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Optimizing Hemp Growth: Harnessing the Synergy of Aquaponics through a Split Root System

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Summary

This study investigated the potential of integrating aquaponics and hydroponics using a split root system to optimize hemp (*Cannabis sativa L.*) growth. The results demonstrated that the single bucket hydroponic system provided the most optimal growing environment measured by fresh weight and kite measurements which outperformed the other treatments. The aerobically digested fish water treatment had significantly lower plant growth. A multiloop system was developed that included the combination of coupled and decoupled aquaponics. Additional work will determine combinations enhance nutrient availability for the plants.

INTRODUCTION

Integrating hemp cultivation with aquaponics presents a sustainable and efficient approach to enhancing plant growth while supporting fish cultivation (Yep, 2019). The split root system, which divides plant roots into two zones to access distinct nutrient environments, has been shown to improve nutrient uptake and overall plant health (Shen, 2004). Since hemp's legalization in the 2018 Farm Bill, there has been little research on indoor cultivation of hemp using aquaponics. This study investigates implementing a split root system with aquaponics and hydroponics for hemp cultivation to optimize nutrient absorption and overall plant health. It also explores research on the possibility of a dual decoupled and coupled aquaponics growing technique, also known as a multiloop system. The split root system involves dividing the roots into two halves and submerging one half into one treatment bucket and the other half into another treatment bucket (**Fig. 1**).

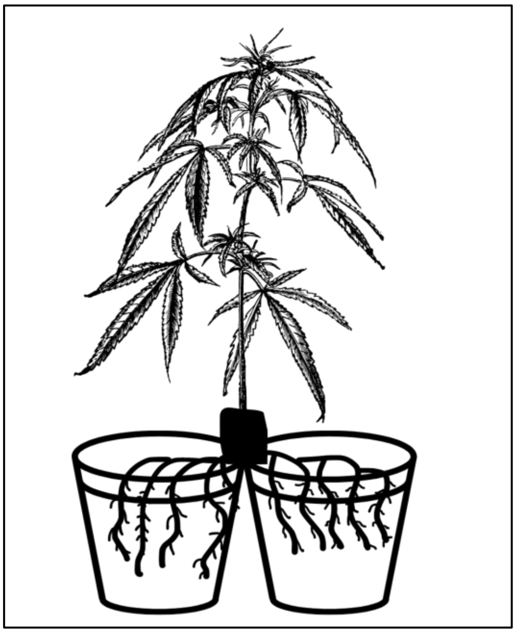

Figure 1. Split root system design.

In the split root system, each hemp plant is positioned in a net pot, with its roots divided into two separate sections. One half of the roots is submerged in a bucket containing one treatment, while the other half is submerged in a second bucket containing a different treatment.

There are two control treatments using single buckets: one with Hydroponic water and another with Fish water–water enriched with fish waste. Throughout the experiment, plant growth was measured through kite measurements–canopy development, pH, EC, and chlorophyll content. Post-harvest measurements such as fresh weight, dry weight, root weight, and root area were taken. A single cultivar, TJ's CBD, will be used to analyze the effects of different root zone treatments. Since hemp recently became legal in the United States, there is almost no research on how hemp is cultivated. This study aims to investigate how well hemp grows in aquaponic treatment.

METHODS AND MATERIALS

This experiment was conducted in the Kenneth Post Lab greenhouse at Cornell University. Twenty-four one-gallon buckets and six two-gallon buckets equipped with 30 aero stones were used to grow hemp using a split root system integrating aquaponics and hydroponics. Eighteen Rockwool cubes, each placed in plastic net pots, housed the rooted hemp cuttings, with the roots divided between the two respective treatments that were randomly chosen for that plant. The cuttings were treated with RootX, a rooting hormone, then were placed in an aeroponics chamber to promote rooting for two weeks.

Then the cuttings were placed in a Rockwool cube, put under a humidity dome, and were in a water bath to encourage longer roots. After two weeks, the roots were long enough to be put into the split root system and their respective treatments (**Fig. 2**).

Figure 2. A comparison of the split root fish water and aerobically digested fish water (bottom right plant) and its size comparison to the single bucket hydroponic treatment (bottom left plant).

The three treatments are composed of fish water, hydroponic water and aerobically digested fish water (**Fig**. 3). Aerobically digested fish water refers to nutrient-rich water that is typically wasted from a fish tank that has been biologically processed by microorganisms in the presence of oxygen, breaking down fish waste into stable, beneficial forms for plant growth. Fish water refers to water that is directly drained from the fish tank with solids still in it. The six combinations of treatments include single bucket fish waste, split root fish water and aerobically digested fish waste, single bucket hydroponics water, split root hydroponics water and aerobically digested fish waste, split root hydroponics water and aerobically digested fish waste, and split root hydroponics and hydroponics. High Pressure Sodium (HPS) grow lights provided consistent lighting, and environmental conditions were carefully controlled. Weekly measurements of plant height, width, and chlorophyll index were recorded, while post-harvest measurements included fresh weight, dry weight, root weight, and root area after three weeks. Data from these measurements were analyzed to compare growth and health outcomes between the different cultivation methods.

