

## Breeding Crops for Urban Agriculture

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### Abstract

Urban agriculture encompasses various forms, including rooftop gardens, community gardens, vertical farming and hydroponics. This method includes unused spaces such as rooftops, vacant spaces and vertical structures to cultivate crops which not only promotes food security but also enhances environmental sustainability by reducing transportation emissions associated with long-distance food distribution. Crop breeding targeted at urban agriculture aims to develop varieties that thrive in confined spaces, adapt to local microclimates and require minimal inputs. Traits like compact growth habits, quick maturation, and resistance to urban pollutants become priorities in crop breeding programs for urban agriculture. This approach not only ensures high yields in restricted spaces but also addresses urban-specific stressors such as air and soil pollution. Additionally, breeding for nutritional density and taste contributes to providing fresh, nutritious produce that meets the diverse preferences of urban consumers. Urban agriculture faces constraints such as limited space, varying climatic conditions and the need for resource efficiency. Modern breeding technique, including genetic engineering and marker-assisted selection, plays a pivotal role in accelerating the development of urban-adapted crop varieties. As urban populations continue to rise, the emphasis on breeding crops suited for urban agriculture becomes imperative for enhancing food security, sustainability, and resilience in the face of urbanization challenges.

**Keywords:** Crop breeding, environmental sustainability, food security, urban agriculture

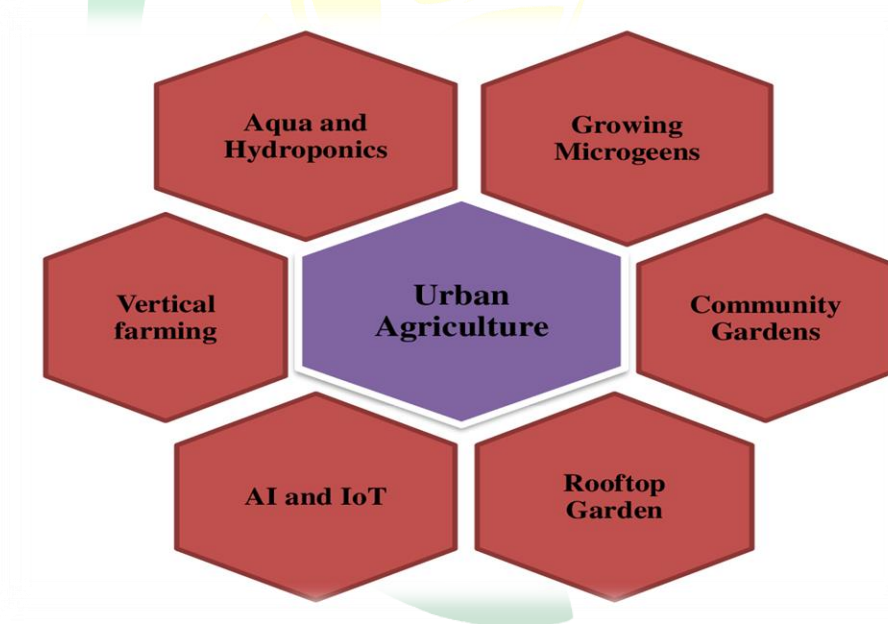
### Introduction

In recent years, a significant paradigm shift has occurred in urban landscapes globally, where concrete jungles are giving way to green oases of urban agriculture. This transformation is indicative of a burgeoning green revolution, a response to the escalating need for sustainable and locally-sourced food. The urbanization trend, with over 55% of the world's population residing in urban areas as of 2022 (Khan et al., 2022), has intensified the demand for innovative

solutions to feed burgeoning city populations sustainably. As cities expand, the traditional model of food production, reliant on vast rural landscapes, becomes increasingly impractical. Urban agriculture emerges as a multifaceted solution to this dilemma, providing a means to cultivate food within the very heart of urban centers (McClintock, 2010). The critical aspect, however, lies in tailoring crops explicitly for these dynamic and often challenging urban environments.

### **The Rising Popularity of Urban Agriculture**

Urban agriculture has gained traction globally due to its potential to address various challenges associated with conventional agricultural practices. With the advent of technology and innovative farming methods, urban spaces are increasingly recognized as viable areas for food production. According to a report by the World Bank, the urban agriculture sector is estimated to provide up to 15-20% of the world's food supply (Taffal, 2022). This growing popularity is driven by the need for food security, reduced carbon footprint, and the desire for communities to reconnect with their food sources.



