

Strawberries on Shelves: The Rise of Vertical Farming

*A Pavithra, Bhyravi B M, Sridhar R and Kavya D V

Department of Fruit Science, College of Horticulture, Mudigere

*Corresponding Author's email: pavithraa0627@gmail.com

Vertical farming presents an innovative and sustainable approach to overcome land scarcity, urbanization, and climate variability in agriculture. By employing hydroponic and aeroponic systems in controlled environments, it optimizes strawberry growth, yield, and quality. Strawberries, being perishable and climate-sensitive, benefit from year-round production, efficient resource utilization, and reduced pest and disease pressure. The use of LED lighting, IoT-based monitoring, and automation further enhances productivity while lowering labor demands. Case studies indicate significant improvements in yield and profitability compared to conventional farming. Despite challenges such as high initial investment and energy requirements, vertical farming holds strong potential for sustainable urban strawberry production.

Keywords: Vertical farming, strawberries, hydroponics, controlled environment agriculture, sustainable production

Introduction

Vertical farming is a method in which crops are grown in vertically stacked layers, often incorporating controlled environmental conditions and which saves water and eliminates the need for soil. A wide variety of plant species can achieve optimal growth rates year-round when grown in controlled environments with constant monitoring and manipulation of environmental factors, such as light, humidity, and temperature (Mir *et al.*, 2022).

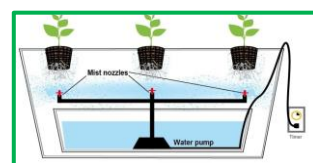
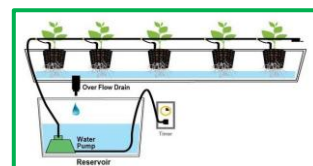
History of vertical farming

Vertical farming dates back to the Hanging Gardens of Babylon (600 BC), one of Philon's Seven Wonders. The term "vertical farming" was first introduced by Gilbert Ellis Bailey in his 1915 book *Vertical Farming*. In the 1930s, William Frederick Gericke pioneered hydroponics at the University of California, Berkeley. During the 1980s, a Swedish ecological farmer proposed vertical farming for urban vegetable production. The concept was revived in 1999 by American ecologist Dickson Despommier, who defined it as the "commercial mass cultivation of plants and animals in skyscrapers" (Mir *et al.*, 2022).

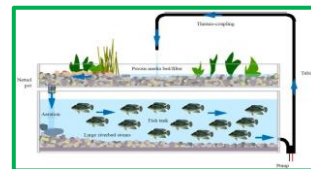
Techniques of Vertical Farming

Hydroponics: Hydroponics is a soilless farming technique in which crops are grown in nutrient-enriched water solutions. Hydroponics offers significant water savings, using up to 90% less water than traditional farming methods.

Aeroponics: Aeroponics involves growing plants in an air-based environment, with roots suspended and periodically misted with a nutrient solution. Aeroponics offers substantial water savings, using up to 98% less water than traditional farming, and promotes rapid growth, leading to higher yields.

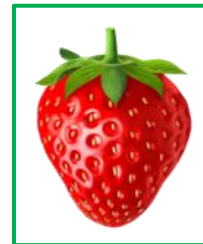


Aquaponics: Aquaponics combines hydroponics and aquaculture to create a symbiotic system in which both plants and fish thrive. Aquaponics is eco-friendly, producing both crops and fish, which can increase the profitability of aquaponics.



Why Strawberries ?

Strawberries, known for their appealing taste and vibrant colour, hold significant value in the global agricultural market. However, traditional farming faces challenges such as limited land availability, pest and disease susceptibility, and unpredictable climatic conditions. Vertical farming offers an innovative solution by providing controlled environments that optimize growth and enhance productivity.



Key growth requirements of strawberry

- Strawberries thrive in cool to subtropical climates with 12 hours of daylight, 8 hours of darkness, and an optimum temperature of 15–26°C. They prefer light, sandy loam soils with a pH of 5–6.5.
- Propagated through runners or micropropagated plants, with spacing of 25–30 cm between plants and 45–50 cm between rows, often planted in March in hilly regions.
- Nutrient management includes 50–60 t/ha of FYM, 80 kg N, 40 kg P₂O₅, and 40 kg K₂O/ha applied in split doses, with drip irrigation preferred—excess irrigation during vegetative growth and restricted irrigation during fruiting. Mulching helps conserve moisture and control weeds.
- Popular varieties include Chandler, Sweet Charlie, Festival, Selva, Albino, Tioga, and Pajaro.
- Fruits are harvested when 50–75% colored, from January to March in subtropical areas and May to June in hilly regions, using shallow cushioned containers to prevent damage. The average yield ranges from 12 to 35 t/ha.

