

EFFECTS OF DIFFERENT FERTILIZERS AND SUBSTRATES ON THE LEAF DEVELOPMENT OF LACTUCA SATIVA IN HYDROPONIC CULTURE

Kuchkorova Gulasal

**Tashkent Institute of Irrigation and Agricultural Mechanization Engineers
(TIAME)-National Research University**

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Abstract: This study investigates the influence of various fertilizers and substrates on the leaf development of *Lactuca sativa* (lettuce) grown under hydroponic conditions. A comparative analysis was conducted using four substrates (vermiculite, perlite, coco coir, and rockwool) and six fertilizer treatments: mineral salts, humic acid, humic acid + mineral salts, microalgae, microalgae + mineral salts. The results indicate significant variations in leaf number depending on the combination of substrate and fertilizer, with rockwool and microalgae + mineral salts showing the highest efficacy.

Annotation

This article explores the effects of various fertilizer types and substrates on the leaf development of *Lactuca sativa* (lettuce) grown in a hydroponic Nutrient Film Technique (NFT) system. The study evaluated four different substrates—vermiculite, perlite, coco coir, and rockwool—combined with six fertilization treatments, including mineral salts, humic acid, and microalgae-based biofertilizers. The results demonstrated that substrate and fertilizer combinations significantly influenced the number of leaves developed by the lettuce plants. The combination of rockwool substrate and microalgae + mineral salts fertilizer yielded the highest leaf production, highlighting the synergistic effect of bio-organic and inorganic nutrient inputs in controlled environment agriculture. The research further supports the environmental and agronomic benefits of integrating biofertilizers into hydroponic systems and emphasizes the potential for sustainable crop production practices in areas with limited arable land. This work contributes valuable insight into resource-efficient and high-yield cultivation strategies relevant to modern soilless agriculture.

Keywords: Hydroponics, *Lactuca sativa*, biofertilizers, substrates, microalgae, mineral salts

1. Introduction Hydroponic systems offer an efficient and sustainable solution to modern agricultural challenges, particularly in regions with limited arable land and changing climatic conditions. *Lactuca sativa*, commonly known as lettuce, is a popular leafy vegetable suitable for hydroponic cultivation due to its rapid growth cycle and responsiveness to nutrient management. This research aims to evaluate how different substrates and fertilizer combinations affect the number of leaves, an important indicator of plant vigor and productivity. Due to its adaptability and versatility in a variety of dishes, such as salads, stews, vegetable curries, sandwiches, and garnishes, lettuce is a critical component of contemporary diets. Its appeal is not limited to the enhancement of the visual and sensory quality of meals; it also substantially contributes to nutritional intake. Moreover, its capacity to be cultivated in a variety of agroecological zones ensures that it is available and accessible in both local and international markets during the year. In addition to its nutritional value, lettuce is becoming increasingly acknowledged for its therapeutic potential. It is recognised as a substantial source of phytonutrients, which are bioactive compounds that possess disease-preventive, anti-inflammatory, and antioxidant properties. These phytochemicals, in conjunction with

essential vitamins and minerals, establish lettuce as a functional food that can offer health benefits that exceed those of fundamental nutrition. The Deep Flow Technique (DFT) and Nutrient Film Technique (NFT) are two of the most common hydroponic systems used for the cultivation of verdant vegetables. Ensures the continuous availability of water and nutrients by replenishing nutrient solutions when water levels decline below a critical threshold in DFT systems. A thin nutrient film that travels over plant roots is the foundation of NFT systems, which are frequently employed in plant factories. For example, NFT is less water-intensive and space-efficient, while DFT guarantees nutrient supply even in the event of pump malfunctions. Each system has its own set of advantages. These systems ensure that the nutrient cycle remains consistent, thereby fostering the optimal conditions for the growth of crops like lettuce. As a modern cultivation system, soilless cultivation offers significant advantages over conventional soil-based agriculture, particularly in enhancing both the yield and quality of horticultural crops. This is achieved by precise regulation of the composition and quantity of nutrient solutions, as well as the properties of the growing media (Nerlich and Dannehl, 2021). At present, rockwool (RC) and coconut coir (CC) are among the most widely used substrates in greenhouse horticulture. Rockwool, in particular, has been utilized for decades due to its optimal physical and chemical characteristics, making it suitable for a wide range of crops.

