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Impact of Organic Fertilization on Kiwifruit Productivity and Quality: A Comprehensive Review

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Abstract Organic fertilization has gained significant attention in horticulture as a sustainable alternative to conventional fertilization methods. Kiwifruit, a globally important crop, presents a unique opportunity to evaluate the impact of organic fertilization on both productivity and quality. This study examines various organic fertilizers used in kiwifruit cultivation, their application methods, and the influence on soil health and nutrient composition. Our analysis focuses on yield performance under organic fertilization, long-term effects on soil fertility, and a comparison with conventional practices. Additionally, the study explores how organic fertilization affects kiwifruit quality, including fruit size, nutritional content, taste, and post-harvest shelf life. Environmental benefits, such as reduced chemical inputs and enhanced sustainability, are highlighted alongside the economic advantages of organic kiwifruit in the market. Challenges, such as lower initial yields and regulatory issues, are discussed, with a case study demonstrating real-world applications. The study concludes by identifying research gaps and emphasizing the need for long-term studies and innovations in organic fertilizer development. Future directions focus on integrating organic practices with precision agriculture for improved productivity and sustainability.

Keywords Organic fertilization; Kiwifruit productivity; Soil fertility; Sustainable agriculture; Organic fruit quality

1 Introduction

Organic fertilization has gained significant attention in horticulture due to its potential to enhance soil health, improve crop yields, and reduce environmental impacts compared to conventional chemical fertilizers (Fan et al., 2023). Organic fertilizers, derived from plant and animal residues, contribute to the sustainability of agricultural systems by improving soil structure, increasing microbial activity, and enhancing nutrient availability (Liu et al., 2020). The application of organic manures, such as dairy manure, vermicompost, and chicken manure, has been shown to positively affect plant growth, nutrient uptake, and soil properties, making it a viable alternative to chemical fertilizers (Lago et al., 2019; Ma et al., 2021).

Kiwifruit (*Actinidia* spp.) is a valuable horticultural crop known for its high nutritional value, including vitamins, minerals, and antioxidants (Sanz et al., 2020). It is widely cultivated in various regions, including China, Italy, New Zealand, and Chile, contributing significantly to the global fruit market. The demand for high-quality kiwifruit has driven research into optimizing cultivation practices to enhance fruit yield and quality. Organic fertilization has emerged as a promising approach to meet these goals while maintaining environmental sustainability (Zhao et al., 2017; Lu et al., 2018).

This study aims to evaluate the impact of organic fertilization on kiwifruit productivity and quality. The study will explore various organic fertilization regimes, including the use of different organic manures and their combinations, and their effects on soil properties, microbial diversity, plant growth, and fruit quality. By synthesizing findings from multiple research studies, this study seeks to provide insights into the benefits and challenges of organic fertilization in kiwifruit cultivation, offering recommendations for best practices to enhance sustainable kiwifruit production.

2 Organic Fertilization Techniques for Kiwifruit

2.1 Types of organic fertilizers used in kiwifruit cultivation

Organic fertilization in kiwifruit cultivation involves the use of various organic materials to enhance soil fertility and plant growth. Commonly used organic fertilizers include dairy manure, vermicompost, poultry manure, and combinations thereof (Sharma and Rana, 2021). For instance, a study on the Allison cultivar of kiwifruit demonstrated the effectiveness of different organic manures such as dairy manure, vermicompost, and chicken manure, either applied solely or in combination (Sharma et al., 2022). Another study highlighted the use of pig and sheep dung compost over a nine-year period, which significantly improved the yield and quality of kiwifruit (Figure 1). Additionally, the application of farm yard manure, green manure, biofertilizers, and vermiwash has been shown to enhance the nutrient content and overall quality of kiwifruit (Khachi et al., 2015).

