

COMPARATIVE STUDY OF MICROGREENS GROWN IN HYDROPONIC SYSTEM AND SOIL-BASED SYSTEM

A.Umadevi Pongiya
Dhanalakshmi Srinivasan College of Arts and Science for
Women(A), Perambalur

K.A.Jayanthi
Dhanalakshmi Srinivasan College of Arts and Science for
Women (Autonomous), Perambalur

Sheela Thangaraj
Dhanalakshmi Srinivasan College of Arts and Science for
Women (Autonomous), Perambalur

S. Seema
Dhanalakshmi Srinivasan College of Arts and Science for
Women (Autonomous), Perambalur

Abstract

Traditional soil-based farming is increasingly facing challenges such as soil degradation, water scarcity, and the effects of climate change. These issues threaten global food security, especially with the world's population expected to reach 9.7 billion by 2050. To meet the growing demand for food, agricultural output must increase significantly. However, conventional farming practices are often inefficient and harmful to the environment. As a result, alternative farming methods, such as hydroponics, aquaponics, and aeroponics, are gaining popularity. Hydroponics, a method of growing plants without soil, offers a sustainable solution. It uses nutrient-rich water instead of soil, allowing for more efficient use of water, space, and nutrients. This method can be practiced indoors, in urban areas, or in controlled environments, making it a flexible and eco-friendly alternative to traditional agriculture. There are various hydroponic techniques, including Deep Water Culture (DWC) and Nutrient Film Technique (NFT), which deliver nutrients and oxygen directly to the plant roots, promoting healthy growth. Microgreens, small plants harvested at an early stage, are well-suited for hydroponic systems. They are nutrient-dense, offering high levels of vitamins,

minerals, and antioxidants. Their fast growth cycle and small space requirements make them ideal for urban farming and commercial production. Additionally, combining hydroponic systems with organic fertilizers can further reduce costs and improve yields, making it a sustainable option for food production. This review highlights the potential of hydroponics and microgreens as effective solutions to the challenges faced by conventional agriculture, offering a more sustainable and efficient way to produce food in the future.

Keywords: Conventional agriculture, Hydroponic system, Microgreens, Plant growth, Nutrient-rich water, Food security, Controlled environment agriculture (CEA), Water scarcity, Climate change.

I. INTRODUCTION

A. Conventional soil-based agriculture

In numerous countries around the world, Farming has continuously been a fundamental industry. It is more important sort of plant that underpins life on soil in numerous ways (Dutta, Monica, et al., 2023)¹⁴. The advancement or philosophy of different food-growing frameworks can be utilized to distinguish them, specifically, surveying surrender

and quality over development frameworks is regularly troublesome, due to the complex intelligence between genotype, physiology, and environment. Bewildering factors are as often as possible neglected in distributed comparisons, and also there is a need to distinguish the most fruitful and proficient strategies for nourishment generation, controlled comparisons must be carried out.

Since it is predicted that there will be 9.7 billion people on the planet by 2050. According to estimates, half of the world's arable land will be useless for agriculture at the same time (Gashgari et al., 2018)18. Therefore, in order to fulfil the huge consumer demand, agricultural output must be expanded by 110%. If the demand is not met, the food crisis is predicted to continue until 2050 (Okemwa, E. 2015)29. The primary cause of this disasters is climate change, which has led to an increase in the frequency of floods and drought. Another factor is soil erosion and degradation brought on by conventional agricultural practices, which primarily rely on the soil and deplete its vitamins and minerals. As a result, the world must create and implement methods to enhance and raise agricultural systems' productivity. These days, farming systems are mostly dependent on soil, water, and disaster resistance. Therefore, the economic policies of the current farming systems must be developed and changed (Gashgari et al., 2018).

