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A Comparative Analysis of the Impact of Organic Comfrey Liquid Fertilizer and Inorganic Fertilizer on the Growth and Yield of Tomato (Solanum Lycopersicum)

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Abstract

The global shift toward sustainable agriculture has increased interest in organic fertilizers as alternatives to synthetic inputs, which are associated with soil degradation and environmental pollution. This study evaluated the effects of organic comfrey liquid fertilizer and inorganic fertilizer on the growth, yield, and economics of tomato (*Solanum lycopersicum)* The global shift toward sustainable agriculture has increased interest in organic fertilizers as alternatives to synthetic inputs, which are associated with soil degradation and environmental pollution. This study evaluated the effects of organic comfrey liquid fertilizer and inorganic fertilizer on the growth, yield, and economics of tomato (*Solanum lycopersicum*) production in Lusaka, Zambia. A randomized complete block design with three treatments control (no fertilizer), organic comfrey liquid fertilizer, and inorganic fertilizer was used. Data on plant height, leaf count, and fruit yield were collected and analyzed using ANOVA and LSD post-hoc tests. Results showed significant differences among treatments in final fruit yield ($F(2,24) = 23.548$, $p < 0.001$). Organic comfrey fertilizer produced the highest mean yield (186.67 g/plant), followed by inorganic fertilizer (128.56 g/plant), and control (75.67 g/plant). Post-hoc comparisons confirmed all treatment means differed significantly ($p \leq 0.001$). Organic fertilizer also promoted greater plant height and leaf count, particularly at later growth stages. Cost-benefit analysis indicated that comfrey fertilizer offered a sustainable and economically viable alternative to inorganic inputs. These findings support the use of comfrey liquid fertilizer as an effective organic amendment for enhancing tomato productivity while supporting soil health and environmental sustainability.

Keywords: Solanum Lycopersicum, Comfrey Liquid Fertilizer, Inorganic Fertilizer, Tomato Yield, Sustainable Agriculture, Organic Farming

1. Introduction

1.1 Background

Agricultural systems worldwide are challenged to meet food security demands while minimizing environmental impact (Pretty, 2008; FAO, 2017) [20, 9]. The intensive use of synthetic fertilizers in conventional farming has contributed to soil acidification, nutrient imbalance, nitrate leaching, and the decline of soil biological activity (Savci, 2012; Chandini, 2012; Brady & Weil, 2016; Havlin *et al*., 2014) [22, 4, 3, 11]. These effects undermine long-term soil fertility and agricultural sustainability. Conventional farming's reliance on synthetic fertilizers has led to soil acidification, nutrient leaching, and loss of soil biodiversity (Savci, 2012; Chandini, 2012; Hijbeek *et al*., 2018) [22, 4, 12]. In response, organic farming practices have gained prominence for their potential to sustain productivity while enhancing ecosystem health (IFOAM, 2005; Reganold & Wachter, 2016) [15, 21]. Organic fertilizers derived from plant or animal residues contribute organic matter that improves soil aggregation, water-holding capacity, and long-term fertility (Brady & Weil, 2016; Liu *et al*., 2010) [3, 18]. They improve soil structure, microbial activity, and long-term fertility (IFOAM, 2005) [15].

Tomato (Solanum lycopersicum) is a globally important vegetable crop, valued for its nutritional and economic significance (FAO, 2023) [10]. Tomato production is nutrient-intensive, particularly with respect to nitrogen and potassium, which are

essential for vegetative growth and fruit development (Marschner, 2012) [19]. In Zambia, tomato production is a key livelihood activity for smallholder farmers, yet yields are often limited by inadequate nutrient management (Chisanga *et al*. (2020) [5]; Chivenge *et al*. (2011) [6]. While inorganic fertilizers like NPK formulations are commonly used to boost yields, their overuse poses sustainability challenges (Chisanga *et al*., 2020) [5]. Organic alternatives such as comfrey (Symphytum spp.) liquid fertilizer offer a promising solution due to their high nutrient content, particularly potassium, which is crucial for fruit development (Marschner (2012) [19]; Wang *et al*. (2023) [25].
Despite its traditional use, empirical evidence comparing comfrey liquid fertilizer with inorganic fertilizers in tomato production remains limited. This study therefore aimed to evaluate and compare the effects of organic comfrey liquid fertilizer and inorganic fertilizer on tomato growth, yield, and economic viability under field conditions in Lusaka, Zambia.