Figure 1 Application of organic fertilizer for kiwifruit

2.2 Application methods and timing

The method and timing of organic fertilizer application are crucial for optimizing kiwifruit growth and productivity. Organic fertilizers can be applied in various forms, such as solid manure or liquid formulations like jeevaamrit. For example, the application of jeevaamrit and ghana jeevaamrit in three equal splits at the end of January, February, and April, along with farm yard manure, was found to be effective in improving leaf area and photosynthetic activity in kiwifruit vines (Garg et al., 2020). Similarly, long-term application of organic amendments, such as pig and sheep dung compost, has been shown to enhance soil microbial diversity and improve fruit yield and quality (Liu et al., 2020). The combination of organic and inorganic fertilizers, applied in balanced proportions, also plays a significant role in maintaining soil fertility and promoting sustainable kiwifruit production.

2.3 Nutrient composition and soil health

Organic fertilizers contribute to the nutrient composition of the soil, thereby improving soil health and plant growth. The use of organic manures has been shown to enhance soil organic matter, microbial biomass carbon, and nutrient availability (Su et al., 2021). For instance, the application of dairy manure and vermicompost significantly improved soil physical properties, such as soil organic carbon content and nutrient availability, leading to better plant growth and fruit quality. Additionally, organic amendments have been found to increase the diversity and abundance of beneficial microorganisms in the rhizosphere, which in turn promotes plant growth and reduces the prevalence of plant pathogenic fungi. The integration of organic fertilizers with inorganic fertilizers has also been shown to improve soil fertility, as evidenced by increased soil organic carbon and available nitrogen content (Zhao et al., 2017). The use of organic fertilizers not only enhances the nutrient composition of the soil but also supports a healthy soil ecosystem, which is essential for sustainable kiwifruit production.

3 Impact of Organic Fertilization on Kiwifruit Productivity

3.1 Yield performance under organic fertilization

Organic fertilization has been shown to significantly enhance the yield performance of kiwifruit. Long-term application of organic amendments, such as pig and sheep dung compost, has been found to improve the yield and quality of kiwifruit by increasing rhizosphere microbial diversity and the relative abundance of plant growth-promoting bacteria (Liu et al., 2020). Additionally, the use of organic fertilizers produced through quick artificial decomposition of biological wastes has been reported to increase kiwifruit yields by 15.2% compared to mineral fertilizer treatments (Ma et al., 2021). Another study demonstrated that the combined application of organic manure and chemical fertilizers (NPKM) resulted in the highest average yield of 44.6 t/ha, outperforming other fertilization treatments.

3.2 Long-term effects on soil fertility and crop sustainability

The long-term application of organic fertilizers not only boosts kiwifruit yield but also enhances soil fertility and sustainability. Organic amendments have been shown to increase soil organic carbon content and improve soil nutrient availability, which are crucial for sustainable crop production (Rahman et al., 2011). The use of organic manures, such as dairy manure and vermicompost, has been found to improve soil physical properties, nutrient absorption, and overall soil health, leading to better crop performance (Sharma et al., 2022). Moreover, organic fertilization practices have been associated with higher soil microbial biomass and enzyme activity, which contribute to improved nutrient cycling and retention in the soil (Lago et al., 2019).

3.3 Comparison with conventional fertilization

When compared to conventional fertilization, organic fertilization offers several advantages in terms of yield, soil health, and environmental sustainability. Studies have shown that organic fertilization can lead to higher fruit quality, including increased vitamin C, soluble solids, and firmness, compared to conventional methods (Zhao et al., 2017; Lago et al., 2019). Additionally, organic fertilization practices have been found to reduce the relative abundance of plant pathogenic fungi and enhance the presence of beneficial microorganisms in the rhizosphere, which can further improve crop health and productivity (Ku et al., 2018). In contrast, conventional fertilization often results in higher nitrate accumulation in the soil, which can lead to environmental issues such as nutrient runoff and water pollution (Lu et al., 2018). Therefore, organic fertilization presents a more sustainable and environmentally friendly alternative to conventional fertilization practices.