Decreased soil yield in agricultural areas, low soil fertility after many years of constant cultivation, and most importantly a decline in the amount of land available to each person are the main problems facing conventional soil-based agriculture. Climate change also includes increased temperatures, more frequent dry spells, unpredictable weather patterns, inadequate

management of water resources within the watershed due to excessive irrigation, which wastes a significant amount of water, uncontrolled pollution of water bodies, and a drop-in groundwater level. These issues pose a severe threat to traditional soil-based agricultural systems, which makes food production increasingly difficult in the modern era. Therefore, more productive and environmentally friendly types of modern farming must be used in combination with conventional soil-based agricultural methods. Today's challenges such as decreased soil productivity, inadequate mineral maintenance, insufficient irrigation water, and climate change should all be taken into consideration by these contemporary agricultural practices. Promoting agricultural methods independent of soils is one way to address these contemporary issues (Majid, Maliqa, et al., 2021)27.

B. Hydroponic System

The idea of cultivating crops indoors was developed to guarantee a consistent production throughout the year. Horizontal towers have been employed for the cultivation in order to save space (Chaudhry et al., 2019)9. Providing optimal conditions required for the crops to flourish all year is also termed Controlled Environment Agriculture (CEA) (Belista, Francis Carl L., et al., 2018)7. The primary goal of CEA is to improve crop quality in an environmentally friendly manner with the least amount of energy, space, labour, investment, and water, in the process facilitating a high yield in a small area. Because it uses fewer resources and costs and yields the best results year-round, regardless of seasonal dependencies, vertical farming is more sustainable than conventional agriculture.

The three artificial farming techniques are hydroponics, aquaponics, and aeroponics. Aeroponics is a vertical farming technique in which the plants are suspended in the air and nutrition water is applied by spraying on the lower portions of the stems and roots. The growing media source in the aquaculture growing technique is water that has been enriched with nutrients. An aquaculture ecology is preserved in the aquaponics method of artificial cultivation. A tank has been employed for cultivating fish, and the hydroponics system consumes water from the fish tank. The water is cleansed and then recycled for the fish, and plant compost is generated from fish. Fish and vegetation survive in this ecosystem in this way (Dutta, Monica, et al., 2023)¹⁴.

While lowering the dangers connected with soil-based cultivation systems, soilless or liquid culture techniques may be used as supplemental cultivation systems to offer an effective remedy to the current challenges related to water and fertile agricultural land scarcity. One such specialized technique that includes growing plants without soil is hydroponics, sometimes known as liquid culture. It is founded on the same principles that nature established as the pattern of life, therefore even though it is artificial, it is not an unnatural method of producing crops (Majid, Maliqa, et al., 2021)²⁷. A sustainable and eco-friendly farming method, hydroponics enables plants to thrive without the need for soil (Sousa, Rui de et al., 2024)⁴⁰. The deep flow technique (DFT), deep water culture hydroponics (DWC), and nutrient film technique (NFT) are among the cultivation methods that the hydroponic system primarily uses. By giving root systems more oxygen than the DFT and floating method, the NFT encourages healthier growth (Majid, Maliqa, et al., 2021)²⁷. Due to the

convenience of setup and administration, it is appropriate for small or urban farm operations, uses less space, and enables effective water and fertilizer administration through a thin, continuous film (Nitu, Oana Alina, et al., 2024)²⁸. One kind of stationary system that uses floating rafts to support plants is the DWC hydroponic system (Gillani, Syed Abreez, et al., 2023)²¹. These rafts float on hydroponic beds that are filled with water that is rich in nutrients. In contrast, NFT hydroponic systems do not require a substrate and are made up of grow channels that use a mechanical pump to circulate a layer of nutrient solution (Abbasi et al., 2021)¹. Through ponds, the Deep Flow Technique (DFT), a hydroponic technique, employs water as a medium to deliver nutrients to plants. Plants are grown in drainage channels with a nutritional solution that flows continuously. Each channel is about four to six cm high, with the root system of each plant constantly submerged in the solution that contains nutrients. After being gathered back into the nutrient basin, the nutrients and other solutions will be constantly being transported to the planting pond using an irrigation pipe (Pramono, S., et al., 2020)³¹.