1.2 Statement of the Problem

Tomato *(Solanum lycopersicum L.)* is a key vegetable crop worldwide, providing essential nutrients to consumers and generating significant income for farmers. Achieving high yields, however, depends heavily on fertilizer use. Inorganic fertilizers have long been the preferred option due to their immediate effectiveness in boosting crop productivity. Yet, their prolonged and intensive use has been linked to serious environmental and agronomic problems, including soil acidification, nutrient leaching, and the depletion of beneficial soil microorganisms (Savci, 2012; Chandini, 2012; Hijbeek *et al*., 2018) [22, 4, 12]. These issues compromise soil health and threaten the long-term sustainability of crop production systems.
Organic alternatives have emerged as promising solutions to these challenges. Among them, comfrey (*Symphytum spp.)* is recognized for its nutrient-rich foliage, particularly its high potassium content, which is essential for fruiting crops like tomato (Marschner (2012); Wang *et al*. (2023)) [19, 25]. However, while comfrey has traditionally been used in small-scale farming systems, there is limited empirical evidence on its comparative performance against conventional inorganic fertilizers in tomato cultivation. This lack of scientific validation poses a barrier to adoption, leaving farmers uncertain about its effectiveness in sustaining yields and crop quality.
Therefore, the central problem this study addresses is the absence of comprehensive, evidence-based research comparing the impact of comfrey liquid fertilizer with that of inorganic fertilizers on tomato growth, yield, and plant health. Without such knowledge, farmers lack the necessary information to make informed decisions about adopting sustainable fertilization practices that could reduce dependency on synthetic inputs while maintaining productivity.

1.3 Objectives

Main Objective

The main research objective was to:
Analyze the comparative effects of organic comfrey liquid fertilizer and inorganic fertilizers on the growth and yield of tomato plants.
In order to archive the main objective the study had the following specific objectives:

1. Compare vegetative growth (plant height and leaf count) under organic comfrey and inorganic fertilizer treatments.
2. Determine the fruit yield response to each fertilizer type.
3. Conduct a cost-benefit analysis of comfrey liquid fertilizer versus inorganic fertilizer.

1.4 Hypothesis Testing

H_0: There is no significant difference in the vegetative growth, yield, and net financial benefit of tomato plants fertilized with organic comfrey liquid fertilizer compared to those fertilized with inorganic fertilizer.
H_1: There is a significant difference in the vegetative growth, yield, and net financial benefit of tomato plants fertilized with organic comfrey liquid fertilizer compared to inorganic fertilizer.

1.5 Theoretical Framework

This research is supported by a union of established agricultural, ecological, and sustainability theories that collectively explain plant physiological responses to nutrient inputs and the long-term dynamics of soil ecosystem health. The framework provides a multi-faceted lens through which to analyze the comparative efficacy of comfrey liquid fertilizer and inorganic fertilizer in tomato (*Solanum lycopersicum*) cultivation.
The foundational principle is Liebig's Law of the Minimum, which suggests that plant growth is inhibited not by the total resources available, but by the uncommon resource the limiting factor (van der Ploeg *et al*., 1999). This law is fundamental to all fertilization practices, as the primary goal of any fertilizer whether organic or inorganic, is to remedy the deficiency of the most limiting nutrient to optimize crop productivity and yield. In the context of this study, both fertilizers aim to overcome potential limitations in key macronutrients like nitrogen (N), phosphorus (P), and potassium (K), which are crucial for tomato growth and fruit development.