4 Quality Parameters of Kiwifruit Affected by Organic Fertilization

4.1 Influence on fruit size and weight

Organic fertilization has been shown to significantly impact the size and weight of kiwifruit (Figure 2). Studies indicate that the application of organic amendments, such as pig and sheep dung compost, can enhance the yield and quality of kiwifruit by improving soil nutrients and microbial diversity (Liu et al., 2020). Additionally, the use of organic manures like dairy manure and vermicompost has been found to improve fruit production and leaf area, which are directly related to the size and weight of the fruit (Sharma et al., 2022). The combined application of organic and inorganic fertilizers also contributes to increased fruit yield and size, although the addition of organic matter alone can significantly enhance fruit quality.

4.2 Nutritional content and taste improvement

Organic fertilization positively influences the nutritional content and taste of kiwifruit. The use of mixed culture fermentation broth (MCF) of *Trichoderma pseudokoningii* and *Rhizopus nigricans* has been shown to increase the total phenol and flavonoid content, as well as the activities of superoxide dismutase (SOD) and peroxidase (POD), which are crucial for improving the nutritional quality of the fruit (Ma et al., 2020). Furthermore, organic fertilizers have been found to enhance the soluble solids content and reduce sugar levels in kiwifruit, contributing to better taste and nutritional value (Zhang et al., 2020). The application of organic manures also improves the chemical composition of the fruit, making it more appealing to consumers (Wang et al., 2021).

Figure 2 Kiwi fruit after applying organic fertilizer

4.3 Shelf life and post-harvest quality

The shelf life and post-harvest quality of kiwifruit are significantly improved through organic fertilization. Pre-harvest treatments with MCF have been shown to prolong the shelf life of kiwifruit by maintaining higher levels of bioactive compounds and antioxidant activities during storage (Wang et al., 2021). Enhanced freshness formulations (EFF) containing antioxidants like geraniol, α-tocopherol, and ascorbic acid have also been effective in preserving the bioactive compounds and storability of kiwifruit during post-harvest storage (Ceglie et al., 2016;

Korkmaz et al., 2023; Mthembu et al., 2023). Additionally, the application of foliar calcium sprays has been found to increase fruit firmness and maintain quality during cold storage, further extending the shelf life of the fruit (Sotiropoulos et al., 2021). Organic fertilizers, by improving the overall quality and nutritional content of kiwifruit, contribute to better post-harvest performance and longer shelf life (Ma et al., 2021).

5 Environmental and Economic Benefits of Organic Fertilization

5.1 Reduction in chemical inputs and soil pollution

Organic fertilization significantly reduces the reliance on chemical inputs, which in turn decreases soil pollution. Studies have shown that long-term organic fertilization improves soil health by increasing microbial diversity and reducing the presence of plant pathogenic fungi (Liu et al., 2020). Additionally, the partial substitution of chemical fertilizers with organic forms has been demonstrated to prevent soil acidification and improve soil fertility, thereby reducing detrimental environmental impacts such as N_2O emissions and nitrate leaching (Tang et al., 2021; Sun and Qian, 2024). This reduction in chemical inputs not only benefits the environment but also enhances the sustainability of agricultural practices.

5.2 Cost-effectiveness and market demand for organic kiwifruit

The economic benefits of organic fertilization are substantial. Organic farming practices have been shown to increase the economic benefit per unit area by 37%-46%, primarily due to reduced agricultural inputs and enhanced crop yields (Gao et al., 2023). Moreover, the market demand for organic kiwifruit is growing, driven by consumer preferences for sustainably produced and chemical-free products. The eco-efficiency of organic orchards, which measures the net profit per unit of greenhouse gas emissions, is significantly higher than that of integrated orchards, making organic kiwifruit production not only environmentally sustainable but also economically viable (Müller et al., 2015).

5.3 Contribution to sustainable agriculture practices

Organic fertilization contributes to sustainable agriculture by promoting practices that enhance soil health, reduce environmental impacts, and support biodiversity. The use of organic amendments has been shown to improve the physical and chemical properties of soil, leading to better nutrient uptake and higher fruit quality (Sharma et al., 2022). Additionally, organic farming practices help in sequestering carbon in the soil, thereby mitigating climate change (Figure 3) (Lago et al., 2020). The integration of organic fertilizers with inorganic ones has also been found to enhance fruit quality without compromising yield, further supporting the sustainability of these practices (Zhang et al., 2020). Overall, organic fertilization aligns with the principles of sustainable agriculture by fostering a more resilient and environmentally friendly farming system.

