



POPULAR SCIENCE ARTICLE

Rooftop Vegetable Gardening: A Sustainable Approach to Urban Agriculture and Food Security

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Abstract

The concept of rooftop vegetable gardening is gaining importance as one of the potential means of bringing people living in cities closer to sustainable vegetable cultivation. An increasing level of awareness among city residents regarding the dangers of pesticide residues in vegetables cultivated using conventional agricultural methods is leading to the desire among people to grow their own food. Rooftop vegetable gardens prove to be highly beneficial to the environment by improving air quality, reducing urban pollution, cooling buildings and enhancing biodiversity in urban areas. Besides facilitating the growth of healthy and safe foods for consumption, rooftop vegetable gardens prove to be quite beneficial to the environment by providing cleaner air, cooling buildings and enhancing biodiversity in urban areas. Moreover, it minimizes the reliance on complex distribution channels and helps in saving energy and cutting down emissions while also making households more food and nutrition secure. Furthermore, rooftop gardening promotes sustainable living and even enhances mental well-being. Nevertheless, successful rooftop gardening requires proper planning and management involving appropriate use of growing media, effective watering, organic fertilization and eco-friendly pest control.

Keywords: Rooftop Vegetable Gardening, Urban Agriculture, Organic Vegetable Production, Container Gardening, Food Security, Carbon Footprint Reduction

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Introduction

The practice of cultivating vegetables on rooftops, commonly referred to as rooftop gardening or rooftop vegetable gardening, is increasingly being recognized as an innovative form of urban agriculture (Orsini *et al.*, 2013). Green roofs also known as living roofs, eco-roofs, or roof gardens are building rooftops covered with a growing medium and vegetation and when utilized for vegetable production, they serve as productive urban food spaces (Walters & Midden, 2018). Rooftop gardening can therefore be described as “nature in the sky,” where underutilized rooftop spaces are transformed into productive green areas that contribute to food production and environmental improvement. Proper understanding of the problems and prospects associated with the adoption of policies will contribute, to a great extent, to increased food

supply in the city (Horst *et al.*, 2024; Dubbeling *et al.*, 2019). Rapid urbanization has led to several environmental and social challenges in cities, including declining air and water quality, loss of green spaces and increased atmospheric temperatures due to the urban heat island effect (Barthel & Isendahl, 2013; Brown & Jameton, 2000). Industrial emissions, vehicular pollution and extensive use of impervious surfaces such as concrete and asphalt further intensify these problems. In addition, limited access to natural and agricultural spaces has created a disconnect between urban populations and food production systems. In such conditions, rooftop vegetable gardening emerges as a practical solution that integrates agriculture into the urban landscape while improving environmental quality. Green roofs have been shown to reduce ambient temperature, mitigate heat stress in buildings

and lower energy requirements for cooling, thereby contributing to energy efficiency (Walters and Midden, 2018). Moreover, rooftop cultivation supports local food production, reduces dependency on long supply chains and helps in lowering carbon emissions associated with transportation. This trend has gained further importance in recent years, as home gardening and urban agriculture have been recognized as effective strategies for improving household food and nutritional security, especially during crises such as the COVID-19 pandemic (Lal, 2020). Urban agriculture, including rooftop and balcony gardening, is increasingly being adopted to enhance food availability and promote sustainability in cities (Allievi *et al.*, 2019). Although rooftop vegetable production is not intended to replace large-scale rural agriculture, it serves as a valuable supplementary system that strengthens urban food security and promotes sustainable living (Meenar *et al.*, 2017). Despite its benefits, rooftop gardening requires careful planning with respect to structural safety, growing media selection, irrigation and nutrient management to ensure long-term productivity and sustainability (Edmondson *et al.*, 2020).



