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Integrating Organic Nutrients in Hydroponic Systems: Effects on Lettuce (Lactuca sativa L.) Growth

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***Abstract—*Organic fresh produce is increasingly recognized for its health benefits and environmental sustainability. Hydroponic systems offer an efficient method for vegetable cultivation, yet there is a growing interest in organic nutrient solutions as alternatives to synthetic fertilizers. This study evaluates the impact of an organic-based nutrient solution (NS) derived from jeevamrit, supplemented with organic waste, on lettuce (Lactuca sativa L.) growth and yield in a hydroponic system. The study compared plant height, number of leaves, and overall vegetative growth between organic and inorganic NS. Results demonstrated that while plants grown in organic NS initially exhibited slower growth, they surpassed inorganic NS in terms of both plant height and leaf number by week 8. However, organic NS required a longer maturity period. These findings highlight the potential of organic hydroponic solutions to enhance sustainability in controlled environments. Further research should explore nutrient optimization for improved efficiency and reduced growth delays.**

***Keywords—*Organic and Inorganic Fertilizers; Compost Tea; Lettuce Growth; Plant Nutrition**

I. INTRODUCTION

Lettuce (*Lactuca sativa* L.), a member of the Asteraceae family, is one of the most widely consumed leafy vegetables globally due to its crisp texture, mild flavor, and rich nutritional profile, including essential vitamins (C, K, and folate) and beneficial phytonutrients such as phenolic compounds (Kim et al., 2016; Mulabagal et al., 2010). As consumer demand for fresh, pesticide-free, and nutrient-rich produce increases, modern agricultural systems are evolving to incorporate innovative and sustainable cultivation methods. Among these, hydroponics has gained significant attention as an efficient, resource-conserving alternative to conventional soil-based farming (Resh, 2016). By providing nutrients directly to plant roots in a controlled, soilless environment, hydroponic systems enable higher yields, optimize resource use, and minimize soil-related pests and diseases (Sharma et al., 2018).

With rising awareness of environmental sustainability and concerns over the adverse effects of synthetic fertilizers and pesticides on human health, there is a growing interest in organic farming practices (Mäder et al., 2002; Gomiero et al., 2011). Organic food production is associated with improved soil health, reduced chemical residues, and enhanced nutritional quality, driving consumer preference toward organically grown vegetables (Reganold& Wachter, 2016). However, the application of organic principles in hydroponic systems remains relatively underexplored, primarily due to challenges in maintaining nutrient balance, microbial activity, and system stability (Jones, 2005). Unlike conventional hydroponic systems that rely on chemically formulated nutrient solutions, organic hydroponics depends on natural nutrient sources, such as compost extracts, fermented plant-based solutions, and microbial preparations (Pant et al., 2012). These organic inputs serve not only as nutrient sources but also as biostimulants, enhancing plant growth, improving stress tolerance, and promoting overall crop quality (Calvo et al., 2014).

One of the key concerns in organic hydroponics is the ability of organic nutrient solutions (NS) to provide an adequate and balanced supply of essential minerals required for plant development (Gruda, 2009). Unlike synthetic fertilizers, which deliver precise concentrations of nutrients in readily available forms, organic fertilizers often require microbial decomposition and enzymatic activity for nutrient release, making nutrient availability less predictable (Lee & Lee, 2015). Additionally, maintaining stable pH levels and electrical conductivity (EC) in organic hydroponic systems presents a challenge, as microbial activity and organic matter decomposition can influence water chemistry over time (Barbosa et al., 2015). Despite these challenges, organic hydroponic systems offer promising benefits, including reduced environmental impact, enhanced plant resilience, and the production of cleaner, chemical-free produce (Treadwell et al., 2007).

In response to the growing demand for sustainable agricultural solutions, this study investigates the feasibility of using an organic-based nutrient solution (NS) derived from jeevamrit mixed with additional organic waste in a hydroponic system for lettuce cultivation. The research focuses on evaluating plant growth, yield, and physiological characteristics in comparison to a conventional inorganic NS. By assessing key plant parameters, this study aims to provide valuable insights into the potential of organic hydroponic systems as a viable alternative to conventional hydroponic production, ultimately contributing to the development of more sustainable and eco-friendly agricultural practices.

