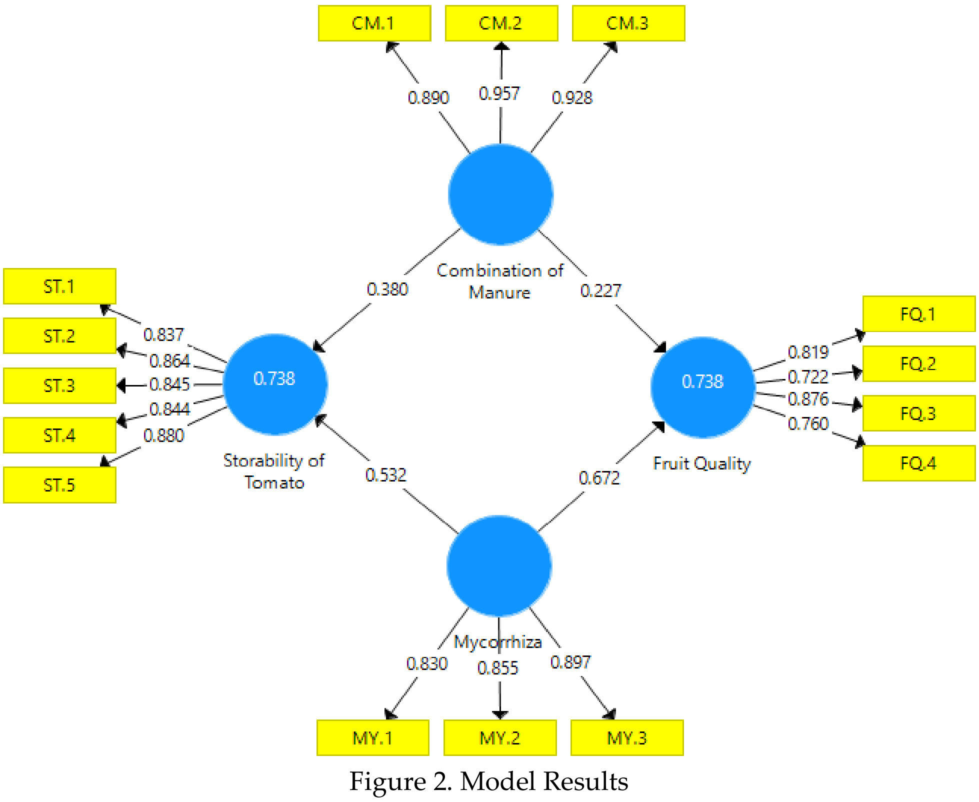

Figure 2. Model Results

Source: Data Processed by Researchers, 2025

4.3 Model Fit Evaluation

Model fit assessment ensures that the structural model aligns well with the observed data. Several fit indices are used, including Standardized Root Mean Square Residual (SRMR), d_ULS, d_G, Chi-Square, and Normed Fit Index (NFI). These indicators help determine if the hypothesized model provides a good representation of reality.

Table 3. Model Fit Results Test

	Saturated Model	Estimated Model
SRMR	0.092	0.099
d_ULS	1.025	1.174
d_G	0.659	0.714
Chi-Square	442.231	461.454
NFI	0.744	0.732

Source: Process Data Analysis (2025)

The SRMR for the Saturated Model is 0.092, and for the Estimated Model is 0.099, indicating an acceptable but not perfect fit. The d_ULS values (Saturated Model: 1.025, Estimated Model: 1.174) are close to 1.0, suggesting a reasonable model fit. The d_G values (Saturated Model: 0.659, Estimated Model: 0.714) are below 1.0, indicating an acceptable fit. The Chi-Square test shows small differences between the Saturated (442.231) and Estimated Models (461.454), suggesting model stability. Finally, the NFI values (Saturated Model: 0.744, Estimated Model: 0.732) indicate an acceptable but moderately strong model fit.

Table 4. Coefficient Model

	R Square	Q2
Fruit Quality	0.738	0.734
Storability of Tomato	0.738	0.733

Source: Data Processing Results (2025)

The R^2 value for both Fruit Quality and Storability of Tomato is 0.738, indicating that 73.8% of the variance in these variables is explained by the predictors, Combination of Manure and Mycorrhiza. This high value suggests strong explanatory power, as R^2 values between 0.50 and 0.75 are considered strong. The independent variables effectively predict the dependent variables, demonstrating that manure and mycorrhiza significantly impact fruit quality and storability. Additionally, the Q^2 values for both variables are 0.734 and 0.733, indicating strong predictive relevance. Since these values are greater than 0 and close to the R^2 values, the model shows excellent predictive accuracy without overfitting. A Q^2 value above 0.35 is considered high, so the model demonstrates very strong predictive power.

4.4 Structural Model Evaluation

The structural model evaluates the relationships between independent and dependent variables through path coefficients, T-statistics, and P-values. Path coefficients (O) measure the strength and direction of relationships, indicating the effect size of each predictor. T-statistics are used to determine statistical significance, with values above 1.96 indicating significance at $p < 0.05$. P-values below 0.05 confirm that the relationships are statistically significant, ensuring that the observed effects are not due to random chance. These criteria help assess the robustness of the structural model and the significance of the proposed relationships.