Figure 1: Rooftop Gardening - A sustainable use of urban roof space for growing plants. (Source: Elitech Drip - Gardening Tips by Siddharth)

Types of Rooftop Gardening

The classification of rooftop gardening systems is based on factors such as substrate depth, structural weight demands and the extent of maintenance required by the cultivator. Container gardening systems act as a simple and flexible entry into gardening, using containers or crates to overcome problems associated with soilborne diseases and nematode infestations that commonly affect conventional surface-based systems (Singh *et al.*, 2025). For buildings with weight restrictions, extensive systems are preferred, as they are lightweight and require only a shallow growing medium of not more than 15 cm, making them suitable for low-maintenance leafy green vegetables (Sanyé-Mengual *et al.*, 2015). In contrast, intensive systems use a thicker substrate, deeper than 15

cm, allowing the cultivation of root vegetables, though they demand stronger structural support and higher maintenance (Whittinghill *et al.*, 2013). In the quest for more innovative solutions, hydroponic and aeroponic systems are also considered, as they offer efficient water use and reduced weight by relying on nutrient-enriched solutions instead of soil (Saha & Eckelman, 2017). Modular systems further add flexibility by using pre-planted trays, helping urban gardeners maximize rooftop space while protecting the roof membrane. (Shehzad *et al.*, 2023). Container vegetable gardening is especially useful in situations where space is limited or the area is unsuitable for traditional cultivation. It allows fresh, organic and nutritious vegetables to be grown in containers placed on a window, patio, balcony, doorstep, or rooftop, providing sufficient space for a productive mini-garden. Problems related to soilborne diseases, nematodes, or poor soil conditions can be easily avoided by adopting container gardening and it is also suitable for areas where soil is insufficient or not available (Singh *et al.*, 2026). Overall, container vegetable gardening is a practical and enjoyable way to engage in home gardening and spend quality time with family, from selecting suitable containers and soil to choosing vegetables and caring for plants throughout the season (Artmann & Breuste, 2020).

Container Gardening System: Container gardening is one of the simplest and most practical forms of rooftop and urban gardening, where plants are grown in pots, tubs, crates, grow bags, or any suitable containers instead of directly in the soil. This system is especially useful in cities where open land is limited, as it allows people to grow vegetables, herbs and even small fruits in compact spaces like rooftops, balconies and patios (Denzon *et al.*, 2023). It also helps avoid many soil-related problems such as poor soil quality, soilborne diseases and nematode infestations, making plant management easier and more controlled. Another advantage of container gardening is its flexibility, as containers can be moved, rearranged, or replaced depending on sunlight availability and space requirements. This system is also beginner-friendly, requiring relatively low initial investment and simple maintenance practices compared to traditional field cultivation. In addition, container gardening supports organic and household food production, allowing families to grow fresh and chemical-free produce at home while also engaging in a relaxing and productive activity. Overall, it is a highly adaptable and efficient

approach for small-scale urban cultivation, especially in areas with space constraints or unsuitable soil conditions.



Figure 2: Container Gardening System - Maximizing greenery in small urban spaces through planters and pots. (Source: Lifestyle Gardening, Sumedha Tripathi, 2024)

Hydroponic Rooftop Gardening: Hydroponic rooftop gardening is a modern and innovative approach to urban cultivation where plants are grown without soil and instead receive nutrients through a water-based solution. This system is gaining popularity in cities where land availability is limited and there is a growing demand for sustainable food production (Panotra *et al.*, 2024). By utilizing rooftops, it makes effective use of unused urban spaces while supporting fresh vegetable and herb production close to households. One of the major advantages of hydroponic systems is their efficient use of water and nutrients, as both are delivered directly to plant roots in a controlled manner, reducing wastage compared to traditional soil-based farming. This method also allows for faster plant growth and higher productivity in a smaller area, making it highly suitable for urban environments. Overall, rooftop hydroponics represents a practical solution for sustainable agriculture in densely populated areas where conventional farming is not feasible (Saha & Eckelman, 2017).



Figure 3: Hydroponic Rooftop Gardening using nutrient solution.