Soil Fertility Theory

To understand the distinct mechanisms of action, the framework incorporates Soil Fertility Theory. This theory elucidates how different fertilizers influence the soil-plant system. Inorganic fertilizers are engineered to deliver high concentrations of readily soluble nutrients, offering a rapid growth response and high short-term yield potential (Savci, 2012) [22]. However, this theory also acknowledges the drawbacks of synthetic inputs, such as their potential to contribute to soil acidification, secondary nutrient depletion, and environmental pollution through leaching and runoff when mismanaged. This creates a contrast with the Organic Matter Theory.

Organic Matter Theory

Emphasizes the critical role of carbon-based inputs in building and sustaining soil health. According to this view, organic fertilizers like comfrey tea contribute not only nutrients but also organic matter, which enhances soil structure (aggregation), water retention capacity, and biodiversity of soil microbes (Reganold & Wachter, 2016) [21]. The nutrient release from organic sources is typically slower and more gradual, mediated by microbial decomposition, which aligns with natural nutrient cycling processes and may lead to more sustained fertility.

Sustainable Agriculture Theory

Finally, this research is situated within the broader context of Sustainable Agriculture Theory. This theory advocates for farming systems that are environmentally sound, economically viable, and socially responsible (Pretty, 2008) [20]. It moves beyond a purely production-centric view to evaluate the long-term impacts of agricultural practices. This theoretical perspective dictates that the comparison between comfrey and inorganic fertilizers extends beyond simple yield metrics to include considerations of soil health resilience, environmental impact such as carbon footprint, water quality, and the economic practicality for farmers seeking to adopt more sustainable practices.

This integrated theoretical framework employs Liebig's Law to explain the why of fertilization, uses Soil Fertility and Organic Matter theories to contrast the how of different fertilizer types, and applies Sustainable Agriculture theory to evaluate the so what, the broader implications of the choice between organic and inorganic inputs (van der Ploeg *et al*., 1999). By applying these interconnected theories, this study will provide a holistic assessment of whether comfrey liquid fertilizer can serve as a viable, effective, and sustainable alternative to synthetic inorganic fertilizers in tomato production.

2. Literature Review

Tomato (Solanum lycopersicum) is one of the most widely cultivated and economically important vegetable crops globally, with annual production exceeding 180 million metric tons (FAO, 2021). The crop contributes significantly to food security, nutrition, and rural livelihoods due to its rich content of vitamins A, C, and E, minerals, and antioxidants such as lycopene (Dorais *et al*., 2008). In Zambia and other developing countries, tomato production has become an important income-generating enterprise for smallholder farmers. However, productivity remains constrained by poor nutrient management and declining soil fertility, prompting interest in sustainable nutrient sources that can maintain yields while reducing environmental impacts associated with synthetic fertilizers (Chisanga *et al*., 2020) [5].

Organic fertilizers have gained increasing attention as sustainable alternatives because they improve soil structure, water-holding capacity, microbial activity, and nutrient cycling while reducing environmental risks (Liu *et al*., 2010; Sharma *et al*., 2014) [18, 23]. Organic amendments such as manure, compost, and plant-based fertilizers have been shown to enhance tomato productivity and soil fertility, particularly in resource-constrained farming systems (Mapfumo & Giller, 2001; Marandu *et al*., 2014). Integrated nutrient management approaches that combine organic and inorganic inputs often outperform sole fertilizer applications by providing both immediate nutrient availability and long-term improvements in soil health (Tittonell *et al*., 2008; Chivenge *et al*., 2011 [6]).