Problems Faced in Traditional Farming of Strawberry

- Strawberries are sensitive to temperature fluctuations, frost, and heavy rainfall. Unpredictable weather can damage flowers and fruit. This often results in reduced yield and poor fruit quality.
- Shallow roots require frequent, precise irrigation. Water stress causes small berries, while excess moisture leads to root rot. Balancing moisture is a constant challenge for farmers.
- Pests like aphids, mites, and thrips are major threats. Diseases such as powdery mildew and grey mold can destroy crops. Farmers rely on pesticides to minimize losses.
- Weeds compete for water, nutrients, and sunlight. This weakens plants and reduces productivity. Weed control demands regular mulching or herbicides.
- Strawberry farming requires heavy manual labor for planting, weeding, and harvesting. Hand harvesting is essential to avoid fruit damage. Labor shortages and rising wages increase costs.
- Continuous cultivation causes pathogen and nematode buildup. This leads to poor plant health and reduced yield. Soil rotation or treatment is needed to sustain productivity.
- Urbanization and infrastructure reduce available farmland. This restricts the expansion of strawberry fields. Farmers must adopt alternative farming solutions.

Need of Vertical Farming in Strawberry

- Vertical farming, a form of Controlled Environment Agriculture (CEA), enables precise control of temperature, humidity, and light for year-round production.
- Hydroponic and aeroponic systems reduce water use by 90–95% through recirculation, ideal for water-scarce regions.
- IoT, AI, and automation improve efficiency by enabling real-time environmental adjustments and lowering labor costs.

- Soil-free cultivation reduces soil-borne pests and diseases, ensuring healthier, chemical-free crops with better quality and shelf life.
- Stacked farming maximizes land use, providing higher yields per unit area, especially in urban settings.

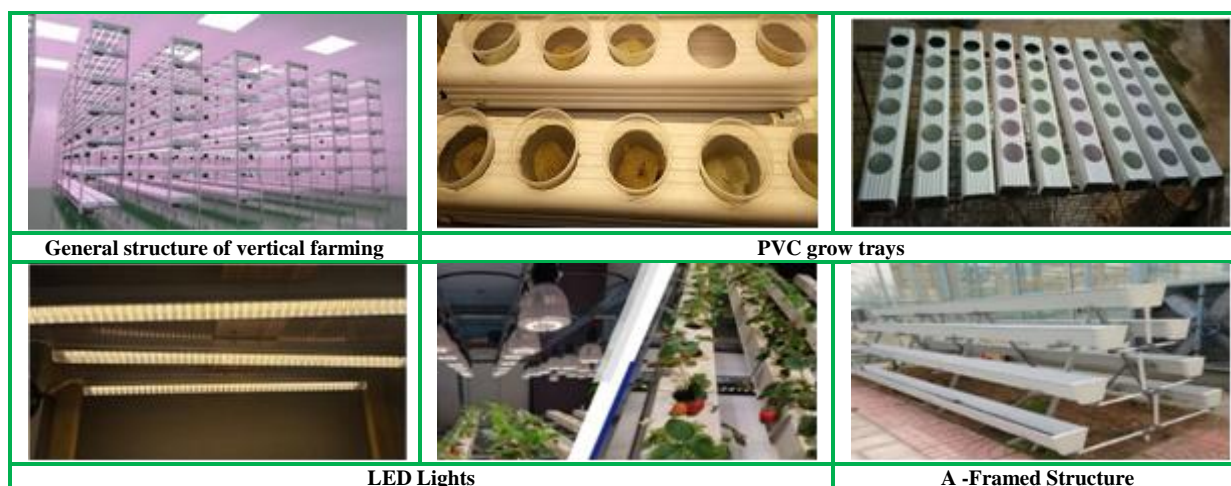
Design and Structure of Vertical Farming in Strawberry

Vertical racks with multiple tiers, in general

- ✓ iRack height will be about 1.5 to 2.5 meters
- ✓ Distance between two tiers 30 to 60 cm
- ✓ Rack width will be 1 to 1.2 metre so that it will help to allow easy access for movement
- ✓ Plant spacing can be maintained about 20 to 30 cm between plant to plant
- ✓ The LED lights were placed at a distance of 20–30 cm from the canopy.
- ✓ The average planting density was 13 bushes per shelf (0.72 m²) or 19 bushes per 1 m².

PVC grow trays were filled with cocpeat or other soilless media and equipped with hydroponic channels.

LED grow lights provide specific wavelengths essential for photosynthesis. Blue light promotes leaf growth, while red light supports flowering and fruiting. Adjustable LEDs ensure optimal conditions throughout the growth cycle, resulting in healthy and high strawberry yields.