Hydroponics can be thought of as a method to grow crops that uses a mixture of nutrients which has been customized to give the determined resource necessary for the growth and development of plants, along with a soilless cultivating substrate. Water management can be defined as the art of controlling water, adding nutrients that plants require, and supplying those nutrients to thirsty roots as needed to maximize yields in the same amount of space while consuming significantly less water and labor. Because hydroponically produced plants are fed a well-balanced diet, they are healthier than their

counterparts cultivated on soil. Since hydroponics allows for total control over crop nutrition, it uses only the quantity of both nutrients and water needed for each crop, which improves water management and nutritional regulation. This is in contrast to conventional agriculture. Hydroponics is generally regarded as a superior method of agriculture in almost every country in the world for the reasons indicated above (Majid, Maliqa, et al., 2021)²⁷.

In developed nations, hydroponic cultivation has been utilized more and more, and several crops, such as tomatoes, cucumbers, lettuce, and others, have been examined using hydroponics (Lee and Lee, 2015)²⁵. The approach is still in its development in developing countries, though, and requires a great deal of study on several topics before being used in crop production. In India, the persistent population expansion has created a market eager to acquire locally cultivated hydroponic vegetables. However, the technique is still far from being used because there is a dearth of research and proof on the several facets of the technology that would both solve producers concerns and provide insight into the production process (Majid, Maliqa, et al., 2021)²⁷. Hydroponic systems require a strong root system, a balanced solution flow rate, sufficient oxygen levels, and ideal greenhouse conditions in order to provide the best possible crop production Al-(Razzaq Tawaha, A., et al., 2018)³⁴. The uptake of nutrients, the growth of roots (increasing shoot and root weights), maintenance, and protection against root-borne diseases all depend on a healthy root system. By establishing a highly oxygenated root zone environment, this is accomplished. Research has indicated that a sufficient amount of dissolved oxygen in the root zone greatly enhances plant

development, yield, and resistance to stress. For instance, by preserving root function and encouraging the development of aerenchyma, which promotes internal oxygen transfer inside the roots, a high amount of dissolved oxygen can lessen the negative impacts of waterlogging and hypoxia (Galindo-Castaneda, Tania, et al., 2022)¹⁷. Insufficient oxygen in the root system zones can impair the function of plant leaves and roots and enhance the risk of disease development (Balliu, Astrit, et al., 2021)⁶. The critical role of oxygen in a variety of plant biochemical processes, such as cellular respiration, oxidative phosphorylation, and reactive oxygen species (ROS), which are essential to particular plant growth characteristics, has been clarified by numerous researches. As a molecular mechanism, oxygen facilitates oxidative phosphorylation, which produces ATP (Taiz, Lincoln, et al., 2010)⁴¹. Dissolved oxygen (DO) is essential for the development and growth of roots. For respiration, a vital function that produces the energy needed for the uptake of nutrients and water, roots require oxygen. The research emphasizes how crucial it is to address root system oxygenation in order to enhance plant productivity and resistance in a range of ecological and commercial scenarios (Fagerstedt, Kurt V., et al., 2024)¹⁵.

C. Components of Hydroponics

A supporting medium, like cocopeat, is used to hold the plants in place, and at predetermined intervals, freshwater dissolved with sufficient quantities of nutrients is given to the roots (Dutta, Monica, et al., 2023)¹⁴. These systems are among the most promising approaches to growing high-quality crops in arid regions and places with a shortage of fertile

agricultural land because they effectively employ scarce water and fertilizer resources (Di Gioia, Francesco, et al., 2018)¹². These systems use a variety of substrates, including water culture systems with nutrient solutions (NS) made from water-soluble nutrients and organic as well as inorganic growing medium (Poudel, P., et al., 2023)³⁰. Generally speaking, the growing medium's moisture content, pH level, ambient light, and temperature must all be regulated. Except for sunlight, every setting is manually controllable. Grow lights are therefore used to conduct indoor farming in metropolitan settings in place of this natural resource. There are several varieties of grow lights available, including fluorescent, high-pressure sodium (HPS) high-intensity discharge (HID), and light-emitting diode (LED) grow lights (Hemathilake, D et al., 2022)²⁴. Another key element of hydroponic cultivation is a nutrient solution, that provides water, oxygen, and vital minerals to plant roots in a soluble form, promoting the best possible growth and development (Baiyin, Bateer, et al., 2021)⁵. Plant health and excellent yields depend on maintaining the proper ratio of water, oxygen, and minerals, managing fertilizer solutions well, and choosing the optimal hydroponic system (Wibisono, V., et al 2021)⁴⁶. Roots require oxygen for energy production and nutrient absorption. Other techniques, such as aeroponics, in which roots are suspended in air and misted with nutrient solution, and oxygenating the nutritional solution with air stones or oxygen generators, can augment the oxygen supply, which is primarily provided by the dissolved oxygen (DO) in the nutrient solution. The importance of LED illumination and root oxygen delivery tackles several contemporary issues in hydroponic farming (Resh, H.

