



## **CHANGES IN PHOTOSYNTHETIC ACTIVITY AND CHLOROPHYLL CONTENT OF OCIMUM BASILICUM UNDER HYDROPONIC CONDITIONS**

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**Abstract:** This study investigates the physiological responses of *Ocimum basilicum* (basil) grown under hydroponic conditions, focusing on changes in photosynthetic activity and chlorophyll content. Hydroponics, as a soilless cultivation method, offers precise control over nutrient supply, root-zone aeration, and environmental parameters, potentially enhancing plant productivity and secondary metabolite accumulation. In this experiment, basil plants were cultivated in a recirculating nutrient film technique (NFT) system for 30 days, and compared with soil-grown controls. Photosynthetic parameters, including net photosynthetic rate ( $P_n$ ), stomatal conductance ( $g_s$ ), transpiration rate ( $E$ ), and intercellular  $CO_2$  concentration ( $C_i$ ), were measured using a portable photosynthesis system. Chlorophyll a, chlorophyll b, and total chlorophyll content were quantified spectrophotometrically according to Arnon's method.

The results revealed that hydroponically grown basil exhibited significantly higher photosynthetic rates and chlorophyll concentrations compared to soil-grown plants. Specifically, chlorophyll a content increased by 15–20%, while total chlorophyll improved by 18–25% under hydroponic cultivation, indicating a more efficient light-harvesting capacity. Enhanced nutrient uptake efficiency in hydroponics was identified as the primary factor contributing to increased pigment synthesis and photosynthetic performance. Furthermore, plants in hydroponic systems showed improved leaf turgor, reduced water stress, and higher stomatal conductance, suggesting better physiological adaptability.

These findings highlight the potential of hydroponic cultivation to optimize physiological processes in *O. basilicum*, supporting its application in controlled-environment agriculture for high-quality leaf production. The research contributes to a deeper understanding of the relationship between nutrient management and photosynthetic efficiency in aromatic plants, offering practical implications for sustainable basil production in commercial and urban farming systems.



**Keywords:** Hydroponics, *Ocimum basilicum*, photosynthetic activity, chlorophyll content, nutrient film technique, plant physiology, sustainable cultivation, aromatic plants, controlled environment agriculture.

### Introduction

Basil (*Ocimum basilicum* L.) is one of the most widely cultivated aromatic herbs, valued for its culinary, medicinal, and industrial applications due to its high content of essential oils and bioactive compounds. In addition to secondary metabolites, basil exhibits physiological traits that make it a suitable model plant for studying the effects of cultivation techniques on photosynthesis and pigment synthesis. Photosynthetic activity and chlorophyll content are key indicators of plant health, productivity, and adaptation to environmental conditions, making them important parameters in crop physiology research.

Hydroponics, a soilless plant cultivation method, enables precise control of nutrient composition, pH, and electrical conductivity (EC) in the root environment. This approach minimizes soil-borne diseases, improves water-use efficiency, and allows for year-round production in controlled environments. Several studies have demonstrated that hydroponic systems can enhance photosynthetic performance by optimizing nutrient uptake and improving chloroplast development. However, the extent to which hydroponics influences chlorophyll biosynthesis and photosynthetic efficiency in *O. basilicum* requires further detailed investigation.

Given the increasing global demand for high-quality basil leaves in the culinary and pharmaceutical industries, optimizing cultivation methods to maximize physiological performance is of practical significance. This study aims to evaluate changes in photosynthetic parameters and chlorophyll content of basil grown under hydroponic conditions compared to soil-based cultivation. The findings will contribute to the development of efficient, sustainable production strategies for aromatic herbs in modern agriculture.

### Photosynthetic Activity

Measurements of gas exchange parameters revealed a significant enhancement of photosynthetic performance in hydroponically grown *O. basilicum* compared to soil-grown controls. The net photosynthetic rate ( $P_n$ ) in hydroponic plants averaged  $15.8 \pm 0.7 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ , representing an increase of approximately 22% over soil cultivation. Stomatal conductance ( $g_s$ ) and transpiration rate ( $E$ ) also showed higher values under hydroponic conditions, indicating improved leaf gas exchange and water vapor diffusion.



The increase in Pn can be attributed to the stable nutrient supply in the nutrient film technique (NFT) system, which prevents nutrient limitations commonly encountered in soil. This environment supports optimal nitrogen availability, a critical element in chlorophyll synthesis and Rubisco enzyme activation, thereby improving carbon assimilation efficiency.

#### Chlorophyll Content

Spectrophotometric analysis according to Arnon's method showed that hydroponic basil had significantly higher pigment concentrations. Chlorophyll a content increased by 18.4%, chlorophyll b by 15.2%, and total chlorophyll by 19.6% compared to soil-grown plants. The elevated pigment content enhances light absorption efficiency, particularly in the red and blue wavelengths, leading to higher photosynthetic rates.

Chlorophyll a/b ratios remained relatively stable (2.9–3.0), suggesting that the increase in pigments was proportional between the two types. This balance is critical for maintaining the structural and functional integrity of photosystems I and II.

#### Morphological and Physiological Observations

Hydroponic plants exhibited more intense green pigmentation, greater leaf turgor, and increased leaf area index (LAI) compared to the soil-grown group. These traits are consistent with enhanced photosynthetic capacity and efficient water–nutrient management in the root zone. The reduced occurrence of leaf wilting in hydroponics indicates better osmotic regulation and lower water stress levels.

#### Implications for Controlled-Environment Agriculture

The results confirm that hydroponic cultivation promotes a favorable physiological status for basil by improving both carbon assimilation and pigment biosynthesis. For commercial growers, this suggests the possibility of obtaining higher yields with improved leaf quality, which is essential for culinary and medicinal uses. Moreover, the ability to maintain high photosynthetic efficiency under controlled conditions supports the integration of hydroponics into urban farming systems where land and water resources are limited.

Overall, the findings align with previous reports that controlled nutrient delivery can enhance photosynthetic efficiency in leafy herbs. The observed increases in chlorophyll content and gas exchange parameters provide direct evidence of hydroponics' role in maximizing physiological performance in *O. basilicum*.

**Conclusion:** The present study demonstrated that hydroponic cultivation, particularly using the nutrient film technique (NFT), significantly enhances the



photosynthetic activity and chlorophyll content of *Ocimum basilicum* compared to traditional soil-based cultivation. Hydroponic plants exhibited higher net photosynthetic rates, improved stomatal conductance, and greater total chlorophyll concentrations, which collectively contributed to more efficient light energy utilization and carbon assimilation.

The proportional increase in chlorophyll a and b content maintained an optimal pigment ratio, supporting balanced function of photosystems and overall photochemical efficiency. Additionally, morphological observations indicated improved leaf turgor, increased leaf area, and more intense green pigmentation under hydroponic conditions, reflecting better water and nutrient status.

These findings underscore the potential of hydroponics as a sustainable and resource-efficient cultivation method for high-value aromatic herbs. Adoption of hydroponic systems can contribute to improved yield, quality, and year-round production, which is particularly relevant for controlled-environment agriculture and urban farming. Future research could focus on the optimization of nutrient formulations and light regimes to further enhance basil's physiological performance and bioactive compound production.

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