BIOPONICS: TRANSFORMING SOIL-LESS URBAN AGRICULTURE

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Global food security is challenged by drastic change in climate pattern, increase in global population and shrinkage of cultivable area due to urbanization. This makes the conventional method of growing fruits and vegetables in soil insufficient to meet the need of growing population. In addition, unrestricted application of hazardous chemicals like pesticides and herbicides in intensive farming methods may harm the environment. Limited utilization of soil and agricultural chemicals are inevitable in reducing the negative impact of agriculture on planet and producing safe food. Here comes the importance of techniques like hydroponics, aquaponics, and bioponics which involves growing in plants limited space without soil (Figure 1).

In hydroponics, plants are grown in nutrient solution where materials like clay balls, metals are being used to support plant roots whereas, aquaponics combines hydroponics and aquaculture techniques (fish farming).

Bioponics is an emerging agriculture technique in which chemical fertilizers are swapped out for organic or natural ones. Similar to hydroponics, it is also an agriculture practice in controlled environment, but in an environmental friendly way excluding agricultural chemicals utilizing recycled plant or animal based materials as the nutrient source. The organic waste gets converted into simple molecules by microbial activities and enhances easy absorption by plants.

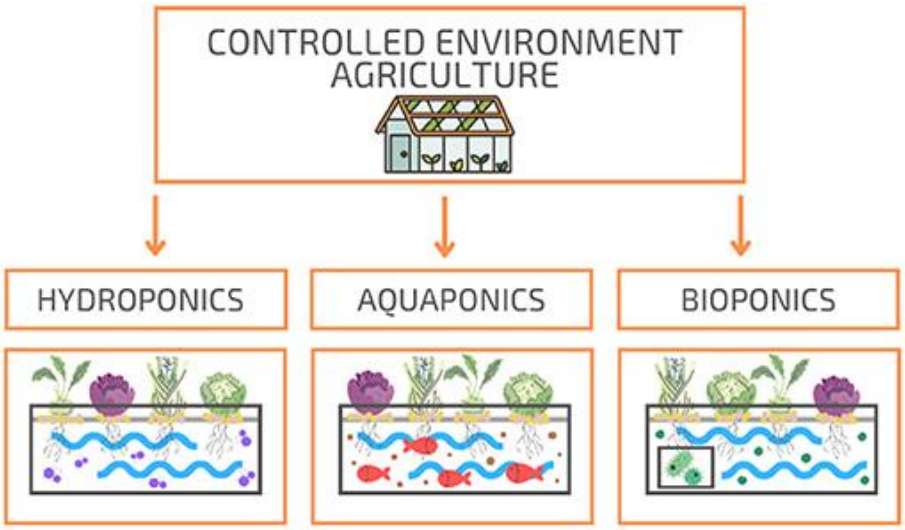

Figure 1. Types of controlled environment agriculture (Source: https://kids.frontiersin.org/articles/10.3389/frym.2023.1009081)

BIOPONICS SYSTEM

The bioponics system (Figure 2) consists of a Biofilter tank, Recirculating tank and a Growing unit. In the biofilter tank microbial activity transforms the animal or plant based compounds into a plant available form of nutrients. The nutrient rich water from the biofilter tank is pumped into the water recirculating tank and the diluted water with nutrients is then pumped from the water recirculating tank in to the plant growing unit.

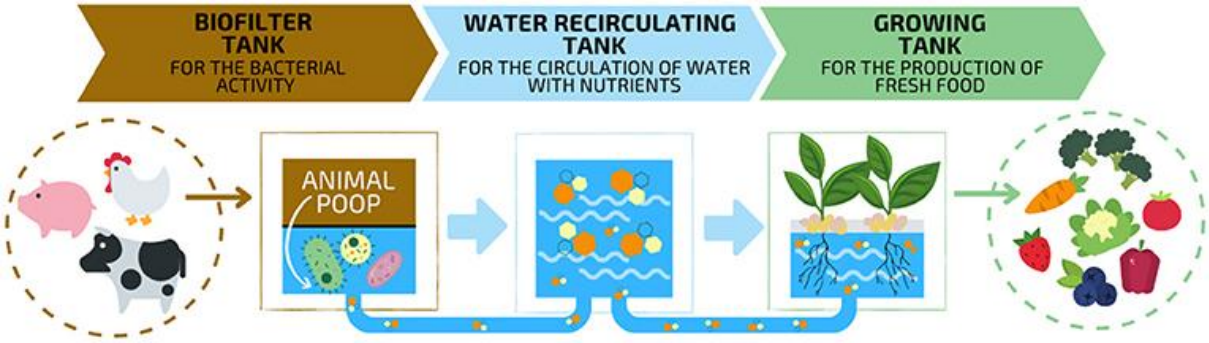

Figure 2. A bioponics system (Source: https://kids.frontiersin.org/articles/10.3389/frym.2023.1009081)

HOW TO MANAGE BIOPONICS

Compared to hydroponics system bioponics systems need more care in management. Consistent monitoring is required to maintain the ideal pH and EC of the solution and also atmost care should be taken in the filtration of nutrient solution to avoid asphyxiation of roots so as to ensure availability of nutrients to plants.

The effectiveness of the system (Figure 3) will further increase if we implement controlled environmental conditions for the lighting, ventilation, temperature, humidity, and pest and disease management.

