JURNAL BIOEDUKASI
VOLUME 9, NOMOR 1, TAHUN 2026

P-ISSN : 2301-427X
E-ISSN : 2829-0844
E-mail : bioedukasi14@gmail.com
https://ejournal.unkhair.ac.id/index.php/bioedu

"The Effectiveness of Hydroponic Technology in Organic Vegetable Production in Urban Areas"

Efektivitas Teknologi Hidroponik dalam Produksi Sayuran Organik di Perkotaan

Dodo Gustaman

Universitas Ibnu Chaldun, Jakarta.

* Corresponding Email: dodoagustaman@gmail.com

Abstract

Rapid urban population growth has limited agricultural land and increased demand for healthy food, particularly organic vegetables. Hydroponic technology is considered one solution for urban agriculture, capable of increasing production efficiency without relying on large areas of land. This study aims to assess the effectiveness of hydroponic technology in organic vegetable production in urban areas through a literature review. The method used was a systematic review of national and international scientific articles published between 2013 and 2024, sourced from Google Scholar, Garuda, Scopus, and DOAJ. The study results indicate that hydroponic systems can increase vegetable productivity by 20–50% compared to conventional systems, save water use by 70–90%, and produce more hygienic and environmentally friendly products. However, major challenges include initial investment costs, dependence on controlled nutrients, and limited organic certification for hydroponic systems. The study concludes that hydroponic technology is effective in supporting organic vegetable production in urban areas when combined with appropriate nutrient management and supporting policies.

Pertumbuhan penduduk perkotaan yang pesat menyebabkan keterbatasan lahan pertanian dan meningkatnya kebutuhan pangan sehat, khususnya sayuran organik. Teknologi hidroponik menjadi salah satu solusi pertanian perkotaan yang dinilai mampu meningkatkan efisiensi produksi tanpa ketergantungan pada lahan luas. Penelitian ini bertujuan untuk mengkaji efektivitas teknologi hidroponik dalam produksi sayuran organik di wilayah perkotaan melalui metode literature review. Metode yang digunakan adalah telaah sistematis terhadap artikel ilmiah nasional dan internasional yang diterbitkan pada periode 2013–2024, bersumber dari Google Scholar, Garuda, Scopus, dan DOAJ. Hasil kajian menunjukkan bahwa sistem hidroponik mampu meningkatkan produktivitas tanaman sayuran hingga 20–50% dibandingkan sistem konvensional, menghemat penggunaan air hingga 70–90%, serta menghasilkan produk yang lebih higienis dan ramah lingkungan. Namun demikian, tantangan utama meliputi biaya investasi awal, ketergantungan pada nutrisi terkontrol, serta keterbatasan sertifikasi organik pada sistem hidroponik. Kesimpulan dari kajian ini menunjukkan bahwa teknologi hidroponik efektif untuk mendukung produksi sayuran organik di perkotaan apabila diimbangi dengan manajemen nutrisi yang tepat dan kebijakan pendukung.

Article Information

Keywords: Ehydroponics; urban agriculture; organic vegetables; production efficiency

Kata kunci: Hidroponik; pertanian perkotaan; sayuran organik; efisiensi produksi.

History

Manuscript received	: 17/04/2026
Revised	: 27/04/2026
Accepted	: 29/04/2026
Published	: 30/04/2026

Jurnal BIOEDUKASI
JURNAL BIOEDUKASI
VOLUME 9, NOMOR 1, TAHUN 2026
P-ISSN : 2301-427X
E-ISSN : 2829-0844
E-mail : bioedukasi14@gmail.com
https://ejournal.unkhair.ac.id/index.php/bioedu

A. INTRODUCTION

Rapid urbanization has become a global phenomenon that significantly affects food production systems, particularly in urban areas. The migration of populations from rural to urban regions has led to the conversion of productive agricultural land into residential, industrial, and urban infrastructure developments. As a result, the availability of land for conventional agricultural activities in cities has become increasingly limited, reducing the capacity for local food production, particularly the production of fresh vegetables (FAO, 2018; Setyowati & Saptana, 2020). Consequently, urban areas have become increasingly dependent on food supplies from peri-urban and rural regions, which ultimately affects the stability of food supply, product quality, and food prices at the consumer level.