Rooftop Greenhouse Gardening: Rooftop greenhouse gardening is an advanced form of urban agriculture where a greenhouse structure, such as a polyhouse or glasshouse is installed on the rooftop of buildings to cultivate crops under controlled environmental conditions. This system combines the advantages of rooftop gardening with protected cultivation, allowing better control over temperature, humidity, light and ventilation. Because of these regulated conditions, vegetables and other crops can be grown throughout the year, even when outdoor weather is not favorable. In urban areas where

land availability is limited, this method makes effective use of unused rooftop space while improving crop productivity and quality. It also helps in reducing pest and disease pressure compared to open-field cultivation, as the growing environment is more protected and managed. Due to these advantages, rooftop greenhouse gardening is increasingly being recognized as a practical and sustainable approach for continuous vegetable production in cities (Whittinghill *et al.*, 2013).



Figure 4: Rooftop Greenhouse Gardening under controlled environmental conditions.

Vertical Rooftop Gardening System: Vertical rooftop gardening system is a space-efficient method of urban cultivation where plants are grown in a vertical arrangement on rooftops using structures such as wall planters, hanging pots, stacked shelves, or green panels (Brenner *et al.*, 2023). This approach is especially useful in cities where horizontal space is limited, as it allows maximum use of available rooftop area by growing plants upward rather than outward. It is commonly used for growing leafy vegetables, herbs and ornamental plants that do not require deep soil. This system not only improves space utilization but also enhances the aesthetic value of buildings while contributing to urban greening (Price *et al.*, 2015). It helps in improving air quality and provides insulation to buildings by reducing heat absorption. Since plants are arranged vertically, proper irrigation and maintenance are important to ensure uniform growth. Overall, vertical rooftop gardening is considered an efficient and practical solution for increasing green cover in densely populated urban environments (Sanyé-Mengual *et al.*, 2015).



Figure 5: Vertical Rooftop Gardening System.

Growing Media

Growing media refers to the material used in containers or beds to support plant growth in rooftop and container gardening systems. Since

plants in such systems do not grow in natural soil, the choice of growing medium becomes very important for proper root development, nutrient supply, aeration and moisture retention. Different materials are often mixed together to create a balanced medium that supports healthy plant growth under controlled conditions. One of the most commonly used components is cocopeat, which is derived from coconut husk. It is lightweight, has excellent water-holding capacity and helps maintain moisture around the roots for a longer time (Deksissa *et al.*, 2021). Vermiculite and perlite are also widely used as soil conditioners; vermiculite improves water and nutrient retention, while perlite enhances aeration and drainage, preventing root rot and waterlogging. Organic materials such as farmyard manure, vermicompost and household compost play a key role in supplying essential nutrients to plants slowly and naturally. Vermicompost, produced by earthworms, is particularly valued for its rich microbial content and ability to improve soil structure and fertility. Vermiwash, a liquid extract obtained from vermicomposting units, is sometimes used as a natural plant tonic to support growth and improve stress resistance (Edwards *et al.*, 2011). Other locally available materials like rice hulls, shredded coconut husks and sugarcane bagasse are often incorporated to improve soil texture, increase porosity and enhance organic content. These materials also support sustainable waste recycling by converting agricultural residues into useful growing components. Overall, the combination of these growing media ensures proper aeration, moisture balance and nutrient availability, which are essential for healthy plant growth in rooftop and container gardening systems. Proper selection and proportion of these materials can significantly influence plant performance and productivity in soilless or semi-soilless cultivation systems (Raviv & Lieth, 2008).

Table 1: Types of Growing Media Used in Rooftop and Container Gardening Systems

Type of Growing Media	Description	Examples
Organic Growing Media	Derived from natural plant or animal sources; improves soil fertility and adds nutrients through decomposition.	Cocopeat, Farmyard manure (FYM), Vermicompost, Household compost, Shredded coconut husk, Sugarcane bagasse
Inorganic/ Mineral Growing Media	Non-living materials mainly used to improve drainage, aeration and root support.	Perlite, Vermiculite, Sand, Gravel

Soilless Commercial Media	Pre-prepared or formulated mixes designed for controlled plant growth in modern systems.	Cocopeat-based mixes, Hydroponic growing cubes, Pre-mixed potting substrates
Recycled Agricultural Waste Media	Eco-friendly materials derived from agricultural by-products used to enhance sustainability (Mahesh <i>et al.</i> , 2023).	Rice hulls, Coir pith, Compost from plant residues

Media Preparation Method



Figure 6: Types of growing media used in rooftop and container gardening systems.