Solid substrate cultivation is extensively employed in greenhouse vegetable production, particularly for fruit-bearing crops such as tomato and cucumber. In Europe, the United States, and Canada, it is estimated that approximately 95% of greenhouse vegetables are cultivated using solid substrates (Grunert et al., 2016). Traditionally, RC and peat have served as the primary materials for substrate-based cultivation systems (Bunt, 1988; Sonneveld, 1993; Raviv and Lieth, 2008). RC, produced by melting diabase and limestone at high temperatures ($\sim 1600^{\circ}\text{C}$), exhibits a stable structure, high water-holding capacity, and moderate porosity, making it favorable for plant growth (Sonneveld, 1993; Raviv and Lieth, 2008). However, as an inorganic and non-biodegradable material, RC presents environmental challenges due to the accumulation of waste in landfills (Cheng et al., 2011).

2. Materials and Methods The experiment was conducted in a controlled greenhouse environment at the Laboratory of Biological Research and Food Expertise, under the Institute of Fundamental and Applied Research at TIAME National Research University. The environmental parameters were kept constant throughout the study: temperature ($22^{\circ}\text{C} \pm 2$), relative humidity (60–70%), and a 16-hour light/8-hour dark photoperiod using LED lighting with a photosynthetic photon flux density (PPFD) of approximately $200 \mu\text{mol m}^{-2} \text{s}^{-1}$.

Lactuca sativa seedlings of uniform size and age were used in the experiment. Seedlings were first germinated in rockwool cubes under nursery conditions and then transplanted into the hydroponic NFT (Nutrient Film Technique) system.

The NFT system consisted of horizontal PVC channels through which nutrient solutions continuously flowed in a thin film, ensuring direct root contact and efficient nutrient uptake. The system was maintained with a closed-loop circulation pump, and nutrient reservoirs were routinely monitored and refilled.

Four different substrates were used to support root anchorage and nutrient absorption: vermiculite, perlite, coco coir, and rockwool.

