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Organic hydroponics: A review

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Highlights

- The certification status of organic hydroponics in different countries was summarized.
- Recent hydroponics studies with diverse organic nutrients were examined, mainly in vegetable crops.
- Feasibility and challenges of organic hydroponics were identified.
- Nutrient solution management challenges for organic hydroponics were explored.

Abstract

This review paper presents a comprehensive evaluation of current studies using organic nutrient sources in hydroponic solution culture. With growing market demand for organic products related to an emphasis on sustainability and environmental consciousness, there is a rising interest in this approach. The paper focuses on three key aspects: (1) offering an overview of the current status of organic hydroponics and organic certification in various countries; (2) defining different organic nutrient sources used in hydroponic systems, which encompass a wide range of materials derived from animals, plants, and algae, and comparing their impact on crop growth to conventional fertilization; and (3) examining challenges in nutrient solution management for organic hydroponics. This review highlights that leafy greens and tomatoes are the focal crops in most studies where various organic fertilizer sources have been evaluated. Additionally, the nutrient film technique and deep water culture are the predominant hydroponic systems utilized. With regard to nutrient solution management, the review underscores the differences in managing electrical conductivity, pH, dissolved oxygen, and microorganisms between organic and conventional solution culture systems. By offering these insights into organic hydroponics, this review aims to foster progress and promote the development of efficient and sustainable organic hydroponic practices.

Introduction

A hydroponic system, or hydroponics, has been often defined as a technique of growing plants without soil by using mineral nutrient solutions with or without the use of soilless substrates, such as gravel, sand, pumice, perlite, vermiculite, rockwool, peat moss, coco coir, or sawdust (Leeand Lee,2015; Waltersetal., 2020; Sharmaetal., 2018; Niuand Masabni,2022). As this definition encompasses both solution culture, where plant roots are suspended or supported in a nutrient solution, and soilless culture, where soilless growing media in containers provide physical support to the plant roots while allowing for nutrient and water uptake (Waltersetal., 2020; Caronand Zheng,2021; Niuand Masabni,2022), “hydroponics” and “soilless culture” have been often used interchangeably (Gómezetal., 2019). However, recent consensus advocates for reserving the term “hydroponics” specifically for solution culture (Waltersetal., 2020; Caronand Zheng,2021; Niuand Masabni,2022). In the context of this review paper, the term “hydroponics” refers exclusively to solution culture.

Depending on methods of applying the nutrient solution, various types of hydroponic systems include deep water culture (DWC), nutrient film technique (NFT), wick, drip, ebb-flow, and aeroponic configurations (Lee and Lee, 2015). A wide range of food crops has been grown successfully in hydroponic systems, including leafy vegetables and herbs, such as lettuce, kale, and basil, and fruiting crops, such as tomatoes, cucumbers, and strawberries (Lee and Lee, 2015; Kozai et al., 2019). Compared to soil-based crop production, hydroponic crop production offers numerous benefits, including the potential for higher yields and higher quality products, higher water and nutrient use efficiency, the ability to reuse water and nutrients, simplified environmental control, and prevention of soil-borne diseases and pests (Barbosa et al., 2015). In addition, current challenges for food production, including climate change, decreases in freshwater resources and arable lands, and limited and unequal access to local fresh produce in urban areas, have led to the increased use of hydroponics.

Organic hydroponics refers to the use of organic nutrient sources in hydroponic systems. Bioponics is another term for organic hydroponics, though this term may also imply that microorganisms are added to the organic fertilizer source to ensure nutrient release (Fang and Chung, 2018). Aquaponics also fits within the definition of bioponics (Fang and Chung, 2018; Szekely and Jijakli, 2022). One of the most important aspects of using hydroponics for successful food crop production is managing the nutrient solution. Nutrient solutions in hydroponic systems must supply essential elements within a narrow pH range to manage nutrient solubility, and thus plant availability. Synthetic inorganic fertilizers have been extensively used to formulate nutrient solutions in hydroponic crop production (Rogers, 2017; Phibunwatthanawong and Riddech, 2019; Richa et al., 2020). In organic hydroponics, organic nutrients such as compost tea, fish emulsion, seaweed extract, vinasses and other waste and natural products are used to provide the necessary minerals and nutrients to the plants. This approach avoids the use of synthetic fertilizers. Future technologies are being developed to repurpose organic-grade municipal solid waste compost products as nutrient sources.