Figure 3. A view of the plants grown in the bioponics unit at RARS Pattambi, Kerala

Addition of Beneficial Micro Organisms: Even though the bioponic system has diverse community of microbes, strategic introduction of additional beneficial microorganisms including bacteria, fungi, and Vesicular Arbuscular Mycorrhizae (VAM) could unlock multitude of benefits to plants. Colonizing on plant roots these microbes act as a barrier against pathogens along with stimulating nutrient absorption and plant growth. For example, introduction of *Bacillus subtilis* control pathogenic infections caused by *Botrytis cinerea* and *Cladosporium fulvum* in tomato (Wang et al, 2018) grown in the bioponics. Studies showed that VAM fungi have potential to increase the surface area for nutrient absorption through forming a symbiotic relationship with plant roots that in turn facilitate nutrient exchange (Wang et al, 2017).

pH Level and Electrical Conductivity: While pH plays a less stringent role in plant growth within the bioponics systems compared to traditional hydroponics, it remains crucial for maintaining the optimal functioning of the entire ecosystem, particularly regarding growth of beneficial microorganisms. Studies have shown that many plants in bioponics can tolerate a wider pH range than in hydroponics, with growth remaining unaffected up to pH 7.5. This is likely due to the buffering capacity of organic matter in the bioponic solution, which helps mitigate fluctuations in pH. It was found that tomato plants grown in a bioponic system with a pH ranging from 6.0 to 8.0 exhibited no significant differences in yield or fruit quality. By understanding the interplay between pH, microbial activity, and plant growth, we can create a thriving bioponics ecosystem that benefits both plants and the vital microorganisms that support plant growth.

Source of Organic Manure: Primary source of plant nutrients in bioponics are mostly recycled form of organic wastes derived from wide range of materials like animal manures, compost, algae, agro industrial and house hold waste and plant extracts. Since plants cannot absorb nutrients as such from these organic materials their decomposition is necessary. Selection of organic materials has to be done considering various factors such as diverse nutrient requirement of plants grown in the bioponics, their growth stages and plant parts to be harvested. While selecting organic manure their carbon-to-nitrogen ratio (C:N ratio) and the speed of mineralization need to be considered. C:N ratio of organic materials used in bioponics were assessed by various researchers.

PLANTS SUITABLE FOR BIOPONICS

Wide varieties of herbs and leafy vegetables can grow well in bioponics gardening and produce from this system can have enhanced aroma and flavor than

those grown in the soil. Basil, cloves, lettuce, palak dill, mint, rosemary, thyme and parsely are some of the good options for the bioponics system. Also, crops like potato, tomato, chilli, cabbage, cauliflower, bell pepper, cucumber and beans were also being cultivated in bioponics in different regions.

PROS OF BIOPONICS

Bioponics offers a compelling alternative to traditional farming methods, delivering a multitude of advantages like; can reduce water usage by up to 90% compared to soil-based agriculture. This remarkable efficiency is achieved through closed-loop systems that capture and reuse water, minimizing waste. Bioponics can lead to 15-30% higher crop yields compared to traditional methods. This is attributed to controlled growing environments, optimal nutrient delivery, and minimized pest and disease pressure. Bioponics abstains chemical fertilizers and pesticides, resulting in naturally organic produce free of harmful residues. This minimizes potential health risks for consumers and contributes to a cleaner environment. Bioponic systems often incorporate organic waste recycling, converting food scraps and other organic materials into nutrient-rich solutions for plant growth. This minimizes waste generation and promotes sustainable resource management. The closed-loop nature of bioponics minimizes nutrient runoff and pollution, promoting environmental sustainability and reducing the impact on surrounding ecosystems. Bioponic systems allow vertical farming that in turn facilitates crop production in limited spaces in the urban areas. Researchers found that vertical farms could produce more food per square meter compared to traditional agriculture due to its space-efficient potential.

CONS OF BIOPONICS

While bioponics offers compelling advantages, it is important to acknowledge the challenges associated with this method. Maintaining optimal conditions for both plants and beneficial microbes can be time-consuming and demands close attention to detail. Bioponics requires 20% more labor and monitoring effort, highlighting its increased management needs. Bioponics utilizes organic materials as nutrients, which can introduce impurities and pathogens requiring additional filtration compared to hydroponics. This adds complexity and cost to the system. Large pH variations in bioponics can significantly disrupt the delicate balance of beneficial microbes. This can negatively impact nutrient cycling and plant growth. Effective bioponics relies on a constant supply of oxygen to support the activity of beneficial microbes involved in nutrient breakdown and plant growth. This necessitates significant investment in aeration equipment and energy use. Successfully managing a bioponic system demands specific knowledge and expertise in areas like microbiology, nutrient management, and system monitoring. Moreover, setting up of bioponics system is expensive and constant power supply and special expertise monitoring is needed in the maintenance of the system.

CONCLUSION

Bioponics is a revolutionary approach in sustainable agriculture that combines traditional hydroponics with organic agriculture. In bioponics, mineral fertilizer based nutrient solutions are replaced by organic form of nutrient solutions and it ensure the waste management by recycling of organic waste into nutrient solution. It reduces the risk of soil borne pathogens and helps in recycling of organic waste and water. It is really an answer to the several challenges faced by modern agriculture like reduced arable land, limited access to resources and issues related to climate change

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