The growing media for rooftop vegetable gardening was prepared using locally available and cost-effective materials to ensure proper plant growth. The main components used were garden soil, river sand and organic manure such as farmyard manure or vermicompost. These materials were mixed in the ratio of 1:1:1 to provide a balanced growing medium. Garden soil was selected for its nutrient-holding capacity and structural support. Sand was added to improve drainage and aeration in the media. Organic manure enhanced soil fertility and microbial activity. In some cases, cocopeat was incorporated to improve water retention and porosity. Neem cake was added to reduce soil-borne pests and diseases. The soil was sieved to remove stones and debris before use. Sand was washed to eliminate impurities. The organic manure used was well-decomposed and free from pathogens. All components were mixed thoroughly on a clean surface. The prepared media was sterilized through solarization by exposing it to sunlight for 2–3 days. This helped in minimizing harmful microorganisms and weed seeds. The mixture was slightly moistened to facilitate uniform mixing. Containers such as pots or grow bags were filled with the prepared media, leaving 2–3 cm space at the top. Proper drainage holes were ensured to avoid waterlogging. The filled containers were irrigated lightly before planting. The media was allowed to settle for about 24 hours prior to sowing or transplanting. Organic manure was added periodically to maintain nutrient supply during crop growth. This method ensures a healthy and productive growing environment

for rooftop vegetables.

Role of Rooftop Vegetable Gardening in Urban Agriculture and Food Security

Utilization of Unused Urban Roof Spaces: Rooftop gardening effectively converts idle and underutilized roof areas into productive green spaces. In densely populated urban regions, rooftops remain one of the few available areas for cultivation. By transforming these spaces into gardens, urban dwellers can contribute to food production without requiring additional land. This approach also improves building efficiency and sustainability. Thus, it promotes optimal use of urban infrastructure while enhancing environmental benefits.

Solution for Land Scarcity Due to Urbanization: Rapid urbanization has significantly reduced the availability of agricultural land. Rooftop gardening offers an alternative solution by enabling crop cultivation in vertical spaces (Elghonaimy & Albadal, 2021). It allows city residents to grow vegetables even in highly congested areas. This practice is particularly beneficial in metropolitan cities where open land is limited. Therefore, rooftop gardening plays a crucial role in addressing land scarcity challenges.

Production of Safe, Organic and Nutritious Food: Rooftop gardening allows individuals to grow vegetables without harmful chemicals and pesticides. This ensures the availability of fresh, safe and organic produce at home (Ben-Othmen *et al.*, 2023). Home-grown vegetables are often richer in nutrients as they are consumed soon after harvest. Additionally, gardeners have full control over cultivation practices. Hence, it improves dietary quality and promotes healthy living.

Reduction in Dependence on Contaminated Market Produce: Market vegetables are often exposed to pesticides, preservatives and contamination during transport and storage. Rooftop gardening minimizes dependence on such produce by providing a reliable source of clean vegetables. Consumers can ensure food safety by adopting organic practices at home. This reduces health risks associated with chemical residues. Thus, it enhances food safety and consumer confidence.

Increased Availability of Vegetables at Household and Urban Levels: Rooftop gardens improve the accessibility of fresh vegetables at the household level. They contribute to continuous supply, especially for daily consumption (Grafius *et al.*, 2020). At a broader scale, widespread adoption can enhance urban

food availability. Several studies have shown that urban agriculture can contribute significantly to improving food security and access to fresh produce in urban areas (Siegener *et al.*, 2018). Urban horticulture practices have also been recognized as an important strategy for ensuring food security and resilience in cities during global crises (Khan *et al.*, 2020). This reduces pressure on rural production systems. Therefore, rooftop gardening strengthens urban food systems and supports food security.