The study of Lago et al. (2020) presents the effects of different agricultural management practices, with or without earthworm addition, on soil respiration, dissolved organic carbon (DOC), and the DOC/DON ratio over time. The results suggest that conventional farming methods generally lead to higher soil respiration and DOC levels compared to integrated and organic systems. However, the DOC/DON ratio fluctuates depending on the time and management practice. These findings indicate that agricultural practices and soil amendments can significantly influence soil carbon cycling and nutrient dynamics, with potential implications for soil health and sustainability in various farming systems.

6 Challenges and Limitations

6.1 Lower initial yield compared to conventional fertilization

One of the primary challenges associated with organic fertilization in kiwifruit cultivation is the lower initial yield compared to conventional fertilization methods. Studies have shown that while organic amendments can improve soil health and long-term productivity, the initial yields are often lower than those achieved with chemical fertilizers. For instance, the application of organic fertilizers, such as pig and sheep dung compost, has been found to enhance soil microbial diversity and fruit quality over time, but the initial yield improvements are not as pronounced as those seen with chemical fertilizers (Liu et al., 2020). Similarly, the use of organic manures alone, without the addition of inorganic fertilizers, has been shown to significantly improve fruit quality and soil health, but the initial yields may not match those obtained with conventional NPK fertilizers (Sharma et al., 2022).