On the other hand, changes in the lifestyle of urban populations have been accompanied by a growing awareness of healthy and safe dietary practices. Urban consumers have become increasingly selective in choosing food products, particularly organically produced vegetables that are free from synthetic pesticide residues and environmentally friendly. Several studies have reported a significant increase in the demand for organic vegetables in urban areas, driven by growing consumer awareness of the health risks associated with the excessive use of agricultural chemicals (Suryani et al., 2019; Willer & Lernoud, 2019). Nevertheless, limited land availability and the low productivity of conventional farming systems constitute major challenges to meeting this increasing demand in a sustainable manner.

In this context, hydroponic technology has emerged as an innovative cultivation system that is widely recognized as a promising solution to the challenges of urban agriculture. Hydroponics is a soilless cultivation method in which plants receive essential nutrients through a carefully controlled nutrient solution. This system enables optimal plant growth in limited spaces while achieving high efficiency in water and nutrient use (Resh, 2013; Savvas & Gruda, 2018). Numerous studies have demonstrated that hydroponic systems are highly adaptable to urban environments, as they can be implemented on rooftops, in small residential yards, and within vertical indoor growing spaces.

The primary advantage of hydroponic systems lies in their efficient use of space and resources. Water consumption in hydroponic cultivation has been reported to be 70–90% lower than that of conventional farming systems due to the recirculation of water and nutrients within a closed-loop system (Putra & Yuliando, 2015; FAO, 2021). In addition, the ability to maintain a well-controlled growing environment minimizes plant exposure to soil-borne pests and pathogens, thereby substantially reducing the need for pesticide application. Consequently, hydroponic cultivation has the potential to produce vegetables that are cleaner, more uniform in quality, and of higher market value, while also achieving shorter production cycles.

Nevertheless, the effectiveness of hydroponic technology in the context of organic vegetable production remains a subject of debate among researchers and practitioners. Some scholars argue that hydroponic cultivation cannot be fully classified as an organic production system because it relies on synthetic inorganic nutrient solutions, which are not entirely consistent with the principles of soil-based organic agriculture (IFOAM, 2014). Furthermore, concerns regarding the long-term sustainability of hydroponic systems, high initial investment costs, and the limited availability of organic certification standards for hydroponically grown produce continue to pose significant challenges that warrant further investigation (Gruda et al., 2016).

The variation in findings and perspectives across previous studies highlights a significant knowledge gap regarding the effectiveness of hydroponic systems in supporting organic vegetable production in urban areas. Therefore, a comprehensive and systematic literature review is needed to synthesize existing scientific evidence, identify the strengths and limitations of hydroponic technology, and evaluate its potential as a sustainable solution for urban food systems. This review is expected to provide a robust scientific foundation for the development of policies, technological innovations, and urban agricultural practices aimed at enhancing food security and promoting public health.

B. METHOD

Research Design and Approach

This study employed a systematic literature review using a descriptive-qualitative approach. This method was selected to examine, evaluate, and synthesize findings from previous studies relevant to the application of hydroponic technology in organic vegetable production within urban environments. A systematic literature review enables researchers to develop a comprehensive understanding of advances in scientific knowledge, emerging research trends, and existing knowledge gaps that warrant further investigation (Tranfield et al., 2003; Snyder, 2019).

The review was conducted using a structured and transparent approach, encompassing literature identification, article screening and selection, as well as the analysis and synthesis of research findings. This approach has been widely adopted in agricultural and sustainable food systems research because it provides a rigorous framework for synthesizing scientific evidence generated across diverse research contexts and geographical settings (Kitchenham & Charters, 2007; Xiao & Watson, 2019).