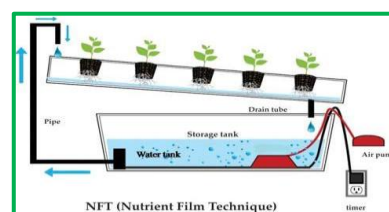
Crop Management in Vertical Farming

Ideal growing conditions for vertical farming in strawberry

- ❖ **Growing Medium:** Perlite, Vermiculite, Sawdust, Cocopeat, Coconut Coir, Peat Moss
- ❖ **Photoperiod:** 10-12 hours of light per day
- ❖ **Temperature:** 18-22⁰ C
- ❖ **Humidity:** 60-70 %
- ❖ **CO₂ level:** 800-1000 ppm enhances photosynthesis and growth
- ❖ **Light intensity:** 350-550 μmol/m²/s

Water Management: In vertical strawberry farming, a thin film of nutrient-rich water flows continuously over plant roots placed in net pots within slightly sloped channels. The solution, pumped from a reservoir, circulates back after use, forming a closed-loop system that minimizes water waste while ensuring efficient nutrient delivery. This method is highly effective and adaptable for strawberries grown in vertical towers.

Pollination in Strawberry: For enclosed farms where natural pollinators are restricted, pollination can be achieved through brush pollination, wind-assisted pollination using fans, the introduction of commercial pollinators such as *Bombus* spp. in glasshouses, or autonomous pollination drones. When insect pollinators are used, it is essential to maintain optimal temperature, humidity, and light conditions within the controlled environment.



Vertical strawberry farming can generate higher revenue per square meter than field farming

Factor	Vertical Farming	Open Field
Initial investment	High (\$500–\$1,500/m ²)	Low (\$5–\$10/m ²)
Operating cost (per season)	Medium–High	Low–Medium
Yield (tons/ha/year equivalent)	30–50	15–20
Labor cost	Low (due to automation)	High
Water use	Very low	High
Revenue potential	High (premium price, year-round)	Medium (seasonal market)
Payback period	3–7 years (estimated)	1–3 years

(Beacham *et al.*, 2019 and Kalantari *et al.*, 2017)

Top Companies involved in Vertical farming of strawberry (Dhiman, 2025)

Company Name	System	Location	Website
Aero Farms	Hydroponics	United States	aerofarms.com
Bowery Farming	Hydroponics	United States	bowery.cp
Bright Farms	Hydroponics	United States	brightfarms.com
Gotham Greens	Hydroponics	United States	gothamgreens.com
Farm. One	Hydroponics	United States	farm.one
Infarm	Hydroponics	United States	infarm.com
Plenty	Hydroponics	United States	plenty.ag
Barton Breeze	Hydroponics	India	bartonbreeze.com
Future Farms	Hydroponics, Aquaponics	India	futurefarms.in
Farm-in-Box	Hydroponics	India	farminbox.in
Oishii	Hydroponics	USA	oishii.com

Success Story

Dhakad, an innovative farmer, developed a tabletop hydroponic model that achieved nearly 50% faster strawberry growth and boosted profits by 70%. In a compact 15 × 20 sq ft area, he successfully grew 600 strawberry pots using a multi-layered pipe system filled with coco peat or pebbles as a growing medium, supported by the Nutrient Film Technique (NFT), which ensured efficient nutrient and water delivery.



Mr. Vijay Thakur, a progressive farmer from Palampur (HP), embraced vertical farming with high-yielding varieties such as Alba and Chandler. His 500 sq. m vertical setup now produces 3,000–4,000 kg of strawberries annually—three to four times higher than traditional farming—earning him Rs. 3.6–6 lakh per year. By integrating resource-efficient methods, controlled environments, and modern technology, both farmers demonstrate how vertical farming not only improves yield and quality but also minimizes land use, labor.



Advantages of Vertical Farming

- **Efficient Land Use:** Vertical farming maximizes land efficiency by stacking crops vertically, allowing for more production per square meter than traditional farming. This is especially beneficial in urban areas, where land is scarce and expensive.

- **Year-Round Production:** By controlling light, temperature, and humidity, vertical farms can grow fruit crops throughout the year. This eliminates seasonal limitations and ensures a continuous supply of fresh produce to consumers.
- **Better Pest and Disease Management:** Vertical farming typically avoids the use of soil, reducing the risk of soil-borne pests and diseases. The enclosed, controlled environment further protects crops from external pathogens, often reducing the need for chemical pesticides to control them.
- **Water Conservation:** Hydroponic and aeroponic systems used in vertical farming can reduce water usage by up to 90% compared to traditional methods. This makes it an ideal solution for areas facing droughts or water scarcity.
- **Higher Yields:** Vertical farms can produce significantly more fruits per square meter than open-field farms. Optimized growing conditions lead to faster plant growth and higher productivities.
- **Resource Efficiency:** Nutrients are delivered directly to plant roots in precise amounts, reducing waste and enhancing uptake. This leads to better growth with minimal use of fertilizers and other inputs by the plants.
- **Advanced Technological Integration:** Modern vertical farms use technologies such as IoT, AI, and automation to monitor and adjust conditions in real time. These innovations improve efficiency, reduce human labor, and ensure ideal growing environments for crops.
- **Support for Urban Horticulture:** Vertical farming allows fresh fruits to be grown close to consumers in cities, reducing transportation time and costs. This reduces the carbon footprint and strengthens the local food security.