M. 2022)³⁵. Strong development is encouraged by optimal light exposure, which improves photosynthesis in leaves, and sufficient root oxygenation, which guarantees effective energy release from carbohydrates. Effective LED lighting can have a big impact on hydroponic development because it emits specific wavelengths that optimize photosynthesis while using the least amount of energy. Combining cutting-edge root zone oxygenation methods with an LED light source that is regulated to enhance plant health, boost yields, and generate better quality. Thus, to overcome the drawbacks of conventional hydroponic techniques and promote sustainable agriculture, creative solutions in these fields are crucial (ARSHAD, Adnan, et al., 2023)⁴.

A consistent soil moisture content at the soil surface cannot be maintained throughout the year using the traditional method. Evaporation risks, soil texture, excessive agricultural field irrigation, vapor flux, and heat exchange challenges can all arise (Sunny Goh Eng Giap et al., 2022)²⁰. The hydroponic method is one way to get around these restrictions while growing plants.

D. AB Mix nutrient solution

AB Mix nutrition is a frequently used additive in hydroponic fertilizers. The use of the AB mix nutrient solution comes with a relatively high cost. Thus, there is a need for alternative technologies to advance hydroponic methods, which will ease the growing of plants in hydroponic systems (Trisnawati, D.P., and Suparti 2023)⁴⁴. The AB mix consists of two components: formula A and formula B. Formula A, designed specifically for vegetables, includes calcium ammonium nitrate {5Ca (NO₃)₂.

$\text{NH}_4\text{NO}_3 \cdot 10\text{H}_2\text{O}$ }, potassium nitrate (KNO_3), Fe-chelate, and Fe-EDTA, while Formula B comprises potassium dihydrophosphate (KH_2PO_4), ammonium sulfate $\{(\text{NH}_4)_2\text{SO}_4\}$, potassium sulfate (K_2SO_4), magnesium sulfate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), and manganese (II) sulfate ($\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$), Copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), zinc sulfate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$), boric acid (H_3BO_3), and ammonium heptamolybdate $\{(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}\}$ are substances of interest (Miftah A Harahap et al., 2020)²³. In hydroponic vegetable cultivation, incorporating liquid organic fertilizer alongside AB Mix is essential to reduce the reliance on inorganic fertilizers. The primary component of tea pulp can be blended with AB Mix fertilizers and liquid organic fertilizer to decrease production costs. Organic material-derived fertilizers consist of sawdust, household waste, plant materials, and animal manure. This organic fertilizer can be made in a way that is sustainable through the utilization of organic waste. There are two types of natural fertilizers: solid and liquid. It is more beneficial to use liquid organic fertilizers than solid ones. This kind of organic fertilizer is referred to as liquid organic fertilizer since it is liquid in consistency and readily absorbed in the soil. Among the benefits of liquid organic fertilizer are its ease of preparation and short turnaround time, its ability to enhance soil particle structure, and its ease of application. According to studies, the ideal way to use liquid organic fertilizer in hydroponics is to combine it with AB Mix nutrients. This way, the nutrients complement one other and can have a perfect effect on plant growth and productivity. Consequently, in order to meet the nutritional needs of crops, liquid organic fertilizer is employed as a

substitution in AB Mix nutrition (Trisnawati, D.P., and Suparti 2023)⁴⁴.