**Figure 1. Components of urban agriculture**

### **Breeding Crops for Urban Settings: The Critical Nexus**

The success of urban agriculture hinges on the cultivation of crops specifically adapted to the unique conditions of urban environments. Breeding crops for urban settings involves a comprehensive understanding of the challenges posed by limited space, altered soil conditions,



and the need for resource efficiency. Scientifically tailored crops can potentially maximize yield, nutritional value, and overall resilience in the face of urban stressors.

### **Challenges and Opportunities in Urban Agriculture: An In-Depth Exploration**

Urban agriculture brings both challenges and opportunities to the forefront. Challenges include limited space, prompting the need for compact plant varieties, and soil quality issues, with urban soils often contaminated by pollutants. However, these challenges also present opportunities for innovation. Vertical farming, for example, addresses spatial constraints by utilizing vertical space efficiently. Furthermore, technologies like hydroponics and aeroponics provide alternatives to traditional soil-based cultivation, overcoming soil quality and contamination issues.

As urban agriculture gains momentum, scientific research plays a pivotal role in unravelling the complexities of these challenges and unlocking the potential of urban food production. In subsequent sections of this article, we will delve into the scientific intricacies of tailoring crops for urban environments, exploring the characteristics of ideal urban crops, successful breeding programs, and the role of technology and innovation. Through this exploration, we aim to provide a comprehensive understanding of the scientific foundations underpinning the green revolution sprouting within our cities.

### **The Urban Agriculture Landscape: A Scientific Exploration**

Urban agriculture has transcended its status as a niche concept and has metamorphosed into a dynamic movement, altering the very fabric of city skylines. This transformation is not confined to the quaint charm of community gardens or the utilitarian grace of rooftop farms; it represents a paradigm shift with profound implications for local food systems. To appreciate the scientific underpinnings of this evolution, we must delve into the intricacies of urban agriculture and its transformative potential.

**1. Scope and Diversity of Urban Agriculture: Beyond Vegetables in the City:** - Urban agriculture encompasses a diverse range of practices, far beyond the simplistic notion of growing vegetables within city limits. From aquaponics systems embedded in high-rise buildings to hydroponic setups thriving in abandoned warehouses, the spectrum is vast and intricate (Mafwila Kinkela et al., 2019). Scientifically, this diversity is a response to the



heterogeneity of urban environments – each space demanding tailored solutions to optimize resource use, mitigate environmental impact, and ensure sustainable productivity.

2. **Transformative Force in Local Food Systems: The Scientific Dynamics:** - The impact of urban agriculture extends beyond the visual aesthetics of green spaces in the city. Scientifically, this phenomenon is a transformative force driven by several key factors:
  - a. **Reduced Food Miles and Carbon Footprint:** The traditional food supply chain involves extensive transportation, contributing to greenhouse gas emissions. Urban agriculture minimizes food miles, reducing the carbon footprint associated with transportation. Studies have shown that locally-produced food significantly lowers greenhouse gas emissions compared to conventionally sourced produce (Sonnino, 2016).
  - b. **Enhanced Food Security:** Urban agriculture contributes to localized food production, enhancing food security in urban areas. By reducing dependency on external sources, cities can better withstand disruptions in the global food supply chain. Scientifically, this is supported by studies demonstrating the positive correlation between urban agriculture and increased food security (Mougeot, 2000).
  - c. **Biodiversity and Ecosystem Services:** Urban agriculture systems, when designed with ecological principles, can enhance biodiversity and provide essential ecosystem services. Green roofs, for instance, support pollinators and improve urban microclimates. Scientifically, research highlights the potential of urban agriculture to contribute to urban biodiversity conservation (Clucas et al., 2010).
3. **Adapting Crops to Unique Urban Conditions: A Scientific Imperative:** - The evolution of cities necessitates a scientific reevaluation of our approach to crop cultivation. Urban environments pose unique challenges, including limited space, altered microclimates, and soil contamination. Breeding crops for these conditions requires a nuanced understanding of plant physiology, genetics, and environmental science.
  - a. **Compact Growth Habits:** Scientifically tailoring crops for compact growth involves manipulating factors like plant architecture, hormone signaling, and genetic expression. Compact growth not only optimizes space but also addresses issues related to shading in densely built urban areas.



- b. **Shorter Maturation Periods:** Accelerating the maturation process without compromising yield and nutritional content is a complex challenge. Genetic modifications and selective breeding are avenues explored by scientists to develop crops that mature swiftly, catering to the fast-paced nature of urban agriculture.
- c. **High Yield and Nutritional Value:** Urban agriculture isn't merely about growing crops; it's about growing nutrient-dense crops efficiently. Scientific interventions, including precision breeding and targeted nutrient supplementation, contribute to achieving high yields without sacrificing nutritional quality.

