From Soil to Air: Exploring the Potential of Aeroponics in Farming

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Agriculture is undergoing major changes worldwide due to the increasing risk of frequent drought caused by global climate change. With the world's population projected to reach 9.6 billion by 2050, there is an increasing demand for food production. Providing a fresh and clean food supply for the fast-growing population using traditional agriculture methods will become increasingly difficult in the future. To effectively adapt to these circumstances, soil-less cultivation, specifically the aeroponics system, is being considered as an alternative technology. In aeroponics, plant roots are suspended in the air using plastic holders and foam materials instead of soil, while nutrient-rich water is delivered through atomization nozzles. This system has shown promising results in various countries and is recommended as the most efficient, economical, and convenient method for plant growth compared to traditional soil-based and other soil-less techniques. Aeroponics is a soilless farming method that allows crops to grow suspended in the air or mist without using soil. By providing optimal conditions for root oxygenation and moisture, aeroponics enables better plant nutrition assimilation and faster plant development. The system offers advantages such as easy separation of plants, simplified crop harvesting, precise control over nutrient and water regimes, and complete access to roots throughout the crop's life cycle. It is also considered a highly feasible method for producing uniform harvests and has shown potential in the cultivation of root crops used in herbal and phytopharmaceutical industries. The history of aeroponics dates back to the early 1920s and has evolved into a commercially successful method, with NASA conducting tests in space and confirming its productivity. Aeroponics is an effective solution for individuals with limited space for plant cultivation, requiring minimal water and space compared to traditional farming methods. It promotes rapid plant growth, increased mineral and vitamin uptake, and accelerated biomass growth. Moreover, it allows for increased planting densities and can be applied to various plant species, including seed production and biopharming. Overall, aeroponics offers a promising approach to address future food crises and promote sustainable agricultural practices.

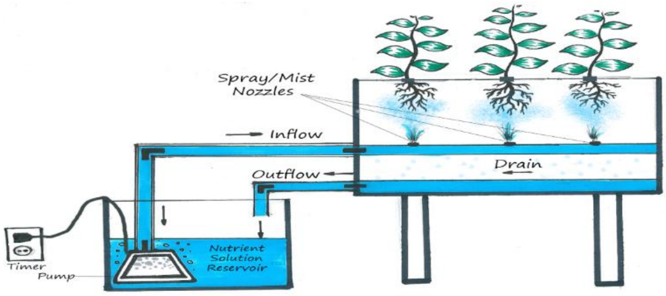

Fig 1: Diagrammatic view of aeroponics system

Recent trends

Aeroponics is a horticultural technique used for the cultivation of various crops, including fruits, vegetables, medicinal plants, and ornamental plants. Aeroponics has been utilized in the cultivation of medicinal plants, resulting in the discovery of new compounds with potential medicinal properties. Aeroponics has shown enhanced growth and root nodulation in *Acacia mangium*, an important legume tree. It has also been used for the cultivation of medicinal plants like ginger, burdock, and *Withania somnifera*, resulting in the discovery of new compounds One of the advantages of aeroponics is its ability to manipulate the root zone temperature, allowing for the production of subtropical and temperate crops in tropical environments. The technique has shown to promote larger root systems and improve the growth and physiology of crops compared to traditional cultivation methods. The aeroponic system has been developed in various structures, including seedbed and pyramid types, and has been used for commercial, experimental, and home gardening purposes. Routine and preventative maintenance are necessary for the efficient and trouble-free operation of the system. While aeroponics is still relatively unknown in many countries, efforts are being made to promote its benefits among farmers and the local community.

Fig 2: Production of potato tuber

Fig 3: Lettuce growing

Fig 4: Aeroponics Strawberry in Tower Garden

Source: Internet

The horticultural aspect of aeroponics involves the propagation of various crops, including fruits, nuts, vegetables, medicinal and aromatic plants, and ornamental plants. It has been successfully used for the production of vegetable crops like cucumber, lettuce, tomato, and leafy vegetables. Aeroponics has also been employed for large-scale production of potato seed tubers and yam. Plants of ornamental value such as croton, geranium, and chrysanthemum have been studied using this technique. Additionally, aeroponics has been used to manipulate root zone temperature for the production of subtropical and temperate crops in tropical environments. The technique has been extensively researched and applied for commercial production, research, and teaching purposes, providing benefits such as reduced production costs and shorter growth durations. In Singapore, the aeroponic system has been utilized to grow a wide range of vegetables, including subtropical and temperate varieties, by controlling the root zone temperature while exposing the aerial parts to hot tropical greenhouse conditions. Studies have shown that cool root zone temperatures promote larger root systems in temperate vegetable crops. The aeroponic system is an economical and efficient technique that allows plants to quickly access nutrients in a controlled environment, and it has gained attention for its potential to reduce costs and improve the understanding of subtropical and temperate crop growth in tropical regions. Various types of aeroponic systems exist, ranging from commercial to experimental and kitchen gardening setups. However, there is a need for scientifically recommended and convenient aeroponic systems that can be widely adopted. Despite the existing aeroponic structures, including seedbed, vertical barrel, prototype, and pyramid types, there is still a need for scientifically recommended and convenient aeroponic systems. Several structures and designs have been developed using different materials, including wood, aluminum, and plastic. The evaluation of proposed aeroponic systems has shown successful plant growth, indicating their potential for sustainable future cultivation. These systems offer the advantage of easy design and suitability for various settings, allowing people to grow plants on balconies, terraces, and even in rooms.