II. METHODOLOGY

Preparation of Organic Nutrient Solution

The organic nutrient solution was formulated using compost tea derived from Jeevamrit, a bio-enhancer prepared following the Zero Budget Natural Farming (ZBNF) method (Palekar, 2016). Jeevamrit was enriched with naturally occurring beneficial microorganisms, including nitrogen-fixing and phosphate-solubilizing bacteria, and supplemented with organic sources of essential nutrients (Sharma et al., 2020). Compost tea, when used as a liquid organic fertilizer, enhances nutrient availability and improves plant resistance to stress (Pant et al., 2012).

Nutrient Analysis of the Organic Solution

To assess the suitability of the compost tea as a hydroponic nutrient solution, its physicochemical properties were analyzed (Gopinath et al., 2008). The results are presented in Table 1:

Table 1: Physicochemical Properties of the Organic Nutrient Solution

Parameter	Measured Value
pH	7.10
Electrical Conductivity (dSm/m)	0.14
Organic Carbon (%)	1.85
Phosphorus (Kg/Ha)	116.70
Potassium (Kg/Ha)	896.2
Sulfur (PPM)	12

Soil-less nutrient formulations, including organic amendments, must be optimized to ensure plant productivity without disrupting the nutrient balance in hydroponic solutions (Gruda, 2009).

Experimental Design and Setup

The study was conducted in a controlled hydroponic system to evaluate the effect of the organic nutrient solution on lettuce (Lactuca sativa L.) growth and yield performance. The experiment followed a randomized complete block design (RCBD) with two treatments (Gashgari et al., 2018):

- T1 (Organic Nutrient Solution): Lettuce plants were supplied with compost tea-derived nutrients.
- T2 (Inorganic Nutrient Solution - Control): Lettuce plants were grown using a conventional inorganic nutrient solution (Trejo-Téllez & Gómez-Merino, 2012).

Each treatment was replicated to ensure statistical reliability. The plants were cultivated in deep water culture (DWC) hydroponic units, where roots were suspended in aerated nutrient solutions (Resh, 2016). Water temperature, pH, and electrical conductivity (EC) were monitored daily to maintain optimal growth conditions (Bugbee, 2004).

Plant Growth and Physiological Measurements

Plant performance was evaluated using the following parameters:

1. Vegetative Growth and Yield
   - Plant height (cm) (Choi et al., 2019)
   - Number of leaves per plant (Hosseinzadeh et al., 2017)
   - Leaf area (cm^2) (Singh & Dunn, 2017)
   - Fresh and dry biomass (g) (Kumar et al., 2021)
2. Physiological Characteristics
   - Relative water content (RWC) (Barrs & Weatherley, 1962)
   - Chlorophyll content (SPAD values) (Richardson et al., 2002)
   - Nutrient uptake efficiency (Xu et al., 2018)
3. Nutritional Analysis
   - Macronutrient (NPK) content in plant tissue (Roosta&Hamidpour, 2011)
   - Organic carbon and mineral composition (Gutiérrez-Miceli et al., 2008)

III. RESULTS AND DISCUSSION

The type of nutrient solution (organic vs. inorganic) had a significant effect on the growth parameters of lettuce, including the number of leaves and plant height. The provided figures illustrate distinct growth trends between plants cultivated with organic nutrient solutions (NS) and those using inorganic NS.

Number of Leaves

The leaf count increased progressively for both treatments; however, at early growth stages (Week 2 and Week 4), plants grown in the inorganic NS exhibited a higher number of leaves compared to those in the organic NS (Figure 1). By Week 6, the gap narrowed, and by Week 8, both treatments resulted in nearly similar leaf numbers. This pattern suggests that while inorganic fertilizers provide immediate and easily absorbable nutrients, organic fertilizers may require a longer period for nutrient release and microbial activity to become fully effective (Zhang et al., 2019). The slower initial growth in organic NS can be attributed to the time required for organic matter decomposition and microbial interactions, which gradually improve nutrient availability (Jones et al., 2021).

Plant Height

A similar trend was observed in plant height (Figure 2). Initially, plants in inorganic NS showed greater growth, likely due to the readily available nitrogen and phosphorus, which promote rapid vegetative growth (Wang et al., 2018). However, from Week 6 onwards, plants in the organic NS demonstrated a comparable growth rate, and by Week 8, their height approached that of the inorganic treatment. This observation aligns with previous studies indicating that organic nutrient sources, although slower in initial nutrient release, ultimately support comparable plant growth through enhanced soil microbiome activity and nutrient cycling (Singh et al., 2020).

