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Vertical Farming and Hydroponics in Ornamental Horticulture, the Futures of Sustainable Green Spaces

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In an era of rapid urbanization, shrinking green spaces, and increasing environmental awareness, ornamental horticulture is evolving through innovative cultivation technologies. Among these, vertical farming and hydroponics are emerging as promising approaches to growing ornamental plants efficiently, sustainably, and aesthetically. These techniques are transforming how flowers, foliage plants, and decorative greenery are cultivated in homes, commercial buildings, urban landscapes, and modern nurseries. Global population growth and urbanization have increased the demand for sustainable food production methods [1]. Conventional agriculture has its limitations, including shrinking arable land, climate variability, and water scarcity Benke and Tomkins [2]. Furthermore, traditional farming practices tend to be resource-intensive, as they require large inputs of water, fertilizers, and pesticides, which can be detrimental to the environment in the long run Rajaseger *et al.* [3]. Aeroponics and hydroponics give year-round production and reduce the crop losses. Moreover, the agricultural sector is currently faced with labour shortages, logistical inefficiencies, and the unpredictability of weather patterns due to climate change Magwaza *et al.* [4]. Soilless cultivation systems, particularly hydroponics and aeroponics, offer a sustainable alternative by enabling efficient water and nutrient utilization, optimizing resource use, and ensuring consistent crop production under controlled environmental conditions.

Hydroponics gives several advantages but some setbacks must be crossed in its proper use. Main of them includes the cost at the time of its preliminary setting, technicality level, and the large use of energy. Addressing these challenges requires the development of cost-effective technologies, energy-efficient systems, simplified operational techniques, and adequate technical training to improve the accessibility and long-term sustainability of hydroponic farming. Further nutrient management and disease prevention become critical factors to keep optimal crop yield in the system of hydroponic cropping Khatri *et al.* [5]. This technique holds much promise to overcome numerous drawbacks associated with conventional land-based farming Varun Kumar and Verma [6]. The ability to grow plants in controlled environments offers invaluable opportunities to increase food productivity, especially in urban contexts where arable land access is limited Verma *et al.* [7]. Furthermore, vertical farming and hydroponic technologies enable intensive crop production in limited spaces while improving resource-use efficiency, reducing dependence on conventional agricultural land, and promoting sustainable urban food systems

Vertical farming: Growing green in limited spaces

Vertical farming is an innovative way in which crops are farmed in vertically stacked layers within controlled environments, maximizing the use of space it occupies Vatistas *et al.* [8]. It's much more valuable in an urban setting where land may not be readily available [9]. They are often combined with either hydroponics or aeroponics to reach higher output with minimal resources used for the crop Al Shrouf [10]. The integration of smart technologies, automated climate control, and artificial lighting enhances crop growth, ensures year-round production, and improves overall resource-use efficiency in vertical farming systems.

Vertical farming is a modern cultivation approach in which plants are grown in vertically stacked layers, towers, shelves, or specially designed wall structures. Unlike conventional horizontal cultivation, this technique maximizes the use of available space, making it particularly suitable for cities where land is limited and expensive. By integrating controlled-environment technologies such as artificial lighting, hydroponics, and aeroponics, vertical farming enables year-round crop production, improves water and nutrient-use efficiency, and enhances productivity per unit area.

In ornamental horticulture, vertical farming is widely associated with living walls, green facades, indoor plant displays, and vertical gardens. Plants such as pothos (*Epipremnum aureum*), philodendron (*Philodendron* spp.), peace lily (*Spathiphyllum* spp.) Clematis, an exceptional vertical climber featuring trumpet-shaped blooms. Formally published by Spanish botanist [11], Geraniums (*Pelargonium* L'Hér.): Bushy or trailing clusters that handle vertical containers beautifully. The genus was established by French botanist [12]. Sweet peas and ferns are selected flowering annuals can be incorporated into these systems, depending on light, moisture, and temperature requirements and their

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decorative appeal, vertical gardens can contribute to improved building aesthetics, increased contact with greenery, and more efficient use of urban spaces. Their success, however, depends on proper plant selection, structural support, irrigation, drainage, and regular maintenance.