Table 5. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values

Combination of Manure -> Fruit Quality	0.227	0.229	0.077	2.967	0.003
Combination of Manure -> Storability of Tomato	0.380	0.378	0.098	3.889	0.000
Mycorrhiza -> Fruit Quality	0.672	0.672	0.070	9.557	0.000
Mycorrhiza -> Storability of Tomato	0.532	0.535	0.089	5.942	0.000

Source: Process Data Analysis (2025)

The Combination of Manure has a positive and significant effect on fruit quality ($\beta = 0.227$, $p = 0.003$), though the effect is moderate, indicating that while manure contributes to fruit quality, its influence is not as strong. However, it has a stronger and highly significant effect on the storability of tomatoes ($\beta = 0.380$, $p = 0.000$), suggesting that manure primarily enhances shelf life rather than immediate quality. On the other hand, Mycorrhiza has a very strong and significant effect on fruit quality ($\beta = 0.672$, $p = 0.000$), indicating its dominant role in improving tomato quality. The effect on storability is also significant but lower ($\beta = 0.532$, $p = 0.000$), showing that mycorrhiza has a more substantial influence on fruit quality than on the shelf life of tomatoes.

Discussion

1. Effect of Combination of Manure on Fruit Quality and Storability

The findings indicate that the combination of manure has a significant positive effect on both fruit quality and storability of tomatoes. The moderate effect on fruit quality suggests that while manure improves the overall health and appearance of tomatoes, its impact on fruit quality is not as strong as other factors, such as mycorrhiza. However, its stronger effect on storability implies that manure plays a critical role in enhancing the shelf life of tomatoes. This aligns with the traditional use of organic fertilizers, like manure, to improve soil health, which in turn contributes to better tomato shelf life by enhancing nutrient availability and plant resilience [25]–[27].

Previous studies have shown that manure, being rich in organic matter and essential nutrients, can improve soil structure, increase microbial activity, and boost nutrient uptake in plants, leading to healthier tomatoes with a longer shelf life. The effect on storability could be attributed to the manure's role in improving the plant's resistance to diseases and environmental stress, thus helping tomatoes remain fresh longer. The moderate effect on fruit quality in this study can also be seen in the context of manure's role in overall plant growth but not necessarily in providing the finer qualities related to texture and taste that may be more influenced by other variables.

2. Effect of Mycorrhiza on Fruit Quality and Storability

The study shows that mycorrhiza has a strong positive effect on both fruit quality and storability of tomatoes. Mycorrhizal fungi form a symbiotic relationship with the plant roots, improving the plant's ability to absorb water and nutrients, particularly phosphorus, which is vital for fruit development. This finding supports the well-established theory that mycorrhizal inoculation enhances plant growth, fruit quality, and even postharvest performance, such as storability.

The very strong effect on fruit quality indicates that mycorrhiza is a more effective factor than manure when it comes to improving the quality of tomatoes. This could be attributed to the fact that mycorrhiza directly influences root health and nutrient absorption, resulting in tomatoes that are larger, more robust, and possibly more flavorful. The moderate but still significant effect on storability suggests that while mycorrhiza improves plant growth and quality, its role in improving storage longevity is somewhat secondary compared to its impact on fruit quality.

The results are consistent with previous research that suggests mycorrhiza plays a critical role in improving plant stress tolerance, making fruits more resilient during postharvest handling

[25]–[27]. Additionally, mycorrhiza might enhance nutrient composition in tomatoes, including antioxidants, which could contribute to better shelf life.

3. Implications for Farmers in Lembang Organic Farming

For organic farmers in Lembang, this study offers valuable recommendations: Mycorrhiza should be prioritized to enhance fruit quality, as it has a stronger and more direct effect on tomato size, taste, and nutritional content. While the combination of manure may not significantly impact immediate quality, it plays a crucial role in improving storability, helping tomatoes stay fresh longer after harvest. The positive effects of manure on soil health also contribute to better tomato production and increased resilience against environmental stress. Considering both factors are significant, farmers should adopt a combination of manure and mycorrhiza to optimize both the quality and shelf life of tomatoes. This strategy supports sustainable farming practices that enhance crop yield, health, and postharvest performance while promoting environmental sustainability.

CONCLUSION

The study highlights the significant role of manure and mycorrhiza in enhancing the quality and storability of tomatoes in Lembang organic farming. While mycorrhiza has a more pronounced impact on fruit quality, manure is crucial for improving storability, making them both valuable components in organic farming systems. The findings suggest that integrating both manure and mycorrhiza into farming practices can lead to improved tomato production, with better quality and longer shelf life. This dual approach benefits farmers in Lembang, providing them with effective tools to optimize tomato cultivation while maintaining sustainability in organic farming practices.

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