Among plant-based organic fertilizers, comfrey (Symphytum spp.) has attracted considerable interest due to its high nutrient content, especially potassium, calcium, and magnesium (Hassan *et al*. (2015) [13]; Duke (1983) [7]. Its deep rooting system enables the accumulation of nutrients from subsoil layers, which are subsequently recycled through composting, mulching, or liquid fertilizer preparation (Hassan *et al*., 2015) [13]. Comfrey liquid fertilizer, commonly known as comfrey tea, is produced through the fermentation of leaves and provides a nutrient-rich extract containing approximately 3.0% nitrogen, 0.8% phosphorus, and 4.5% potassium, together with essential micronutrients (Hassan *et al*. (2015) [13]; Marschner (2012) [19]. In addition to nutrients, comfrey contains bioactive compounds such as allantoin and cytokinins that may stimulate plant growth and improve physiological performance (El-Ghamry *et al*. (2009) [8].

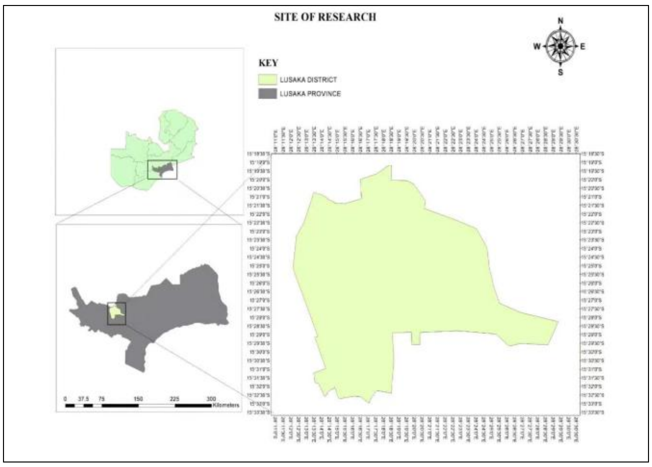
Previous studies have demonstrated the potential benefits of comfrey fertilizer in vegetable production. Wang *et al*. (2023) [25] reported increases in tomato plant height, leaf area, and fruit yield following comfrey application, Wang *et al*. (2023) [25] observed improvements in fruit firmness, lycopene content, and overall fruit quality. Similar positive responses have been reported in spinach, lettuce, pepper, and eggplant, suggesting broad applicability across horticultural crops (Chivenge *et al*. (2011) [6]; Kumar *et al*. (2022) [14]; Li *et al*. (2025) [17]. Furthermore, comfrey-based fertilizers have been associated with enhanced soil organic matter, microbial activity, and drought resilience, making them particularly relevant for smallholder farming systems facing climate variability and soil degradation (Reganold & Wachter (2016) [21]; Li *et al*. (2025) [17].

3. Materials and Methods

Research Location

The study was conducted at Plot 31077, along Silverstreet off Mumba Kapumpa Road, approximately 1.3 km from the Information and Communications University (ICU) main campus in Lusaka, Zambia. The site lies at a latitude of -15.4450488 and longitude of 28.2754109, with an elevation of 11168 meters above sea level. The location was selected due to its accessibility, favorable climatic conditions for tomato production, and suitability for conducting field experiments without disturbances. The area experiences a subtropical climate, with distinct wet and dry seasons that influence agricultural activities. Average annual rainfall ranges between 800–1,000 mm, concentrated mostly between November and March, while mean annual temperatures range from 15 °C to 27 °C, (Esser, 2017).

Map of Lusaka showing study area



Materials

The various tools that were used in the experiment include hand hoe, rake, watering can, digital scale, measuring tape and a ruler, hand handbook and pens for recording data. The materials included Tomato seeds (Starke Arye, Tengeru Select), Agro Easy Grow fertilizer and organic comfrey liquid fertilizer. The Tengeru Select variety is an ideal crop for the trial site, the variety is well liked because of its adaptability, profitability in terms of market value and demand.

Experimental Design

A Randomized Complete Block Design (RCBD) with three replications was employed. The experiment consisted of three treatments: T1 (Control, no fertilizer), T2 (Organic comfrey liquid fertilizer), and T3 (Inorganic fertilizer). The study was conducted at Plot 31077, Lusaka, Zambia (Latitude: -15.4450488, Longitude: 28.2754109), during the 2025 growing season.