### Challenges in Urban Agriculture

Urban agriculture, while promising, is not without its share of formidable challenges that demand innovative and scientifically grounded solutions. Perhaps the most glaring hurdle is the limitation of space. As urban landscapes become increasingly populated and developed, the availability of horizontal space for traditional farming diminishes. The need for a paradigm shift toward compact plant varieties becomes evident, a scientific endeavor requiring an understanding of plant genetics, physiology, and growth patterns. This shift prompts exploration into the realm of vertical farming, a revolutionary concept where crops ascend towards the sky rather than sprawling horizontally (Chatterjee et al., 2020). This vertical approach not only optimizes space but also challenges traditional notions of cultivation, requiring meticulous adjustments in irrigation, lighting, and nutrient delivery systems.

Another critical challenge in urban agriculture lies beneath the surface – the quality of urban soil and the pervasive issue of contamination. Urban soils often carry the legacy of industrial activities, pollutants, and other contaminants that can compromise the health and productivity of crops. Scientifically addressing this challenge involves breeding crops with inherent resilience to contaminants, a process that delves into plant genetics to fortify natural defense mechanisms. Simultaneously, urban agriculture explores alternative cultivation methods that circumvent traditional soil reliance. Hydroponics and aeroponics emerge as promising alternatives, where plants grow in nutrient-rich water or mist, eliminating soil-related issues altogether. These innovative methods not only mitigate the impact of urban soil quality but also contribute to water conservation and resource efficiency. The challenges posed by limited space and soil quality in urban agriculture are not isolated; they intertwine with

broader issues of sustainability and resource management. Scientific solutions, therefore, must be holistic, addressing not only the immediate spatial constraints but also the long-term health of the cultivation environment. The shift towards compact plant varieties and vertical farming epitomizes a scientific response to the spatial limitations, while the exploration of resilient crops and alternative cultivation methods reflects a nuanced understanding of the intricate interplay between plants and their urban habitats.

### Tailoring Crops for Urban Environments

In the pursuit of ideal crops for urban environments, the scientific endeavor extends to creating a botanical marvel, a plant adapted to the unique challenges presented by the urban landscape. The characteristics of the ideal urban crop are threefold: compact growth habits, shorter maturation periods, and high yield coupled with superior nutritional value (Eigenbrod and Gruda, 2015). These traits collectively serve to optimize space, accommodate the fast-paced urban lifestyle, and ensure a bountiful harvest of nutrient-dense produce. Achieving this botanical ideal requires a nuanced understanding of plant genetics, physiology, and environmental interactions.

Compact growth habits are a key feature of urban crops (Table 1). This adaptation involves manipulating plant architecture to limit outward expansion, ensuring efficient space utilization. Through selective breeding and genetic modification, scientists work to create plants that maintain robust growth in confined spaces, be it within vertical farming structures or community garden plots. Compact growth not only addresses spatial limitations but also aligns with the aesthetic and functional requirements of urban landscapes.

**Table 1. List of Ideal Urban Crops with Growing Characteristics**

| Species  | Characteristics                             | Crop Duration                        | Ideal Growing Method                 |
|----------|---|--------------------------------------|--------------------------------------|
| Tomatoes | Compact growth, well-suited for containers  | 60-85 days<br>(depending on variety) | Container gardening, vertical stakes |
| Lettuce  | Fast-growing, can be grown in small spaces  | 45-55 days                           | Raised beds, hydroponics             |
| Radishes | Quick maturation, suitable for shallow beds | 20-30 days                           | Container gardening, intercropping   |

|                           |   |                               |  |
|---------------------------|---|-------------------------------|--|
| Spinach                   | Leafy greens, tolerates partial shade     | 40-50 days                    | Vertical gardening, shaded areas       |
| Herbs (Basil, Mint, etc.) | Compact, aromatic, adaptable              | Varies by herb type           | Windowsill gardening, mixed containers |
| Strawberries              | Low-growing, ideal for hanging containers | 4-6 weeks (from transplant)   | Hanging baskets, strawberry towers     |
| Microgreens               | Rapid growth, high nutrient density       | 7-21 days (depending on type) | Indoor trays, hydroponics              |
| Bell Peppers              | Compact, well-suited for containers       | 60-90 days                    | Container gardening, trellising        |
| Cucumbers                 | Vertical growth, suitable for trellises   | 50-70 days                    | Trellis systems, vertical gardening    |
| Carrots                   | Deep-rooted, suitable for deep containers | 70-80 days                    | Deep containers, raised beds           |

Shorter maturation periods represent a strategic response to the rapid pace of urban life. Urban dwellers, accustomed to the immediacy of city living, benefit from crops that mature swiftly without compromising yield or nutritional content. Scientific interventions, ranging from selective breeding for early maturation traits to the application of advanced biotechnological methods such as CRISPR, contribute to the development of crops that align with the time constraints of urban agriculture.