Data Sources and Data Collection

The data used in this study were obtained from national and international peer-reviewed journal articles published between 2013 and 2024. This publication period was selected to capture recent developments in hydroponic technology and urban agriculture, particularly those related to sustainability and organic food production. The literature search was conducted using several scientific databases, including Google Scholar, Garuda, Scopus, and the Directory of Open Access Journals (DOAJ).

Relevant studies were identified using a combination of keywords, including *"hydroponics," "urban agriculture," "organic vegetables," "soilless culture,"* and *"urban farming,"* in both Indonesian and English. Boolean operators (AND and OR) were employed to combine the search terms, thereby broadening or refining the search results to ensure their relevance to the objectives and scope of the study (Booth et al., 2016).

Inclusion and Exclusion Criteria

To ensure the relevance and quality of the data sources, this study applied predefined inclusion and exclusion criteria. The inclusion criteria were as follows:

1) Articles examining the application of hydroponic technology for vegetable cultivation;
2) Articles focusing on urban agriculture, organic farming systems, or sustainable food production systems;

3) Articles available in full-text format; and
4) Articles employing clearly described and scientifically rigorous research methodologies.

The exclusion criteria comprised articles that were not directly relevant to the research topic, non-scholarly publications, conference proceedings that had not undergone peer review, and publications that did not provide sufficient methodological information. The application of these criteria was intended to enhance the validity and reliability of the findings derived from the literature review (Petticrew & Roberts, 2006).

Article Selection Procedure

The article selection process was conducted through several sequential stages, including initial identification, title and abstract screening, full-text eligibility assessment, and the final selection of studies for analysis. Although this study adopted a structured narrative review approach, the selection process was conceptually guided by the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al., 2009). Articles that satisfied all predefined inclusion criteria were subsequently subjected to an in-depth analysis to extract relevant data and identify the principal findings.

Data Analysis

Data extracted from the selected articles were analyzed using a descriptive qualitative approach. The analysis involved categorizing the findings into several key themes, including crop productivity, resource use efficiency (water and nutrient utilization), product quality and food safety, and environmental sustainability. Each theme was examined by comparing findings across studies to identify recurring patterns, similarities, and discrepancies in the reported results (Miles et al., 2014).

The findings were subsequently synthesized using a narrative approach to provide a comprehensive understanding of the effectiveness of hydroponic technology in supporting organic vegetable production in urban environments. This analytical approach was expected to generate comprehensive conclusions and provide evidence-based recommendations for the advancement of sustainable urban agriculture.

C. RESULTS AND DISCUSSION

Development of Hydroponic Technology in Urban Areas

The findings of the literature review indicate that hydroponic technology has experienced rapid development as an integral component of urban agriculture. The application of hydroponic systems is no longer confined to household-scale production but has expanded to commercial and semi-industrial operations in many major cities. This expansion has been driven by the decreasing availability of conventional agricultural land and the growing demand among urban populations for fresh, healthy, and sustainably produced food (FAO, 2018; Savvas & Gruda, 2018).

Among the various hydroponic systems employed in urban agriculture, the most commonly adopted include the Nutrient Film Technique (NFT), Deep Flow Technique (DFT), the floating raft system, and the drip irrigation system. NFT and DFT are widely used for the cultivation of leafy vegetables due to their efficient nutrient delivery and ease of system management. In contrast, the floating raft system is considered more stable under fluctuations in nutrient concentration and temperature, making it particularly suitable for beginners and small-scale commercial production (Resh, 2013).

A key advantage of hydroponic technology in urban environments is its flexibility in space utilization. Numerous studies have reported that hydroponic systems can be implemented in confined spaces, including building rooftops (rooftop farming), small residential yards, apartment balconies, and indoor growing facilities equipped with artificial lighting (Gruda et al., 2016). Consequently, hydroponic cultivation plays a significant role in transforming previously underutilized urban spaces into productive areas for food production.