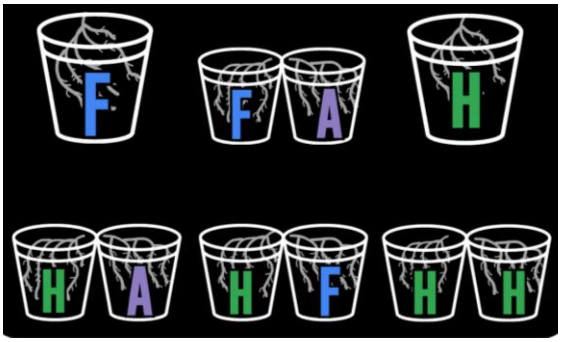

Figure 3. Hemp plants were subjected to six treatments. H (Hydroponics only) , HA (Hydroponics- Aerobically digested fish waste), HH (Hydroponics-Hydroponics, FA (Fish waste and Aerobically digested fish waste), HF (Hydroponics-Fish), and F (Fish only).

Multi-Loop Aquaponics System:
The multi-loop system built for this study includes both decoupled and coupled aquaponics setups to compare their effects on hemp growth (**Fig. 4**). In the decoupled setup, nutrients supplied by the fish do not meet the nutrient threshold for hemp, and separating the water systems prevents chemical exposure to the fish while allowing precise control over the plants' nutrient

intake. Conversely, in the coupled setup, the water recirculates between the fish tank and the plant grow beds, creating a single-loop system. This design allows for the direct use of fish waste as nutrients for plants. Due to the project's time constraints, the decoupled system was implemented with a drip-to-drain setup, while the coupled system maintained a recirculating loop. This dual approach aims to optimize environments for both the fish and the hemp, and to compare the outcomes between the two systems.

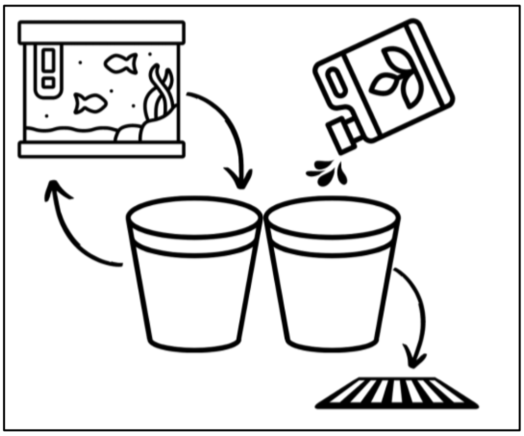

Figure 4. The multi-loop aquaponics system design. The left bucket demonstrates a closed loop between the bucket and the fish tank, while the right bucket demonstrates an open system with additive fertilizer that is drip to drain.

RESULTS AND DISCUSSION

The hydroponics single bucket (H) treatment resulted in the highest mean fresh weight after three weeks of growth significantly outperforming other treatments (**Fig. 5**). Plants in the split root fish waste and aerobically digested fish waste (FA) treatment had the lowest mean fresh weight. Treatments F (Fish only), HA (Hydroponics-Aquaponics), HF (Hydroponics-Fish), and HH (Hydroponics-Hydroponics) showed intermediate results. Statistical analysis indicated that treatments labeled with the same letter are not significantly different from each other at a p-value threshold of 0.05. This data suggests that the hydroponic system, whether coupled with aquaponics or used independently, tends to support better plant growth in terms of fresh weight compared to fish-based treatments.

