Aquaponics Association Fact Sheet March 2017

Aquaponic Systems Utilize the *Soil Food Web* to Grow Healthy Crops

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Summary of Research

1. **Where does the soil food web live in a bioponic system?**
   - Microbes aggregate on all surfaces within a bioponic system and suspended in the water column.
   - Roots are a hotspot of microbial activity in both bioponic systems and in soil.
   - Micro niches within the systems provide bacteria with ideal conditions for growth.
   - Different system components provide unique environments and host varying microbial communities.

2. **How big and diverse is the soil food web in a bioponic system?**
   - Bioponic systems have been found to host a comparable quantity and diversity of microorganisms to soil, if not greater.
   - The USDA's Hydroponic and Aquaponic Task Force case study of hydroponic tomatoes found that the number of bacteria, fungi, protozoa, and nematodes in the system was above expected levels to be found in a typical organic soil.

3. **What does the soil food web do in a bioponic system?**
   - Soil Food Web microorganisms break down solids and make macro- and micro-nutrients more available to plants.
   - Soil Food Web microorganisms provide biocontrol and disease-suppression, improving overall plant health and quality.
   - Bacteria inhabiting the rhizosphere of plant roots improve cell processes with the plant tissue.
   - Studies have found that crop spoilage and fecal microorganisms are less prevalent in bioponic systems compared soil.

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Introduction

Whether as a consumer, grower, policy-maker, or business owner, we all make decisions that affect where and how our food is produced.

Our food system is rapidly changing due to the convergence of pressing global issues including climate change; environmental degradation; water depletion; economic insecurity; health problems due to poor diets and pollution; and rapid population growth and urbanization.

As we shape our new food system, one critical consideration is whether we retain access to high quality fresh fruits and vegetables, particularly those grown sustainably.

We must assess whether new growing methods like aquaponics can deliver fresh fruits and vegetables grown from seed, with the same symbiotic biological processes used by plants since the dawn of time.

Aquaponics combines recirculating fish culture with hydroponic plant production and provides produce that fits the mold of many consumer demands. Aquaponics is a sustainable way to produce fish and plants as it conserves water resources, recovers nutrient rich aquaculture discharge, limits the use of chemical additives for both fish and plants, and improves plant growth rates over soil-based agriculture.

Although the dynamics are different, aquaponic production depends on the same biological processes used by plants in soil-based agriculture. Healthy soil has an extremely large, diverse ecosystem of microorganisms that coexist in a symbiotic relationship with plants. Microorganisms such as bacteria, fungi, protozoa, nematodes, and others are responsible for a range of vital processes for plants such as nutrient-delivery, disease-suppression, and environmental regulation. The term for this is the *Soil Food Web*.

Despite the lack of soil, the same diverse microbial community exists in aquaponic systems. This Fact Sheet conveys research-based information on how aquaponic systems utilize the Soil Food Web to produce the highest-quality agricultural crops.

Research cited in this document is based on aquaponic systems and biologically active forms of hydroponic systems. The 2016 USDA Hydroponic and Aquaponic Task Force Report referred to these systems as “bioponic”.

1. Where Does the Soil Food Web Live in a Bioponic System?

- In bioponic systems, Soil Food Web microorganisms aggregate onto solid surfaces like roots, walls of tanks, pipes, floating particles, and especially within the "biofilter," a component for the specific purpose of housing beneficial bacteria.
- Certain microorganisms can excrete a gel-like substance that allows them to "floc" and remain suspended in the water column. Microorganisms such as *Pseudomonas* sp. and *Bacillus* sp. excrete extracellular polymeric substances that allow the microbes to aggregate together within the water column (HP/AP Report).
- As in soil, roots in bioponic systems are a hotspot of microbial activity (Hrynkiewicz et al. 2012).
- Aquaponic systems have micro niches that allow bacteria to grow and thrive in areas that differ based on availability of oxygen, nutrients, and other growth parameters. Micro niches can improve effectiveness and functionality of certain bacteria by allowing them to thrive in environments specific to their ideal growth parameters (Munguia-Fragozo et al. 2015).
- Significant differences in microbial communities have been found in recirculating aquaculture system tanks, solids filters, biofilters, and culture water representing unique and complex environments. Microbial communities will differ from system to system reflecting different fish culture species, water quality parameters, feed, pH, or other factors (Schreier et al. 2010).

2. How Big and Diverse is the Soil Food Web in a Bioponic System?

- Studies have found between 1,000,000 and 10,000,000 colony-forming units per milliliter (cfu/ml) of bacteria and 10 to 1,000 cfu/ml of fungi in hydroponic systems (Waechter-Kristensen et al 1999).
- 10,000,000,000 cfu/gram of roots were found in hydroponic systems (Chave, et al. 2008).
- Studies show that bioponic systems have a comparable – if not greater - quantity and diversity of microorganisms as compost and soil, respectively (Taber, 2016).
- Bacteria, fungi, protozoa, and nematodes on growing media in hydroponic tomatoes is above expected levels than found in a typical organic soil, signaling a high capacity to cycle nutrients. Nutrient cycling by Soil Food Web organisms is so effective in bioponic production systems that it can assimilate 300 lbs of nitrogen per acre (HP/AP Report).

3. What Does the Soil Food Web Do in a Bioponic System?

- The Soil Food Web actively cycles nutrients in bioponic systems. Microbes release enzymes that decompose floating organic matter, take up the available nutrients, and eventually make these nutrients available to other microbes or to plants (HP/AP Report).
- Microbes assist in chelating metals to increase uptake of nutrients into the plant roots (HP/AP Report).
- The Soil Food Web performs biocontrol by protecting plants from pathogens. A relatively high proportion of samples from aquaponic lettuce roots found bacteria strains implicated in biocontrol including *Pseudomonas* spp., *Acidovorax* spp., *Sphingobium* spp., or *Flavobacterium* spp. (Schmautz et al. 2017).
- Plant growth promoting rhizobacteria in water-based systems signal plants to create secondary metabolites like flavonoids and other antioxidants that assist in suppression of plant disease, nitrogen fixation, cell regulation, and color properties (Taber, 2016).
- Microbes in aquaponic biofilters are found to perform: nitrification; heterotrophic and auto trophic denitrification; nitrate reduction to ammonia; and anaerobic ammonium oxidation.
- Aquaponically grown lettuce has significantly lower concentration of spoilage and fecal microorganisms compared to lettuce grown in soil (Sirsat et al. 2013).

Conclusion

Aquaponics is a sustainable way to produce fish and plants as it conserves water resources, recovers nutrient rich aquaculture discharge, limits the use of chemical additives for both fish and plants, and improves plant growth rate over soil-based agriculture.

Research shows that, as in soil, bioponic systems employ the Soil Food Web to perform a range of vital functions. All stakeholders can consider bioponic systems an excellent option for delivering healthy, natural crops to a growing population with minimal environmental impact.

Citations

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