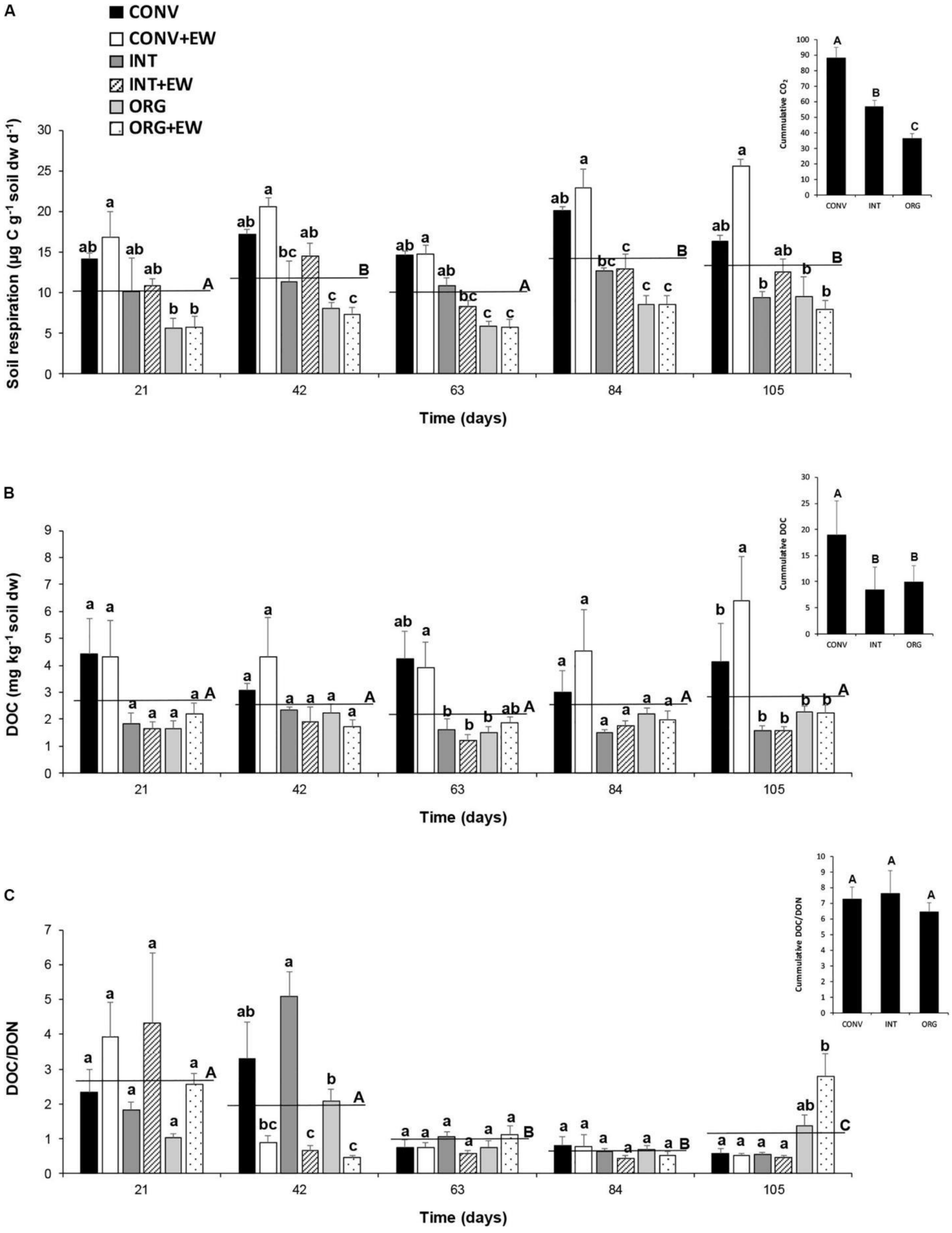

Figure 3 Changes in the average values of soil respiration (μg C g^{-1} soil dw d^{-1}) (A), DOC (mg kg^{-1} soil dw) (B), and DOC/DON ratio (C) measured at each treatment (agricultural management and earthworm conditions combined) during the incubation period together with the averaged values per sampling time (horizontal lines) and the accumulated values (inset). Different letters represent significant differences (repeated measures ANOVA) between treatments per sampling date (lower case) and between successive sampling times (upper case) and between treatments (ANOVA; insets) (Adopted from Lago et al., 2020)

6.2 Availability and quality of qrganic fertilizers

The availability and quality of organic fertilizers can also pose significant challenges. Organic fertilizers are often derived from various sources, including animal manure, compost, and crop residues, which can vary widely in nutrient content and quality. This variability can make it difficult to achieve consistent results in kiwifruit production. For example, a study on the effects of different organic manures on kiwifruit growth and yield found that the nutrient content and efficacy of the manures varied significantly, impacting the overall productivity and quality of the fruit (Wu et al., 2022). Additionally, the production of high-quality organic fertilizers through methods such as quick artificial decomposition of biological wastes can be complex and resource-intensive, further complicating their widespread adoption (Ma et al., 2021).

6.3 Regulatory frameworks and certification issues

Regulatory frameworks and certification issues are another set of challenges that can hinder the adoption of organic fertilization practices in kiwifruit cultivation. Organic farming practices are subject to stringent regulations and certification standards, which can vary by region and country. These regulations often require detailed documentation and regular inspections to ensure compliance, which can be burdensome for farmers. Moreover, the lack of standardized guidelines for the use of organic fertilizers can lead to inconsistencies in their application and effectiveness. For instance, the need for balanced fertilization planning to optimize kiwifruit yield and quality highlights the complexity of adhering to regulatory standards while achieving desired outcomes (Torkashvand et al., 2016). The variability in organic fertilizer quality and the stringent certification processes can thus pose significant barriers to the widespread adoption of organic fertilization in kiwifruit production.

7 Case Study

7.1 Overview of kiwifruit orchard using organic fertilization (location, farm size, and practices)

The case study focuses on a kiwifruit orchard located in the Bay of Plenty, New Zealand, which is known for its favorable climate for kiwifruit cultivation. The orchard spans approximately 10 hectares and employs BioGro certified organic practices. The primary organic amendments used include composted pig and sheep dung, dairy manure, vermicompost, and chicken manure. These organic materials are applied at varying rates to enhance soil health and productivity (Müller et al., 2015).