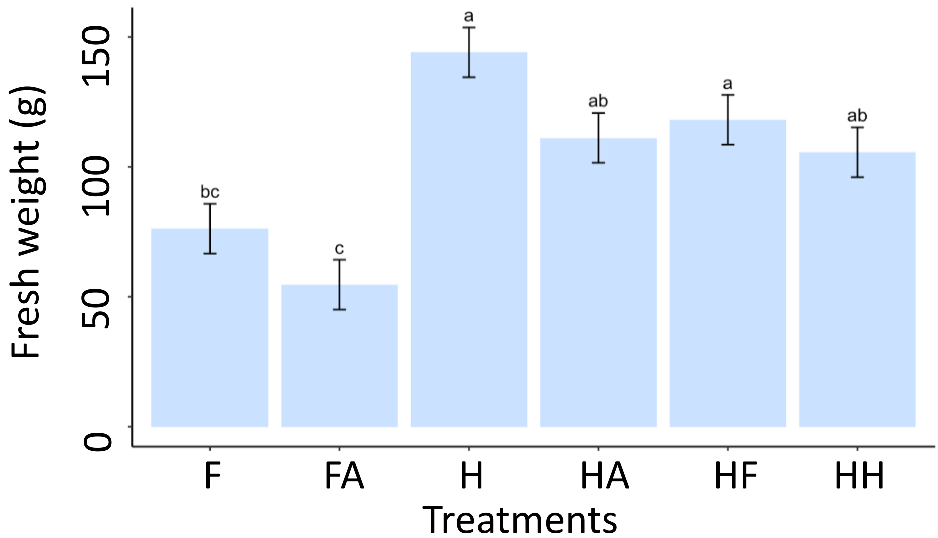

Figure 5. Fresh weight (g) fresh weight in hemp plants in hydroponic or aquaponic solutions. Treatments sharing the same letter above the bars are not significantly different from each other ($p > 0.05$), as determined by a post-hoc test.

There is no significant difference in kite measurements among the various treatments, after three weeks of growth in their respective treatments as indicated by the identical letter 'a' above all bars (**Fig. 6**). This suggests that the different treatments do not have a statistically significant impact on the kite measurements of the hemp plants.

The kite measurements across all treatments range from approximately 900 to 1300 units, with no clear pattern or substantial variation among the treatments. This uniformity indicates that, within the parameters of this experiment, the type of nutrient system—whether it involves fish waste, hydroponics, or a combination thereof—does not significantly affect the kite measurement of the plants.

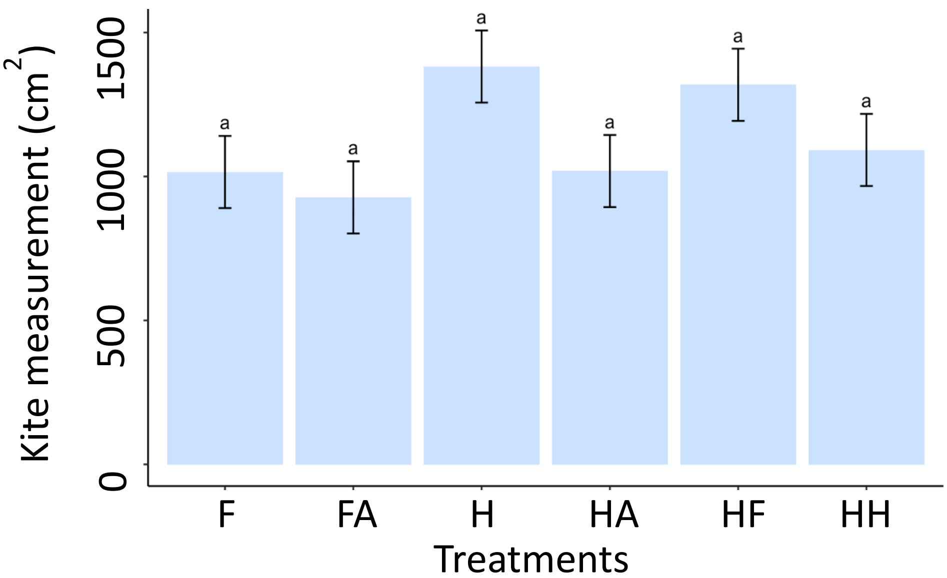

Figure 6. Kite measurements in hemp plants in hydroponic or aquaponic solutions. Treatments sharing the same letter above the bars are not significantly different from each other ($p > 0.05$), as determined by a post-hoc test.

Conclusion:

This study investigated the potential of integrating aquaponics and hydroponics using a split root system to optimize hemp (*Cannabis sativa L.*) growth. The results demonstrated that the single bucket hydroponic system provided the most optimal growing environment measured by fresh weight and kite measurements which outperformed the other treatments. The aerobically digested fish water treatment demonstrated significantly lower plant growth. This result highlights the challenges in the use of organic aquaponics as a nutrient source for hemp instead of non-natural alternatives like fertilizer hydroponics. The investigation of a multiloop system, the combination of coupled and decoupled aquaponics, shows challenges for precise nutrient management and a labor-intensive design, but it allows for the diversification of income and semi-organic production. Further refinement of the design system is needed in order to enhance nutrient availability for the plants.

These findings underscore the potential of hydroponics as a reliable method for hemp cultivation while revealing the complexities of integrating aquaponics into commercial hemp production. Future research should focus on optimizing fish safe nutrient formulations for aquaponic systems, investigating longer cultivation periods, aquaponics' effect on cannabinoids, and exploring the scalability of multiloop systems. This study contributes valuable insights into sustainable hemp cultivation practices and serves as a foundation for further exploration into innovative agricultural systems.

LITERATURE CITED

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