High yield and nutritional value form the cornerstone of the ideal urban crop. While optimizing space and expediting maturation are crucial, the goal is to provide a rich harvest of nutrient-dense produce. Precision breeding techniques, combined with advancements in agronomy and fertilization practices, enable the cultivation of crops that not only thrive in urban settings but also offer a healthful bounty to urban consumers.

### **Technology and Innovation**

In the realm of urban agriculture, technology and innovation stand as pivotal pillars, propelling the field into uncharted territories. Biotechnology, in particular, emerges as a transformative force, fundamentally altering the landscape of urban crop breeding. The application of genetic modification techniques for disease resistance enables the creation of



crops endowed with natural defenses against prevalent urban pathogens. Notably, the precision breeding capabilities of CRISPR technology offer unprecedented precision in manipulating the genetic makeup of crops, allowing scientists to fine-tune desirable traits with remarkable accuracy (Kwon et al., 2020). This technological prowess opens new frontiers in the creation of robust and resilient crops tailored to the unique challenges posed by urban environments.

Simultaneously, the marriage of agriculture and technology gives rise to the concept of smart farming, where the Internet of Things (IoT) takes center stage (Gunawan et al., 2019). Through interconnected sensors and devices, smart farming provides real-time monitoring and control over various aspects of crop cultivation. In urban settings, where space is limited and efficiency is paramount, IoT-enabled systems become invaluable. These systems offer insights into environmental conditions, nutrient levels, and irrigation needs, allowing for precise adjustments that optimize crop growth. The integration of smart farming technologies not only streamlines the cultivation process but also contributes to resource conservation and sustainability.

Furthermore, data analytics emerges as a powerful tool in the arsenal of urban agriculture (Allioui and Mourdi, 2023). The vast amount of data generated by smart farming systems provides a wealth of information that, when analyzed, offers valuable insights into crop performance. Data-driven approaches sharpen our understanding of the intricate relationships between environmental factors, crop genetics, and overall productivity. By harnessing this wealth of information, farmers and researchers can make informed decisions to enhance yields, improve resource efficiency, and address specific challenges unique to urban agricultural settings.

### **Community Engagement and Sustainable Practices**

In the bustling landscapes of urban environments, community engagement stands as the beating heart of urban agriculture, manifesting in tangible and impactful ways. Community gardens emerge as vibrant hubs, exemplifying how shared spaces can foster a sense of collective responsibility and a deep connection to the food we cultivate. An illustrative example can be found in cities like New York, where initiatives such as the "New York City GreenThumb" program have transformed vacant lots into thriving community gardens, bringing together diverse groups of residents to actively participate in the cultivation and care of shared green spaces (Elder, 2005). These gardens not only beautify the urban landscape but





also serve as communal platforms for knowledge exchange and social bonding, reinforcing the symbiotic relationship between urbanites and their cultivated sustenance.

Educational programs represent another facet of community engagement, empowering urban dwellers to become informed stewards of their own food sources. For instance, in cities like Berlin, the "Prinzessinnengarten" initiative integrates educational programs into its community gardening efforts (Dagher, 2015; Mayayo et al., 2019). Workshops on sustainable farming practices, composting, and water conservation equip urbanites with the knowledge and skills needed to actively contribute to the ecological health of their shared spaces. By imparting practical insights, these programs foster a sense of environmental responsibility and empower individuals to make informed choices in their daily lives.

Promoting crop diversity within urban agriculture becomes pivotal, transcending the pursuit of variety to embody a strategic response to ensure food security and resilience against the unpredictability of climate change. In Tokyo, the "Tokyo Farmers" project exemplifies this principle by encouraging the cultivation of diverse crops within shared urban spaces (Niwa, 2012). By diversifying the range of crops grown, communities not only enjoy a variety of fresh produce but also mitigate the risks associated with relying heavily on a single crop. This diversity acts as a buffer against the impacts of climate change, pests, and other unforeseen challenges, reinforcing the resilience of urban agricultural systems.