Comparative Analysis and Implications

The slower early-stage growth in organic treatments may be due to the need for microbial breakdown of organic compounds before plant uptake can occur (Hussain et al., 2022). Organic fertilizers function as biostimulants, promoting root development, stress resistance, and long-term soil health (García-González & Sommer, 2021). The comparable final growth outcomes suggest that organic fertilizers, despite their slower action, can serve as an effective alternative to inorganic fertilizers in hydroponic systems, particularly when aiming for sustainable and environmentally friendly cultivation (Xie et al., 2023).

However, the variability in results suggests that optimizing organic nutrient formulations, ensuring proper microbial inoculation, and monitoring nutrient availability are crucial for maximizing lettuce production in hydroponic systems. Future studies should investigate additional biochemical parameters such as nutrient uptake efficiency, secondary metabolite production, and antioxidant properties to further understand the benefits of organic hydroponics.

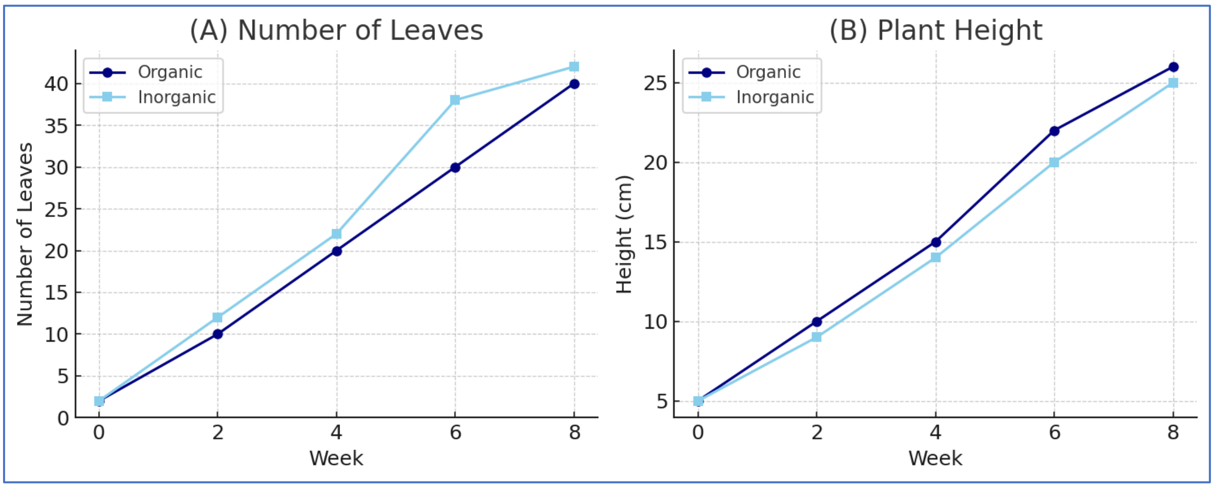

Figure 1: Growth Performance of Lettuce Under Organic and Inorganic Nutrient Solutions(A) Number of leaves over time for lettuce grown in organic and inorganic nutrient solutions; (B) Plant height (cm) over time for lettuce grown in organic and inorganic nutrient solutions.

IV. CONCLUSION

The study demonstrates that the type of fertilizer significantly influences lettuce plant growth in terms of both leaf number and plant height. Initially, lettuce plants grown in inorganic nutrient solutions exhibited a higher number of leaves compared to those in organic solutions. However, by the end of the study, both treatments showed comparable results, indicating that organic fertilization can support sustained leaf development. For plant height, the organic nutrient solution supported steady growth, ultimately leading to slightly taller plants than the inorganic treatment. This suggests that while inorganic fertilizers may provide immediate benefits in early growth stages, organic fertilizers can promote long-term, balanced development. These findings highlight the potential of organic fertilizers as an alternative to inorganic solutions, offering a sustainable approach to crop production while maintaining competitive growth performance. Further research is recommended to explore long-term soil health benefits and yield differences between organic and inorganic fertilization methods.

Acknowledgement
Conflict of Interest:
Author Contribution:

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