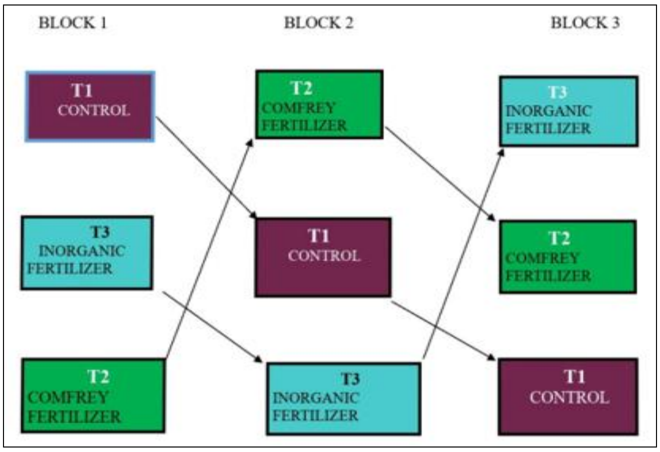


Fig 1: Experimental Design

Preparation and Application of Treatments

Comfrey liquid fertilizer was prepared by fermenting chopped comfrey leaves (Symphytum officinale) in water for 4–6 weeks, following established methods (Kuepper, 2010) [16]. The resultant concentrate was diluted at a ratio of 1:10 before application as a soil drench. The inorganic treatment utilized a commercially available compound fertilizer (NPK), applied at the recommended agronomic rate for tomatoes.

Data Collection

Plant height(cm) and leaf count were measured at 30, 60, and 90 days after sowing (DAS). At maturity, total fruit yield per plant was measured by weighing all harvested fruits. A basic cost benefit analysis was conducted, accounting for inputs such as land preparation, irrigation, pest management, harvest, and fertilization costs.

Statistical Analysis

Collected data were subjected to Analysis of Variance (ANOVA) using SPSS software. Where ANOVA indicated significant differences ($p < 0.05$), means were separated using the Least Significant Difference (LSD) post-hoc test.

Analysis of variance (CRBD-**ANOVA-Test Result)**

This Complete Randomized Block Design Analysis of Variance (CRBD-ANOVA) test resolves the question whether there is a significant difference in the growth and yield of tomato.

The Null-hypothesis stated that there is no significant difference in the vegetative growth, yield, and net financial benefit of tomato plants fertilized with organic comfrey liquid fertilizer compared to those fertilized with inorganic fertilizer. While the alternative hypothesis stated that there is a significant difference in the vegetative growth, yield, and net financial benefit of tomato plants fertilized with organic comfrey liquid fertilizer compared to inorganic fertilizer.

Ethical Considerations

Proper management and disposal of chemical fertilizers were ensured to minimize potential negative impacts on the environment, soil, water, animals, and humans at the experimental site. The purpose, procedures, potential risks, and benefits of the study were clearly explained. Transparency and honesty in reporting research findings were maintained. No data was manipulated to fit desired outcomes, and any limitations or conflicts of interest in the study were acknowledged. The use of comfrey liquid fertilizer was also monitored to ensure it did not adversely affect the local environment.

4. Results

Vegetative Growth Parameters

Plant height differed significantly among treatments at all growth stages(30 DAS: $F(2,6)=5.976$, $p=0.037$; 60 DAS: $F(2,6)=11.651$, $p=0.009$; 90 DAS: $F(2,6)=58.188$, $p<0.001$). At 90 DAS, plants treated with organic comfrey fertilizer were tallest (150.1 cm), followed by inorganic (100.9 cm) and control (96.0 cm). Similarly, leaf count was significantly higher in fertilized plots, with the organic treatment showing superior performance, especially at the flowering and fruiting stages (Fruiting stage: $F(2,24)=16.64$, $p<0.001$).