7.2 Fertilization practices implemented and yield results

The orchard implements a combination of organic fertilization practices, including the application of dairy manure, vermicompost, and chicken manure in different proportions. For instance, treatments such as 50% dairy manure combined with 50% vermicompost or chicken manure have been tested. These practices have shown to significantly improve the growth parameters such as leaf number, leaf area, and stem diameter, as well as enhance soil chemical properties (Table 1) (Sharma et al., 2022). Over a period of nine years, the application of organic amendments has led to an increase in fruit yield and quality, with notable improvements in the relative abundance of beneficial microorganisms in the rhizosphere.

Table 1 Impact of organic manures on the plant growth characteristics of *Actinidia deliciosa* cv 'Allison' (Adopted from Sharma et al., 2022)

Code	Treatments	Total No. of Leaves	Total Area of Leaves per Plant (m^2)	Stem Diameter Increase
T_1	100% Dairy manure (DM)	328 ± 4.16^{d}	3.81 ± 0.09^{d}	0.32 ± 0.001^{d}
T_2	100% Vermicompost (VC)	349 ± 8.33^{c}	4.09 ± 0.07^{c}	0.36 ± 0.01^{c}
T_3	100% Chicken manure (CM)	298 ± 6.81^{f}	3.33 ± 0.07^{f}	0.22 ± 0.01^{g}
T_4	50% DM+ 50% CM	303 ± 6.24^{ef}	3.40 ± 0.01^{f}	0.27 ± 0.01^{f}
T_5	50% DM + 50% VC	370 ± 0.88^{b}	4.30 ± 0.01^{b}	0.39 ± 0.01^{b}
T_6	50% CM + 50% VC	313 ± 4.16^{def}	3.63 ± 0.04^{e}	0.29 ± 0.01^{e}
T_7	DM + CM + VC in equal proportions	315 ± 4.13^{de}	3.64 ± 0.01^{e}	0.30 ± 0.01^{e}
T_8	Recommended dose of fertilizers	408 ± 9.89^{a}	4.83 ± 0.12^{a}	0.46 ± 0.01^{a}
	* LSD (*p* 0.05)	18.09	0.20	0.01

Note: * LSD=Least Significance difference; the values shown are the mean±SE. Different letters in the same column indicate a significant difference at the p=0.05 level (Adopted from Sharma et al., 2022)

The study of Sharma et al. (2022) illustrates the effects of various organic manure treatments on the growth of *Actinidia deliciosa* cv 'Allison'. The recommended dose of fertilizers (T8) resulted in the highest values for total leaf number, leaf area, and stem diameter increase, indicating superior plant growth compared to organic treatments. Among organic manures, 50% dairy manure with 50% vermicompost (T5) led to significantly better growth in most parameters than other organic treatments. This suggests that combining organic manures can be beneficial, but the standard recommended fertilizers still outperform organic amendments in promoting plant growth.

7.3 Quality analysis and consumer perception of organic kiwifruit

The quality of organic kiwifruit has been assessed through various parameters including fruit firmness, soluble solids content (SSC), and nutrient composition. Organic treatments have been found to significantly improve the fruit's chemical composition, leading to higher SSC and better overall fruit quality compared to conventional methods (Zhang et al., 2020). Consumer perception of organic kiwifruit is generally positive, with a preference for the improved taste and perceived health benefits associated with organic produce. Additionally, the eco-efficiency of organic orchards, which measures the net profit per kg of greenhouse gas emissions, is significantly higher than that of integrated orchards, further enhancing consumer appeal.

7.4 Lessons learned and recommendations for future application

The long-term application of organic fertilization has demonstrated several benefits, including improved soil health, increased microbial diversity, and enhanced fruit yield and quality. Key lessons learned include the importance of balanced nutrient application and the positive impact of organic amendments on soil and plant health (Liu et al., 2020). For future applications, it is recommended to continue exploring the optimal combinations and rates of organic amendments to maximize productivity and sustainability. Additionally, integrating organic practices with advanced monitoring of soil and plant health can further optimize the benefits of organic fertilization. Emphasizing eco-efficiency and sustainability metrics can also help in differentiating organic products in the market and meeting consumer demands.