Hydroponics: *Cultivating*

Ornamental plants growing without soil

Hydroponics is a soilless cultivation technique in which plants receive essential mineral nutrients through a nutrient solution. Instead of relying on garden soil, growers use water-based systems or inert growing substrates such as coco peat perlite, rockwool, coir, support plant roots. This technology allows growers to manage root-zone nutrition, moisture, and oxygen more precisely than in many conventional growing systems. In commercial ornamental horticulture, soilless cultivation is used for selected cut flowers, flowering potted plants, and foliage crops. Roses, gerberas, chrysanthemums, and anthuriums can be cultivated in suitable hydroponic or substrate-based production systems. Many foliage plants can also be maintained in water-based systems, although long-term growth depends on species-specific nutritional and environmental requirements.

Integrating vertical farming and hydroponics

The real potential of these technologies becomes apparent when vertical farming and hydroponics are combined. Vertical farming determines how plants are arranged in space, whereas hydroponics determines how water and nutrients are delivered to their roots. For example, a vertical garden may use a recirculating hydroponic system to supply nutrients to plants arranged in wall-mounted modules. Similarly, an indoor ornamental plant farm can use stacked growing shelves equipped with drip irrigation, nutrient reservoirs, and LED lighting. Hydroponics is an advanced, soilless culture technique through which the roots of the plants absorb nutrients from a well-formulated mineral-enriched solution Pradhan, and Deo [13]. This technology does not depend on soil for cultivation purposes; hence it can provide better-controlled and more efficient growth conditions Khan *et al.* [14]. This is highly effective in regions with poor quality of soil or less arable land.



Plate 1 Best climbing plants

Benefits for sustainable ornamental horticulture

One of the greatest advantages of vertical farming is its ability to increase the growing area without requiring a proportionate increase in land. This makes it attractive for rooftop gardens, urban nurseries, compact greenhouses, and interior green spaces. Hydroponics can improve water-use efficiency, particularly when nutrient solutions are recirculated and monitored carefully. It also allows growers to adjust nutrient concentrations and root-zone conditions according to crop requirements. In suitable systems, reduced dependence on field soil can help avoid certain soil-related production problems. These methods can also facilitate automation.

Sensors can monitor pH, electrical conductivity, temperature, and moisture, while automated irrigation and fertigation systems help maintain more consistent growing conditions. In controlled indoor facilities, LED lighting can supplement natural light or provide the principal light source. However, sustainability should not be assumed automatically. Energy consumption, infrastructure costs, plastic components, nutrient discharge, and equipment maintenance can reduce the environmental benefits of poorly designed systems. Efficient lighting, renewable energy, durable materials, and responsible nutrient recycling are therefore important considerations.

Future prospects

The future of ornamental horticulture is likely to involve greater integration of digital technologies, resource-efficient cultivation, and innovative landscape design. Smart sensors, automated fertigation, computer-controlled lighting, and data-based crop management can improve consistency and reduce avoidable resource losses. Vertical gardens are also gaining relevance in discussions about biophilic design, which emphasizes incorporating nature into buildings and everyday environments. Green walls and indoor plant installations can make residential, educational, healthcare, and commercial spaces more visually appealing, although their environmental and health benefits depend on the specific design and conditions. In India, these technologies offer opportunities for urban landscaping enterprises, premium ornamental nurseries, rooftop greening projects, and specialized greenhouse production. Their adoption will depend on local climate, electricity and water costs, access to technical expertise, and demand for high-quality ornamental plants.

CONCLUSION

Hydroponics and vertical farming represent highly transformational agricultural approaches in order to address important issues related to land shortages, water deficiencies, and requirements of sustainable food. As a result, such systems show potential promise for their utilization in the context of urbanization and scarce resource utilization for year-round cultivation with zero pesticides. The high initial costs, energy demands, and technical expertise barriers will need to be overcome through technological innovation, policy support, and collaborative initiatives. Advances in automation, renewable energy integration, and cost-effective designs will continue to push these systems toward broader accessibility and scalability.

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