Table 1: Anova results of plant height

Plant Height		Sum of Squares	df	Mean Square	F	Sig.
30DAS	Between Group	63.762	2	31.881	5.976	.037
	Within Groups	32.007	6	5.334		
	Total	95.769	8			
60DAS	Between Group	846.996	2	423.498	11.651	.009
	Within Groups	218.100	6	36.350		
	Total	1065.096	8			
90DAS	Between Group	6633.380	2	3316.690	58.188	.000
	Within Groups	342.000	6	57.000		
	Total	6975.380	8			

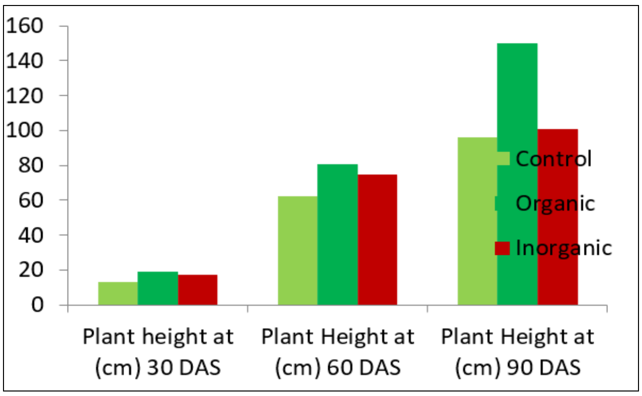


Fig 2: Graphical Representation of effect on plant height

Table 2: Anova results for Leaf Count

ANOVA

Leaf Count		Sum of Squares	Df	Mean Square	F	Sig.
Veg	Between Groups	25.407	2	12.704	5.339	.012
	Within Groups	57.111	24	2.380		
	Total	82.519	26			
Flower	Between Groups	404.519	2	202.259	10.873	.000
	Within Groups	446.444	24	18.602		
	Total	850.963	26			
Fruiting	Between Groups	537.185	2	268.593	16.643	.000
	Within Groups	387.333	24	16.139		
	Total	924.519	26			

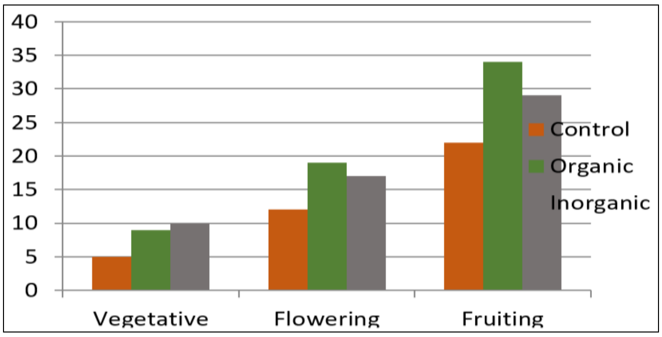


Fig 3: Graph representation of the effect of organic and inorganic Fertilizer on leaf count

Fruit Yield

A highly significant treatment effect was observed on total fruit yield($F(2,24)=23.548$, $p<0.001$). The organic comfrey treatment yielded the highest mean of 0.373 t/ha, followed by the inorganic treatment (0.299 t/ha) and the control (0.151 t/ha). LSD post-hoc tests confirmed that all pairwise differences between treatment means were statistically significant ($p<0.05$).