8 Future Directions and Research Gaps

8.1 Need for comprehensive long-term studies

While existing studies have demonstrated the benefits of organic fertilization on kiwifruit productivity and quality, there is a significant need for comprehensive long-term studies. Current research, such as the study by Liu et al. (2020), has shown that long-term organic fertilization improves kiwifruit productivity by enhancing rhizosphere microbial diversity and network complexity. However, these studies often span only a few years. Extending the duration of these studies would provide more robust data on the sustainability and long-term impacts of organic fertilization practices. Additionally, long-term studies could help in understanding the cumulative effects of organic amendments on soil health and plant resilience against diseases and environmental stresses.

8.2 Innovations in organic fertilizer development

Innovations in the development of organic fertilizers are crucial for optimizing their effectiveness. The study by Ma et al. (2021) highlights the potential of quick artificial decomposition technology to produce fertilizers containing small molecular organic compounds from crop residues and biological wastes. These fertilizers have been shown to significantly increase kiwifruit yields and enhance the nutritional content of the fruits. Future research should focus on refining these technologies to produce more efficient and cost-effective organic fertilizers. Additionally, exploring the use of diverse organic materials and their combinations could lead to the development of tailored fertilizers that meet specific crop and soil requirements.

8.3 Integrating organic practices with precision agriculture technologies

The integration of organic fertilization practices with precision agriculture technologies presents a promising avenue for enhancing kiwifruit production. Mechanized technologies for scaffolding cultivation, as reviewed by Mu et al. (2018), can improve the efficiency and standardization of organic farming practices. Precision agriculture tools, such as soil sensors and automated irrigation systems, can be used to optimize the application of organic fertilizers, ensuring that nutrients are delivered precisely when and where they are needed (Zhang et al., 2023). This integration can lead to better resource management, reduced environmental impact, and improved crop yields and quality. Future research should explore the synergies between organic practices and precision agriculture to develop holistic farming systems that maximize productivity and sustainability.

9 Concluding Remarks

The comprehensive review of the impact of organic fertilization on kiwifruit productivity and quality reveals several key findings. Long-term organic fertilization significantly enhances the productivity of kiwifruit by improving rhizosphere microbial diversity and network complexity, which in turn promotes plant growth and fruit yield. Organic manures, such as dairy manure and vermicompost, have been shown to improve soil physicochemical properties, nutrient uptake, and fruit quality, including soluble solids content and leaf nutrient status. The combination of organic and inorganic fertilizers also positively affects growth, photosynthetic characteristics, and fruit quality, although the addition of organic matter does not always increase yield compared to inorganic fertilizers alone. Furthermore, organic fertilizers produced through quick artificial decomposition of biological wastes can significantly increase kiwifruit yields and enhance the nutritive components of the fruits. Balanced fertilization with N, P, K, and organic manure is crucial for maintaining soil fertility, which is essential for sustaining high yields and improving fruit quality.

For kiwifruit growers, the adoption of organic fertilization practices offers several benefits. The use of organic amendments can lead to higher fruit yields and improved fruit quality, which are critical for market competitiveness and consumer satisfaction. Additionally, organic fertilization contributes to better soil health by enhancing microbial diversity and soil nutrient content, which can reduce the dependency on chemical fertilizers and promote sustainable farming practices. The agricultural industry can leverage these findings to develop and promote organic fertilization products and practices that support environmental sustainability and meet the growing demand for organic produce. Moreover, the integration of organic and inorganic fertilizers can be optimized to balance the benefits of both approaches, ensuring high productivity and quality while maintaining soil health.

The future of organic fertilization in kiwifruit production looks promising, with substantial evidence supporting its positive impact on productivity, fruit quality, and soil health. Continued research and innovation in organic fertilization techniques, such as the development of fertilizers with small molecular organic compounds, can further enhance the efficiency and effectiveness of organic amendments. Additionally, the adoption of integrated nutrient management strategies that combine organic and inorganic fertilizers can provide a balanced approach to fertilization, maximizing the benefits while minimizing potential drawbacks. As consumer demand for organic produce continues to rise, kiwifruit growers and the agricultural industry must embrace and invest in organic fertilization practices to ensure sustainable and profitable production in the long term.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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