Reduced Reliance on External Food Supply Chains: Urban food supply chains often involve long-distance transportation, storage and distribution. Rooftop gardening reduces dependency on these systems by enabling local production. This minimizes the impact of supply disruptions and price fluctuations (Hawes *et al.*, 2024). It also reduces transportation costs and carbon emissions. Hence, it contributes to a more resilient and sustainable food system.

Promotion of Biodiversity: Rooftop gardens provide habitats for beneficial organisms such as pollinators, birds and insects. These gardens support ecological balance within urban environments. The presence of diverse plant species enhances biodiversity and ecosystem services. Pollinators like bees play a key role in crop production. Therefore, rooftop gardening contributes to urban ecological sustainability.

Enhancement of Aesthetic Value: Rooftop gardening improves the visual appeal of buildings and surrounding areas. Green spaces create a pleasant and relaxing environment for residents. They also increase property value and attractiveness. The presence of plants can improve mental well-being and reduce stress. Thus, rooftop gardens enhance both aesthetic and psychological benefits.

Utilization of Domestic Waste Resources: Rooftop gardening promotes the efficient use of household waste such as kitchen scraps and greywater. Organic waste can be converted into compost for plant nutrition. Rainwater and runoff can be reused for irrigation. This approach aligns with the principles of a circular economy, where organic waste is efficiently recycled into valuable inputs for sustainable food production systems (Selvan *et al.*, 2023). This reduces waste generation and promotes resource recycling. Therefore, it supports sustainable waste management practices.

Recreation and Entertainment: Gardening on rooftops provides a space for relaxation and leisure activities. It allows families to spend quality time together in a natural environment.

Engaging in gardening activities can reduce stress and improve mental health. It also encourages physical activity and learning. Hence, rooftop gardening serves as a source of recreation and enjoyment.

Future Prospects in Rooftop Vegetable Gardening (RVG)

The future of rooftop vegetable gardening is highly promising, especially in the context of rapid population growth and increasing pressure on food demand and expenditure (Agarwal *et al.*, 2023). This is also supported by recent market analyses indicating a rapid growth in urban farming and rooftop cultivation systems due to increasing demand for sustainable and locally produced food (Anon., 2024). In many regions, agricultural land is continually shrinking as it is converted into residential, commercial and industrial areas, limiting the scope for expanding traditional food production systems (FAO, 2017). At the same time, concerns related to food safety are also rising due to the excessive use of chemicals, such as artificial ripening agents, inorganic fertilizers and pesticides, which may affect human health and environmental quality (Al-Kodmany, 2024). In such a situation, rooftop farming emerges as a practical and sustainable alternative. It uses unused rooftop space to grow fresh vegetables, thereby reducing dependence on external food supply chains. This system not only helps in producing pesticide-free vegetables at household level but also encourages self-reliance and healthier food habits (Chatterjee *et al.*, 2020). Additionally, rooftop gardens contribute to environmental improvement by enhancing air quality, reducing carbon dioxide levels and moderating urban heat effects, which collectively support a healthier urban ecosystem (Sanyé-Mengual *et al.*, 2015). Furthermore, rooftop vegetable gardening helps in reducing input costs associated with transportation and market dependency while promoting local food production. With continuous technological advancements such as hydroponics, vertical systems and smart irrigation methods, urban agriculture is becoming more efficient and accessible (Daneshyar, 2024). These innovations are expected to strengthen the role of rooftop farming in future cities by improving access to fresh and nutritious food and enhancing overall urban sustainability (Whittinghill *et al.*, 2013).

Conclusion

Rooftop gardening is a unique and innovative approach to urban agriculture that makes effective use of unused rooftop spaces in cities. It helps in increasing greenery in urban areas,

improving air quality and supporting a healthier living environment. By introducing plants into built-up spaces, it also contributes to reducing the urban heat island effect and improving overall microclimatic conditions. In addition, rooftop gardening promotes local food production by enabling households to grow fresh vegetables and herbs at home. This reduces dependence on external food sources and supports access to safe, chemical-free produce. Overall, rooftop gardening is a practical and sustainable solution that enhances environmental quality while improving urban lifestyle and food security.