Table 3: Anova results for fruit yield

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.230	2	.115	23.548	.000
Within Groups	.117	24	.005		
Total	.347	26			

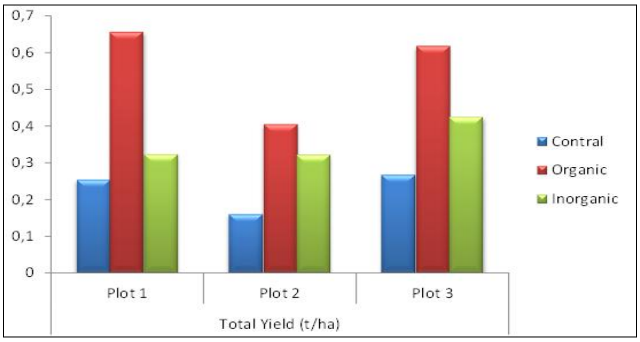


Fig 4: Graphical representation of fruit yield

Cost-Benefit Analysis

The analysis revealed that while the cost of inorganic fertilizer input was higher, the organic comfrey treatment delivered a greater yield increment per unit of cost incurred. This suggests a better economic efficiency and potential for higher net returns when using the locally produced organic amendment, particularly for smallholder farmers.

Table 4: ANOVA results for cost-benefit analysis

		SS	df	Mean Square	F	Sig.
Land preps	Between Groups	.000	2	.000	.000	1.000
	Within Groups	7500.000	9	833.333		
	Total	7500.000	11			
Irrigation weeding	Between Groups	13650.000	2	6825.000	1.804	.219
	Within Groups	34050.000	9	3783.333		
	Total	47700.000	11			
Pest Disease	Between Groups	463050.000	2	231525.000	1.546	.265
	Within Groups	1348150.000	9	149794.444		
	Total	1811200.000	11			
Harvest Post handling	Between Groups	10850.000	2	5425.000	.692	.525
	Within Groups	70575.000	9	7841.667		
	Total	81425.000	11			
	Between Groups	8.000	2	4.000	.	.
	Within Groups	.000	9	.000		
	Total	8.000	11			
Ferti	Between Groups	30416.667	2	15208.333	3.079	.096
	Within Groups	44450.000	9	4938.889		
	Total	74866.667	11			

5. Discussion, Conclusion and Recommendations

Discussion of Key Findings

Effects on Growth

Fertilizer application significantly enhanced tomato vegetative growth, with the magnitude of the effect increasing throughout the growing period. Plants treated with organic comfrey liquid fertilizer consistently recorded the greatest plant height at 30, 60, and 90 DAS, followed by inorganic fertilizer and the unfertilized control. The effect of fertilizer on plant height was significant at all growth stages and became progressively stronger over time, explaining approximately 67%, 80%, and 95% of the variation in plant height at 30, 60, and 90 DAS, respectively. Post-hoc comparisons showed that organic fertilizer significantly increased plant height compared with the control at all stages and significantly outperformed inorganic fertilizer by 90 DAS. These findings suggest that comfrey fertilizer provided a sustained nutrient supply that promoted continuous vegetative growth.

A similar trend was observed for leaf production. Organic fertilizer produced the highest leaf counts during the vegetative, flowering, and fruiting stages, while the control consistently recorded the lowest values. ANOVA results confirmed significant treatment effects on leaf count at all growth stages, with the strength of the effect increasing as plants matured. Post-hoc analyses indicated that both organic and inorganic fertilizers significantly increased leaf numbers compared with the control, but by the fruiting stage, the organic treatment produced significantly more leaves than the inorganic treatment. The enhanced canopy development under comfrey fertilizer likely improved photosynthetic capacity and supported greater plant growth.

Effects on Yield

Fertilizer treatment had a significant effect on tomato yield. Organic comfrey liquid fertilizer produced the highest mean yield (0.373 t ha^{-1}), followed by inorganic fertilizer (0.299 t ha^{-1}), while the control recorded the lowest yield (0.151 t ha^{-1}). ANOVA revealed a highly significant treatment effect on yield ($F(2,24) = 23.548$, $p < 0.001$), demonstrating that fertilizer type was a major determinant of productivity. LSD post-hoc comparisons showed that all pairwise differences were significant, establishing the ranking: Organic >

Inorganic > Control. The superior yield under the organic treatment is likely attributable to improved nutrient availability, enhanced canopy development, and better soil biological activity associated with organic nutrient sources.