### **Prospects**

As we cast our gaze into the future of urban agriculture, discernible trends and innovations herald a promising landscape. The integration of renewable energy sources emerges as a transformative force, offering a sustainable power foundation for urban farming. Initiatives incorporating solar panels, wind turbines, and other renewable technologies not only reduce the carbon footprint of urban agriculture but also contribute to creating resilient and self-sufficient food systems. Concurrently, continued advancements in crop breeding technologies amplify the potential for a greener tomorrow (O'sullivan, et al., 2019). Breakthroughs in precision breeding, genetic modification, and other biotechnological approaches promise crops that are not only resilient to urban challenges but also optimized for nutritional content and resource efficiency. These advancements not only augur well for urban agriculture but have far-reaching implications for global food systems.

### **Conclusion**



This exploration into the dynamic realm of urban agriculture underscores the critical role it plays in shaping a sustainable future. The integration of renewable energy sources and the relentless progress in crop breeding technologies represent beacons guiding us toward a greener and more resilient urban agriculture. The potential impact of this movement extends beyond the confines of city skylines; it reverberates across global food systems. The article resonates with a call to action, advocating for a collective commitment to supporting and nurturing urban agriculture initiatives. The seeds of change have been sown in our cities, embodying the potential to transform the way we feed our communities. By actively participating in and endorsing urban agriculture, we become architects of a healthier, more sustainable future for generations to come.

### References

- Allioui, H., & Mourdi, Y. (2023). Exploring the full potentials of IoT for better financial growth and stability: A comprehensive survey. *Sensors*, 23(19), 8015.
- 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.
- Clucas, B., Parker, I. D., & Feldpausch-Parker, A. M. (2018). A systematic review of the relationship between urban agriculture and biodiversity. *Urban Ecosystems*, 21, 635-643.
- Dagher, R. B. (2015). *Urban agriculture as a design strategy to improve livelihoods in disadvantaged neighborhoods: the case of Nabaa (Bourj Hammoud, Beirut)*- (Doctoral dissertation).
- Eigenbrod, C., & Gruda, N. (2015). Urban vegetable for food security in cities. A review. *Agronomy for Sustainable Development*, 35, 483-498.
- Elder, R. F. (2005). Protecting New York City's Community Gardens. *NYU Env'tl. LJ*, 13, 769.
- Gunawan, R., Taufik, I., Mulyana, E., Kurahman, O. T., & Ramdhani, M. A. (2019, July). Chatbot Application on Internet Of Things (IoT) to Support Smart Urban Agriculture. In *2019 IEEE 5th International Conference on Wireless and Telematics (ICWT)* (pp. 1-6). IEEE.



- Khan, A. H., Rasool, S., & Younas, H. A. (2022). Assessing and prediction of living standards in smart cities using machine learning. *International Journal of Computational and Innovative Sciences*, 1(3), 8-16.
- Kwon, C. T., Heo, J., Lemmon, Z. H., Capua, Y., Hutton, S. F., Van Eck, J., ... & Lippman, Z. B. (2020). Rapid customization of Solanaceae fruit crops for urban agriculture. *Nature Biotechnology*, 38(2), 182-188.
- Mafwila Kinkela, P., Kambashi Mutiaka, B., Dochain, D., Rollin, X., Mafwila, J., & Bindelle, J. (2019). Smallholders' Practices of Integrated Agriculture Aquaculture System in Peri-urban and Rural Areas in Sub Saharan Africa. *Tropicultura*.
- Mayayo, A. M., van Koppen, K., & Buijs, A. (2019). Community gardens as possible challengers of (eco) gentrification?
- Mougeot, L. J. (2000). Urban agriculture: Definition, presence, potentials and risks, and policy challenges. *Cities feeding people series; rept. 31*.
- Niwa, N. (2012). Why is there agriculture in Tokyo? From the origin of agriculture in the city to the strategies to stay in the city. In *Sustainable food planning: evolving theory and practice* (pp. 283-294). Wageningen Academic.
- O'sullivan, C. A., Bonnett, G. D., McIntyre, C. L., Hochman, Z., & Wasson, A. P. (2019). Strategies to improve the productivity, product diversity and profitability of urban agriculture. *Agricultural Systems*, 174, 133-144.
- Sonnino, R. (2016). The new geography of food security: exploring the potential of urban food strategies. *The Geographical Journal*, 182(2), 190-200.
- Taffal, N. (2022). A Proposal to Improve the Three SDGs in Nigeria's Urban Agriculture World Bank Project Proposal.