Challenges and Limitations Oof Vertical Strawberry Farming

- **High Costs:** Vertical farming involves a heavy initial investment in LED lighting, HVAC, sensors, and automation. Electricity bills further add to operational expenses. It often takes 3–7 years for farmers to break even, depending on market conditions.
- **Energy Use:** Artificial lighting can contribute up to 50% of total energy consumption. In regions dependent on fossil fuels, this raises sustainability concerns. Integrating renewable energy is crucial to make vertical farming more viable.
- **Pollination:** Closed environments limit natural pollination. Farmers must rely on manual pollination or commercial bumblebees. Both options add labor, cost, and management complexity to the system.
- **Plant Health:** Although soil-borne diseases are reduced, high humidity can trigger fungal outbreaks. Pests such as spider mites and aphids spread quickly in dense setups. Strict monitoring and effective IPM strategies are essential.
- **Labor & Design:** Managing multi-tier farms requires skilled labor for pruning, harvesting, and equipment maintenance. Poor design can make access difficult and increase workload. Ergonomic layouts are key to efficient operations.
- **Policy Gaps:** There is a lack of region-specific guidelines and extension support for vertical strawberry farming. Limited subsidies and unclear policies hinder growth. Stronger government support could accelerate adoption.

Future Prospects

- **Rising Adoption:** With the proven success of vertical strawberry farming, more farmers—both urban and traditional—are expected to adopt these techniques. This approach allows high-quality production even in limited spaces. It represents a practical solution for modern agriculture.
- **Technological Advances:** Emerging innovations in automation, robotics, and data analytics will transform vertical farming. These tools will enhance precision, reduce labor costs, and boost productivity. Technology will be the driving force behind scalable and profitable systems.

- **Breeding Collaboration:** Collaborating with plant breeders will develop strawberry varieties ideal for vertical cultivation. These varieties will deliver higher yields, superior quality, and stronger disease resistance. This synergy will further optimize vertical farming outcomes.
- **Sustainability Focus:** Vertical farming reduces water usage and pesticide dependence significantly.
Such eco-friendly practices match the growing demand for sustainable food. It offers a climate-smart solution for future farming needs.
- **Food Security:** As farmland shrinks, vertical farms offer a reliable alternative. By producing fresh strawberries locally, they cut transport emissions. This ensures a steady supply of safe and nutritious produce.

Conclusion

Vertical strawberry farming represents a transformative approach to agriculture, offering solutions to the challenges faced by traditional farming methods. With its emphasis on space efficiency, sustainability, and high-quality produce, vertical farming has the potential to revolutionize strawberry cultivation in the future. These innovative systems and techniques pave the way for a future where strawberries can be grown year-round in urban environments, ensuring a consistent supply of fruit.

References

1. Beacham, A. M., Vickers, L. H., & Monaghan, J. M. (2019). Vertical farming: A summary of approaches to growing skywards. *Journal of Horticultural Science & Biotechnology*, 94(3), 277–283.
2. Chadha, K. L. (Ed.). (2022). Handbook of horticulture (Vol. 1, 1200 p.). Indian Council of Agricultural Research.
3. Dhiman, A. (2025). Urban horticulture via vertical farming: Unlocking the potential, addressing challenges and exploring future prospects for fruit crops: A review. *Biological Agriculture SciTech Environment*, 5(1), 19–27.
4. Kalantari, F., Mohd Tahir, O., Joni, R. A., & Fatemi, E. (2017). Opportunities and challenges in sustainability of vertical farming: A review. *Journal of Landscape Ecology*, 11(1), 35–60.
5. Mir, M. S., Naikoo, N. K., Kanth, R. H., Bahar, F., Bhat, M. A., Nazir, A., Mahdi, S. S., Amin, Z., Singh, L., Raja, W., Saad, A., Bhat, T. A., Palmo, T., & Ahngar, T. A. (2022). Vertical farming: The future of agriculture: A review. *Pharma Innovation Journal*, 11(2), 1175–1195.
6. Zacharaki, A. K., Monaghan, J. M., Bromley, J. R., & Vickers, L. H. (2023). Opportunities and challenges for strawberry cultivation in urban food production systems. *Plants, People, Planet*, 6, 611–621.