Cost Benefit Analysis

Although numerical differences were observed among treatments for several production cost components, ANOVA indicated that these differences were generally not statistically significant. Land preparation, irrigation and weeding, pest and disease management, and harvest/post-harvest costs did not differ significantly among treatments ($p > 0.05$). However, inorganic fertilizer recorded the highest expenditure for fertilization and tended to incur greater costs for irrigation, weeding, and pest management, whereas the organic treatment maintained moderate input costs. Fertilization costs approached statistical significance ($p = 0.096$), suggesting a tendency toward higher resource requirements under the inorganic treatment. Given that organic comfrey fertilizer achieved the highest yield while maintaining relatively moderate production costs, it demonstrated greater economic efficiency and potential profitability than inorganic fertilizer under the conditions of this study. These findings highlight the potential of comfrey liquid fertilizer as a cost-effective and sustainable alternative for tomato production.

Conclusion

The findings of this study demonstrate that fertilizer type significantly influenced tomato growth and yield, with organic comfrey liquid fertilizer consistently outperforming inorganic fertilizer and the unfertilized control. Comfrey fertilizer produced the greatest plant height throughout the growing period, accounting for substantial variation in growth responses (67% at 30 DAS, 80% at 60 DAS, and 95% at 90 DAS). It also resulted in significantly higher leaf production during the fruiting stage and achieved the highest fruit yield per plant (186.67 g), exceeding both inorganic fertilizer (128.56 g) and the control (75.67 g). The superior performance of comfrey fertilizer suggests that it provides a more sustained nutrient supply and promotes enhanced vegetative growth and productivity. Additionally, its relatively low input requirements indicate potential economic advantages for farmers. However, the study's findings should be interpreted within the context of its limitations, including the single-site, single-season design, limited replication, and absence of soil and plant tissue analyses. Further multi-location and multi-season studies are recommended to validate these results and better understand the mechanisms underlying the observed responses.

Limitations

The nutrient composition of comfrey liquid fertilizer varied depending on factors such as growing conditions, harvest time, and preparation methods. This variability may have affected the consistency and replicability of the results obtained in the study. Environmental conditions, including temperature, humidity, and soil characteristics, also influenced the effectiveness of comfrey liquid fertilizer on tomato growth and yield. These factors may have introduced variability into the results and limited the extent to which the findings could be generalized to other locations or environmental conditions.

Controlling all external variables proved challenging during the study. Factors such as pest infestations, disease incidence, and unexpected weather events may have influenced tomato growth and yield, potentially confounding the observed treatment effects.

Furthermore, the study focused primarily on the short-term effects of comfrey liquid fertilizer on tomato growth and productivity. Consequently, the long-term impacts of repeated comfrey fertilizer application on soil health, nutrient dynamics, and sustained tomato yield were not investigated and remain areas for future research.

Recommendations

For practical application, farmers may consider producing and using comfrey liquid fertilizer as an on-farm organic nutrient source, applying it periodically throughout the tomato growth cycle. To maximize benefits and maintain long-term soil productivity, comfrey fertilizer should be integrated with broader soil fertility management practices, including organic matter additions, crop rotation, and effective pest management. Training and extension services can support proper preparation, dilution, and application procedures to ensure effectiveness and minimize contamination risks. Farmers are also encouraged to assess the cost–benefit performance of comfrey fertilizer under their local conditions and conduct small-scale trials before large-scale adoption, as its effectiveness may vary with soil, climate, and tomato variety. Furthermore, attention should be given to quality and safety considerations, including variability in nutrient content and the presence of pyrrolizidine alkaloids in comfrey tissues. Overall, the findings demonstrate that comfrey liquid fertilizer outperformed inorganic fertilizer in enhancing tomato growth, canopy development, and fruit yield, indicating its potential as a sustainable and cost-effective nutrient management option for smallholder and resource-limited farming systems. Continued research and site-specific adaptation are recommended to support wider adoption and long-term sustainability.

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