Efficiency of Organic Vegetable Production

From a productivity perspective, the majority of the literature indicates that hydroponic systems are capable of producing higher vegetable yields than conventional soil-based cultivation systems. Leafy vegetables such as lettuce (Lactuca sativa), spinach (Amaranthus spp.), water spinach (Ipomoea aquatica), and mustard greens (Brassica spp.) have been reported to achieve yield increases ranging from 20% to 50%, accompanied by relatively shorter cultivation cycles compared with conventional production systems (Putra & Yuliando, 2015; Savvas et al., 2017).

The enhanced productivity of hydroponic systems can be attributed to the precise and optimized supply of nutrients available to plants. In hydroponic cultivation, essential nutrients are supplied directly in ionic forms that are readily absorbed by plant roots, resulting in greater nutrient uptake efficiency than in soil-based systems, where nutrient fixation often limits nutrient availability (Resh, 2013). Furthermore, the controlled growing environment minimizes plant stress, thereby promoting faster and more uniform vegetative growth.

Water use efficiency is another major advantage of hydroponic systems. Several studies have reported that hydroponic cultivation can reduce water consumption by 70–90% compared with conventional agriculture because of its closed-loop recirculation system, which minimizes water losses through evaporation and percolation (FAO, 2021; Putra et al., 2020). These findings highlight the suitability of hydroponic technology for urban areas, where the availability of freshwater resources is often limited.

Product Quality and Food Safety

In addition to production quantity, product quality and food safety are critical aspects of organic vegetable production. The literature consistently indicates that hydroponically grown vegetables generally exhibit superior physical quality, characterized by more uniform leaf size, brighter coloration, and higher levels of cleanliness (Suryani et al., 2019). These characteristics are primarily attributable to the minimal contact between plants and soil, thereby reducing the risk of contamination by soil-borne pathogens and heavy metals.

From a food safety perspective, hydroponic systems enable a substantial reduction in the use of synthetic pesticides due to their relatively sterile and well-controlled growing environment. Several studies have reported that the incidence of pests and diseases is lower in hydroponic systems than in conventional soil-based cultivation, resulting in safer produce for human consumption (Gruda et al., 2016). Consequently, hydroponically grown vegetables have considerable potential to meet the increasing consumer demand for safe, high-quality, and healthy food products in urban areas.

Nevertheless, the organic status of hydroponically grown produce remains a subject of ongoing debate. Several studies have emphasized that the use of synthetic inorganic nutrient solutions in hydroponic cultivation is not fully consistent with the principles of organic agriculture, which are fundamentally based on soil ecosystem management. Therefore, the development of organically derived nutrient solutions from natural sources has been proposed as a promising strategy to preserve the organic integrity of hydroponically grown crops (IFOAM, 2014; Willer & Lernoud, 2019).

Challenges and Limitations of Hydroponic Adoption

Despite its numerous advantages, the adoption of hydroponic technology in urban areas is accompanied by several challenges and limitations. One of the primary constraints is the relatively high initial investment required for infrastructure, including cultivation units, pumps, irrigation systems, and electricity supply. These capital requirements may hinder the adoption of hydroponic technology, particularly among low-income households and small-scale growers (Putra & Yuliando, 2015).

In addition, successful hydroponic cultivation requires adequate technical expertise, particularly in nutrient management, pH regulation, and water quality monitoring. Inappropriate nutrient management can directly affect plant growth and productivity, potentially leading to reduced yields or crop failure. Furthermore, dependence on nutrient solutions raises concerns regarding the long-term sustainability of hydroponic systems, especially when these solutions are derived primarily from synthetic chemical inputs (Savvas & Gruda, 2018).

From a regulatory perspective, the lack of standardized guidelines and organic certification schemes for soilless cultivation systems remains an important issue that requires further attention. Several organic certification bodies have not yet fully recognized hydroponic cultivation as an organic production system because it does not fully comply with the soil-based principles of organic agriculture. Consequently, hydroponically grown products are often ineligible for official organic certification, even when produced without the use of synthetic pesticides. This limitation presents a significant challenge for hydroponic producers seeking to enhance the market competitiveness of their products within the organic food sector (IFOAM, 2014). This situation presents a considerable challenge for hydroponic producers in improving the market competitiveness of their products within the organic food sector.