A potential advantage of organic hydroponics is that nitrate (NO_3) accumulation in leaf tissue, which is a human health risk when consumed at high levels (Karwowska and Kononiuk, 2020), is often reduced when organic nutrient sources are used instead of conventional fertilizers high in nitrate. For example, Fang and Chung (2018) found that nitrate levels in two of three cultivars of lettuce were reduced to 800–2000 ppm nitrate compared to 5000–5500 ppm nitrate in lettuce conventionally fertilized. Similarly, Williams and Nelson (2016) observed that in a trial with 'Rex' butterhead lettuce, leaf petiole nitrate levels were 600–1100 ppm in conventionally fertilized treatments, but 35–200 ppm in plants fertilized with a commercial organic nutrient blend.

Because of the strong market demand for organic products, the desired flavor of some organic products, and the potential for reduced nitrate accumulation in plant tissue and other perceived health benefits, interest in organic hydroponics is growing. Furthermore, organic-based materials can be utilized as biostimulants. Moreover, the use of hydroponic production systems with organic inputs in urban areas may offer the opportunity to produce organic fresh vegetables without the use of synthetic inputs in locations where traditional organic cultivation is not possible. Finally, organic hydroponics is an integral component of developing technologies that enable the intertwined relationships between food, energy, water, and repurposed waste for nutrient generation (Shamshiri et al., 2018).

However, in addition to certification issues regarding organic hydroponic products in many countries, these production systems are still under investigation. Generally, achieving high plant yield with organic nutrient sources comparable to that from conventional hydroponic fertilizers is challenging, as noted in an early publication on the topic (Atkin and Nichols, 2004). A productive organic hydroponic setup requires a balanced and stable pH level, precise control of electrical conductivity (EC) in the nutrient solution, and the presence of adequate microorganisms. Organic nutrient sources may contain too many constituents (e.g., micronutrients) or unneeded constituents [e.g., sodium (Na)] that require regular ion-specific monitoring of nutrient reservoirs.

This review paper presents a comprehensive evaluation of the current state of knowledge about organic hydroponics in solution culture with the aim of promoting further research, innovation, and adoption of sustainable, organic hydroponic systems. Specifically, the objectives of this review paper were (1) to provide an overview of the status of organic hydroponics and organic certification in different countries; (2) to compare different organic nutrient sources and their impact on hydroponic crop yield; and (3) to examine recent findings on nutrient solution management in organic hydroponics. This review paper solely focuses on organic hydroponics using solution culture. Other review papers are available regarding use of organic nutrient sources in soilless culture (Bergstrand, 2022, Burnett et al., 2016).

Section snippets

Overview of organic certification

The term “organic” has different definitions in countries around the world, and the concept of “organic hydroponics” is especially controversial because it may not fully align with the traditional criteria for organic production, which places a strong emphasis on soil biological cycles. This discrepancy has led to divergent organic certification outcomes depending on the international region. In the United States, hydroponic operations can be certified as organic under USDA regulations by…

Review of recent organic hydroponic studies

In this section, we examined recent studies on organic fertilizers used in hydroponic solution culture published in the last two decades (Table 1). Our findings revealed a diverse range of materials derived from animals, plants, and algae serving as nutrient sources in organic fertilizers. Animal-based options included manure extracts and fish products, while plant-based alternatives encompassed vinasses, corn steep liquor, and vermicompost tea. Algae-based fertilizers included both the direct…

Nutrient content and electrical conductivity (EC)

Nutrient management in organic hydroponic systems offers unique challenges. Conventional hydroponic growers often rely on routine EC measures to determine when nutrient additions to recirculating solutions are needed. This measure is not as meaningful with organic nutrient sources because uncharged ions do not contribute to the measurement and many organic molecules do not all have charge until microbial degradation begins. As such, in research using an NFT system and liquid organic…

Conclusion and future outlook

Organic hydroponics is increasingly recognized as a promising solution to address a range of pressing sustainability challenges (Di Gioia and Rosskopf, 2021, Szekely and Jijakli, 2022). The use of organic fertilizers in hydroponic systems is allowable for certified organic production in the United States, and this production method is a foundation of emerging technologies for sustainable, circular food production that enables the intertwined relationships between energy, water, and nutrient…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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