Declaration

The authors declare that there is no conflict of interest.

References

- Agarwal, V., Malhotra, S., & Dagar, V. (2023). Coping with public-private partnership issues: A path forward to sustainable agriculture. *Socio-Economic Planning Sciences*, 89, 101703.
- Al-Kodmany, K. (2024). Mitigating climate change: The potential of vertical farming to feed high-density cities. In *The Routledge Handbook on Greening High-Density Cities* (pp. 50-70). Routledge.
- Allievi, F., Antonelli, M., Dembska, K., & Principato, L. (2019). Understanding the global food system. In *Achieving the Sustainable Development Goals Through Sustainable Food Systems* (pp. 3-23). Cham: Springer International Publishing.
- Anon. (2024). *Urban farming market size, share, growth and industry analysis, by type (food crops and non-food crops)*. Business Research Insight.
- Artmann, M., & Breuste, J. (2020). Urban agriculture—more than food production. In *Making Green Cities* (pp. 75-176). Springer, Cham.
- Barthel, S., & Isendahl, C. (2013). Urban gardens, agriculture and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, 86, 224–234.
- Ben-Othmen, M. A., Cardoze, V., Hani, J., & Sauvee, L. (2023). Community-based urban agriculture for food justice: A review. *Urban and Regional Agriculture*, 11–40.
- Brenner, J., Schmidt, S., & Albert, C. (2023). Localizing and prioritizing roof greening opportunities for urban heat island mitigation: Insights from the city of Krefeld, Germany. *Landscape Ecology*, 38(7), 1697–1712.
- Brown, K. H., & Jameton, A. L. (2000). Public health implications of urban agriculture. *Journal of Public Health Policy*, 21(1), 20–39.
- Chatterjee, A., Debnath, S., & Pal, H. (2020). Implication of urban agriculture and vertical farming for future sustainability. In *Urban Horticulture - Necessity of the Future*.