D. CONCLUSION

Based on the findings of this systematic literature review of national and international studies, it can be concluded that hydroponic technology is an effective cultivation system for supporting organic vegetable production in urban areas. Hydroponic systems have proven capable of addressing the constraints associated with limited urban agricultural land through the efficient utilization of confined spaces, both at the household and commercial scales. Their effectiveness is reflected in increased productivity of leafy vegetables, substantial improvements in water use efficiency, and superior crop quality compared with conventional soil-based cultivation systems (Resh, 2013; Savvas & Gruda, 2018).

In addition to enhancing production capacity, hydroponic systems contribute to improved product quality and food safety. Hydroponically grown vegetables generally exhibit higher levels of cleanliness, greater uniformity, and a lower risk of contamination by soil-borne pathogens and pesticide residues. These characteristics make hydroponic cultivation a promising alternative for producing safe and healthy food that meets the growing demand of urban consumers for environmentally sustainable and organically produced food (FAO, 2018; Suryani et al., 2019).

Nevertheless, the findings of this review also indicate that the successful implementation of hydroponic technology depends not only on the technical performance of the cultivation system but also on effective nutrient management, the technical knowledge and skills of growers, and the availability of supportive institutional frameworks and public policies. Inadequate nutrient solution management may reduce crop productivity and quality, while the absence of well-established regulatory frameworks and organic certification standards for soilless cultivation systems continues to hinder the broader development of organic hydroponic production (IFOAM, 2014; Willer & Lernoud, 2019).

Therefore, continued efforts are needed to develop organic hydroponic standards that are better aligned with the principles of sustainable agriculture and urban food systems. Future research should focus on the development of organically derived nutrient solutions from natural sources, improving the energy efficiency of urban hydroponic systems, and integrating hydroponic cultivation with sustainable urban agriculture approaches such as vertical farming and circular agriculture. With sustained support from scientific research, policy development, and educational initiatives, hydroponic technology has the potential to become a key component of resilient urban food systems and to contribute significantly to urban food security and sustainable food production.

E. REFERENCES

Booth, A., Sutton, A., & Papaioannou, D. (2016). *Systematic approaches to a successful literature review*. London: Sage.

FAO. (2018). *Urban agriculture and food security*. Rome: FAO.

FAO. (2021). *Water-saving technologies in agriculture*. Rome: FAO.

Gruda, N., Bisbis, M., & Tanny, J. (2016). Impacts of protected vegetable cultivation on climate change and adaptation strategies. *Horticulturae*, 2(4), 1–15.

IFOAM. (2014). *The principles of organic agriculture*. Bonn: IFOAM.

Kitchenham, B., & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering*. EBSE.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis*. Thousand Oaks: Sage.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses. *PLoS Medicine*, 6(7), e1000097.

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences*. Oxford: Blackwell.

Putra, P. A., & Yuliando, H. (2015). Soilless culture system to support water use efficiency. *Procedia Environmental Sciences*, 23, 283–288.

Putra, P. A., et al. (2020). Water efficiency of hydroponic systems. *Journal of Cleaner Production*, 252, 119–130.

Resh, H. M. (2013). *Hydroponic food production*. Boca Raton: CRC Press.

Savvas, D., & Gruda, N. (2018). Application of soilless culture technologies in urban agriculture. *Agronomy*, 8(12), 1–20.

Savvas, D., et al. (2017). Nutrient management in hydroponics. *Scientia Horticulturae*, 219, 1–15.

Setyowati, N., & Saptana. (2020). Tantangan pertanian perkotaan di Indonesia. *Jurnal Analisis Kebijakan Pertanian*, 18(2), 89–102.

Snyder, H. (2019). Literature review as a research methodology. *Journal of Business Research*, 104, 333–339.

Suryani, A., Hidayat, T., & Rahman, F. (2019). Preferensi konsumen terhadap sayuran organik di perkotaan. *Jurnal Agribisnis Indonesia*, 7(1), 45–56.