E. Microgreens

Immature leafy green alternatives that are called microgreens are becoming more popular in the culinary community because of their unique flavors and abundant vitamin profiles (Ghoora, Manjula D et al., 2020)¹⁹. Their early growth stage, which typically displays two fully grown cotyledon leaves and the earliest stages of the first set of genuine leaves, helps identify them (Singh, Mandeep, et al., 2023)³⁹. Although microgreens have been grown commercially since the 1980s, their appeal has grown recently among eateries and health-conscious people. Microgreens are a growing type of leafy green made from several kinds of crop seeds, such as vegetables, herbs, grains, legumes, and beans. They provide better bioavailability of minerals, vitamins, flavonoids, phenolic compounds, dietary fibers, enzymes, chlorophylls, and antioxidants, all of which lower the risk of cancer, heart disease, and other illnesses (Dimita, Rosanna, et al., 2022)¹³.

Microgreen production involves a variety of growth methods, including soil-based and soilless systems, as well as regulated indoor, outdoor, and other conditions (Sharma, Avinash, et al., 2024)³⁷. Microgreens are a great option for domestic developing, urban and semi-urban farming, and transit distance reduction because to their quick development cycle (7–21 days), low spatial needs, and high nutritional profile (Tavan, M. et al., 2021)⁴². Numerous factors, including the selection of suitable species, growing conditions, substrate types, seed quality and purity, germination processes, irrigation techniques, fertilizer application, harvesting

methods, phytosanitary standards, and post-harvest conditions of storage, affect the commercialization and the cultivation at home of microgreens (Luo, L. et al., 2024)²⁶. The nutritional makeup of microgreens is not well understood, although several studies indicate that they contain more antioxidant chemicals than mature plants of the same type (Yadav, Lalu Prasad, et al., 2019)⁴⁸.

The benefits of growing particular microgreens in hydroponic systems or soilless media supplemented with nutrients have been the subject of numerous studies (Chen, Hsiangting, et al., 2020)¹⁰. The growing media used to cultivate rapini microgreens that are used peat moss and artificial mats (Di Gioia, Francesco, et al., 2017)¹¹. Tissue media (tissue paper with water), foam media (foam with water), soil media, and soil + cow dung (1:1) ratio of medium were utilized for the development of mustard, leaf mustard, radish, and cabbage microgreens (Agric Res, J. 2019)². In a different study, the kale (*Brassica oleracea*), Swiss chard (*Beta vulgaris* L), arugula (*Eruca sativa*), and pak choi (*Brasica rapa* var *chinensis*) microgreens were grown in various soilless medium, including PitMoss, vermicast, sawdust, mushroom compost, perlite, and Pro-mix BXTM (Saleh, Roksana, et al., 2022)³⁶. In addition, the ingredients from agriculture and food waste are utilized to grow aquatic spinach and sunflowers microgreens (Thepsilvisut, Ornprapa, et al., 2023)⁴³. Studying the morphological features of microgreens is essential for a number of reasons. One important aspect of the microgreens' harvesting period is the overall development and growth rate (Fraszczak, Barbara, et al., 2023)¹⁶. Nutrient uptake and utilization throughout the chosen stage of development are often shown by the fresh amount

and the dried amount of those parameters. In addition to this, it offers information on plants' water content, which is essential for determining their water status and drought resistance (Bulgari, Roberta, et al., 2017)⁸. Furthermore, a plant's ability to photosynthesize is directly correlated with the overall length and width of its leaves. A leaf's pigment content and capacity to retain sunlight are often higher on larger surfaces, which improves photosynthetic activity and fosters better growth (Xiao, Z. et al., 2019)⁴⁷. The commercial value of microgreens is closely related to their yield and biomass. Because they affect marketability, shelf life, yield, nutritional content, and product uniformity, microgreens' morphological characteristics are critical from the standpoint of the Industry (Singh, Aishvina, et al., 2024)³⁸. Research on the physical, nutritional, and antioxidant characteristics of these microgreens is, nevertheless, scarce. Research studies comparing different genotypes within microgreen families and assessing the effects of growth circumstances on their quality criteria are few in the literature. The goal of the current study is to commercially cultivate high-quality microgreens that are using burlap as a free of soil growth media, with a focus on factors including biomass yields, biochemical characteristics, and antioxidant activity, all of which are intended to improve consumer nutrition (Gunjal, Mahendra, et al., 2024)²².

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