- IntechOpen.
- Daneshyar, E. (2024). Residential rooftop urban agriculture: Architectural design recommendations. *Sustainability*, 16(5), 1881.
- Deksissa, T., Trobman, H., Zendejdel, K., & Azam, H. (2021). Integrating urban agriculture and stormwater management in a circular economy to enhance ecosystem services. *Sustainability*, 13(15), 8293.
- Denzon, W., Estose, M. C., Villanueva, K. C., & Jao, J. H. (2023). Container gardening program as a way of food augmentation: Action research. *Multidisciplinary Science Journal*, 5(4), e2023043.
- Dubbeling, M., van Veenhuizen, R., & Halliday, J. (2019). Urban agriculture as a climate change and disaster risk reduction strategy. *Field Actions Science Reports*, 20, 32–39.
- Edmondson, J. L., Cunningham, H., Densley Tingley, D. O., Dobson, M. C., Grafius, D. R., et al. (2020). The hidden potential of urban horticulture. *Nature Food*, 1(3), 155–159.
- Edwards, C. A., Arancon, N. Q., & Sherman, R. (Eds.). (2011). *Vermiculture technology: Earthworms, organic wastes and environmental management*. CRC Press.
- Elghonaimy, I. H., & Albadal, N. A. (2021). Vertical farming projects and reducing urban heat islands phenomenon in cities. In R. Rahbarianyazd (Ed.), *Contemporary approaches in urbanism and heritage studies* (pp. 95–105).
- Food and Agriculture Organization of the United Nations. (2017). *The future of food and agriculture: Trends and challenges*. FAO.
- Grafius, D. R., Edmondson, J. L., Norton, B. A., Clark, R., Mears, M., et al. (2020). Estimating food production in an urban landscape. *Scientific Reports*, 10(1), 5141.
- Hawes, J. K., Goldstein, B. P., Newell, J. P., Dorr, E., Caputo, S., Fox-Kämper, R., & Cohen, N. (2024). Comparing the carbon footprints of urban and conventional agriculture. *Nature Cities*, 1(2), 164–173.
- Horst, M., McClintock, N., & Hoey, L. (2024). The intersection of planning, urban agriculture and food justice: A review of the literature. *Planning for Equitable Urban Agriculture in the United States*, 83(3), 89–120.
- Khan, M. M., Akram, M. T., Janke, R., Qadri, R. W. K., Al-Sadi, A. M., & Farooque, A. A. (2020). Urban horticulture for food secure cities through and beyond COVID-19. *Sustainability*, 12(22), 9592.
- Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. *Food Security*, 12(4), 871–876.
- Mahesh, K. M., Aithal, P. S., & Sharma, K. R. S. (2023). Impact of Aatmanirbharta (self-reliance) agriculture and sustainable farming for the 21st century to achieve sustainable growth. *International Journal of Applied Engineering and Management Letters*, 7(2), 175–190.
- Meenar, M., Morales, A., & Bonarek, L. (2017). Regulatory practices of urban agriculture: A connection to planning and policy. *Journal of the American Planning Association*, 83(4), 389–403.
- Orsini, F., Kahane, R., Nono-Womdim, R., & Gianquinto, G. (2013). Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development*, 33, 695–720.
- Panotra, N., Belagalla, N., Mohanty, L. K., Ramesha, N. M., Tiwari, A. K., et al. (2024). Vertical farming: Addressing the challenges of 21st century agriculture through innovation. *International Journal of Environment and Climate Change*, 14(4), 664–691.
- Price, A., Jones, E. C., & Jefferson, F. (2015). Vertical greenery systems as a strategy in urban heat island mitigation. *Water, Air, & Soil Pollution*, 226, 1–11.
- Raviv, M., & Lieth, J. H. (Eds.). (2008). *Soilless culture: Theory and practice*. Elsevier.
- Saha, S., & Eckelman, M. J. (2017). Environmental impacts of urban hydroponic food production systems. *Environmental Science & Technology*, 51(2), 683–691.
- Sanyé-Mengual, E., Oliver-Solà, J., Montero, J. I., & Rieradevall, J. (2015). An environmental and economic life cycle assessment of rooftop greenhouse implementation in Barcelona, Spain. *Journal of Cleaner Production*, 75, 1–10.
- Selvan, T., Panmei, L., Murasing, K. K., Guleria, V., Ramesh, K. R., et al. (2023). Circular economy in agriculture: Unleashing the potential of integrated organic farming for food security. *Frontiers in Sustainable Food Systems*, 7, 1170380.
- Shehzad, M., Younis, A., Asif, M., & Hameed, M. (2023). Prospects of green roof technology as a sustainable solution to urban pollution index. *Journal of Agriculture and Food Research*, 14, 100751.
- Siegner, A., Sowerwine, J., & Acey, C. (2018). Does urban agriculture improve food security? A systematic review. *Sustainability*, 10(9), 2988.
- Singh, A. P., Dey, A. K., Sharma, S., Meena, S. and Kumari, C. 2025. The Nematology Paradox: An Underrated Science in Plant Protection. *Vigyan Varta* 6 (10): 85-88.
- Singh, A. P., Thakur, S. K., Keshari, N., Sharma, S., Kumar, A., Prajapati, A. K., & Dey, A. K. (2026). Exploring the role of quantum dot-based nanotechnologies for nematode detection and management: A review. *Asian Journal of Biotechnology and Bioresource Technology*, 12(2), 30–42.
- Tripathi, S. (2024, January 21). *Space problem? Start with container gardening planters and maximize greenery in small areas*. *Indiatimes*. <https://www.indiatimes.com/lifestyle/gardening/container-gardening-5-things-to-know-about-balcony-plants-606087.html>
- Walters, S. A., & Midden, K. S. (2018). Sustainability of urban agriculture: Vegetable production on

- green roofs. *Agriculture (Switzerland)*, 8(11), 168.
- Whittinghill, L. J., Rowe, D. B., & Cregg, B. M. (2013). Evaluation of green roof agriculture production systems for urban food security. *Agricultural Systems*, 109, 1-7.