Recent studies on aeroponics

Barker (1922) introduced the concept of air plant growing systems, which eliminate the need for soil incorporation. NASA (2006) highlighted the significant advantages of aeroponics, such as water conservation, nutrient efficiency, and reduced cultivation time. Hoffman and Kolb (1997) investigated the effects of barley yellow dwarf on winter wheat seedlings grown in an aeroponics system, observing a decrease in root length and root-to-shoot ratio. Leoni *et al.* (2008) demonstrated successful tomato production using aeroponics, particularly in hybrid varieties, resulting in abundant and high-quality fruit. Luo *et al.* (2009) pioneered the cultivation of hearted lettuce in tropical regions through aeroponics and root cooling techniques, while also studying the impact of environmental factors on lettuce physiology. Bucksetha *et al.* (2016) and Stoner and Clawson (1998) emphasized the importance of optimizing water droplet size in aeroponic systems to balance oxygen availability and root development. Sun *et al.* (2004) reported improved physiological parameters in plants grown aeroponically, including increased stomatal conductance and net photosynthetic rate. Christie and Nichols (2004) successfully applied aeroponics for mass production of seed potatoes and gourmet early potatoes by controlling tuber initiation through intermittent irrigation. Irman *et al.* (2012) explored techniques for rapid multiplication of seed tubers, combining tissue culture with hydroponic and aeroponic systems. Chang *et al.* (2012) discovered that interrupting nutrient supply during stolon growth stimulates root activity and tuber initiation in hydroponic potato production. Chandra *et al.* (2014) compared the yield and phytochemical properties of aeroponically grown crops with conventional soil cultivation, finding comparable results and even higher yields in the aeroponic system. He *et al.* (2008) investigated the interaction between iron stress and root-zone temperature on Chinese broccoli grown aeroponically, observing negative impacts on productivity and nutrient uptake under high root-zone temperatures. Hartung *et al.* (2002) examined the growth of chickpea and lupin in aeroponic and hydroponic cultures, investigating the influence of root anatomy, pH, and abscisic acid concentrations on growth variations. Chica Toro *et al.* (2018) constructed absorption curves for white chrysanthemum in an aeroponic system, revealing variations in nutrient accumulation throughout different growth stages. These studies collectively contribute valuable insights into the application of aeroponics in diverse crops, the physiology of plants grown aeroponically, nutrient management strategies, and yield optimization.

Advantages

Aeroponic farming, a technique where plant roots are suspended in the air and a nutrient solution is misted over them, offers several advantages in agriculture. One key advantage is the reduction in fertilizer usage, as all the nutrients are contained and not wasted in groundwater or deep soil layers. Additionally, water usage is significantly reduced since evaporation and inefficient absorption are minimized. The cost-effectiveness of aeroponic gardens is higher compared to hydroponics, with fewer complex systems involved. Disease damage is also reduced, as plants are separated, preventing the spread of infections. The growth of plants is faster and healthier due to improved oxygen supply, resulting in a 45-70% faster harvest rate. Studies have shown increased flavonoid content in aeroponically grown plants. Furthermore, round-the-year cultivation is possible, independent of external weather conditions. Aeroponics facilitates fast plant growth, requires easy system maintenance, and decreases the need for nutrients and water. The mobility of plants is enhanced, and vertical farms can be constructed for high yield in limited space. It also has educational value, aiding plant and root growth studies. Other benefits include proper root growth, easy fruit harvest, disease-free produce, potential applications in moon stations, and the ability to grow healthier and more nutritious plants at home. Aeroponics is suitable for nurseries, enabling rapid propagation of seeds and cuttings. Additionally, it reduces water and fertilizer usage while maximizing crop yields. Even temporary power loss does not harm plants. The aeroponic farming system involves suspending plant roots in the air and misting them with a nutrient solution. This system offers advantages such as being lightweight, unlimited airflow, reduced disease spread, water savings, and flexibility in modifying root-zone environmental factors.

Disadvantages

Aeroponics, while offering numerous advantages in agriculture, also comes with some disadvantages that need to be considered. One drawback is that it can be more expensive for large-scale production, making it less accessible for ordinary farmers who may struggle to manage the sophisticated instruments involved. There is also the risk of mister spray heads clogging, which can hinder the production of the necessary nutrient mist for the plants. Additionally, there is a common perception among consumers that aeroponically grown plants are not as nutritious as those grown through other methods. Maintenance of an aeroponics farm can be costly, and dependence on the system's components, such as high-pressure pumps, sprinklers, and timers, leaves the plants vulnerable to damage if any of these components break down. Technical knowledge is required to effectively maintain the system and ensure the right amounts of nutrients are provided. The root chamber must be kept sanitary to prevent diseases from affecting the roots, necessitating regular disinfection. The cost of aeroponic systems can be high, often amounting to hundreds of dollars. Power loss over an extended period can cause irreversible damage to the plants, highlighting the need for reliable electricity connections or backup power sources. Overcoming these technical challenges requires a multidisciplinary approach, incorporating knowledge from various fields such as engineering, biology, biochemistry, and computer science. It is essential to have independent and reliable power sources in place to ensure uninterrupted operation of the aeroponic system. Although initial costs may be higher, the long-term benefits include reduced labor costs, minimal input requirements for fertilizers and pesticides, and significantly higher plant yields, making it a potentially cost-effective choice.

Conclusion & future aspects

In conclusion, aeroponics not only presents a practical solution for current agricultural challenges but also holds great potential for future advancements. As the technique continues to be adopted in various settings, from laboratory experiments to greenhouse cultivation, there is room for further research and development to optimize aeroponic systems for commercial and home operations. By disseminating information and raising awareness about the benefits and maintenance of aeroponic systems, we can encourage its wider adoption among farmers and local communities worldwide. With its ability to conserve water, save space, and offer sustainable farming practices, aeroponics has the potential to revolutionize traditional agriculture and contribute to a more secure and productive food future.

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