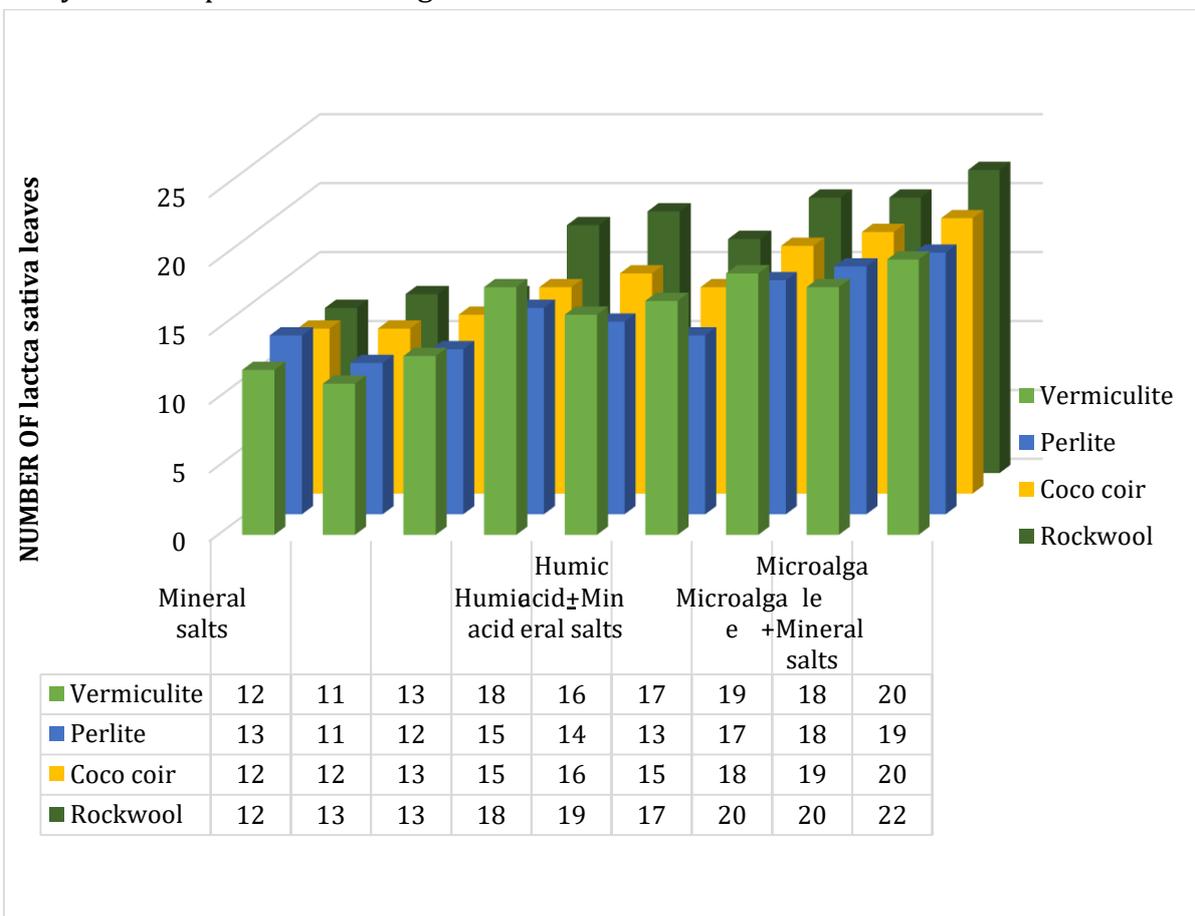
Six distinct fertilizer treatments were applied:

1. Mineral salts (standard NPK hydroponic formulation)
2. Humic acid
3. Humic acid + mineral salts
4. Microalgae extract (from *Spirulina platensis*)
5. Microalgae + mineral salts

Fertilizer application was standardized for concentration and frequency to avoid bias in nutrient supply. Solutions were prepared fresh weekly.

The primary parameter measured was the number of true leaves per plant. Observations were made after a 30-day growth period post-transplantation. Leaf counts were conducted manually on a representative sample of plants per treatment group.

The data were statistically analyzed using ANOVA followed by post hoc Tukey's HSD test to determine significant differences between treatments at a 95% confidence level ($p < 0.05$). All analyses were performed using SPSS software.



3. Results and Discussion The data show clear differences in leaf development across treatments and substrates:

- **Mineral salts:** Average leaf counts ranged from 11 to 13, with perlite yielding the lowest number (11) and rockwool the highest (13).
- **Humic acid:** The addition of humic acid alone slightly increased leaf production, with leaf counts ranging from 12 (perlite) to 16 (rockwool).
- **Humic acid + mineral salts:** A more notable improvement was observed with this combination, particularly in rockwool (19 leaves), compared to 14 in perlite.
- **Microalgae:** Treatments using microalgae showed significant enhancement in leaf

number, especially with coco coir (18 leaves) and rockwool (20 leaves).

- **Microalgae + mineral salts:** This combination achieved the highest leaf count overall, with rockwool producing 22 leaves and vermiculite 20.

These results highlight that rockwool consistently supported superior leaf growth, and that biofertilizers, particularly microalgae in combination with mineral salts, maximized productivity.

The synergy between organic and inorganic fertilization appears to enhance nutrient uptake efficiency, likely due to improved microbial activity and nutrient availability facilitated by the biofertilizers.

4. Conclusion This study confirms the beneficial impact of combining microalgae with mineral salts on lettuce growth in hydroponic systems. Among the tested substrates, rockwool proved to be the most effective medium for supporting leaf development. The integration of biofertilizers into hydroponic nutrient management strategies represents a sustainable path forward for increasing crop yields while minimizing environmental impacts.

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