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Tissue Analysis of Hydroponically Grown Sweet Basil (Ocimum Basilicum L.)

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Abstract

This study investigated the nutrient composition of *Ocimum basilicum* L. (sweet basil) cultivated in a household hydroponic greenhouse module, with emphasis on tissue analysis of selected micronutrients and vitamin A. Basil plants were grown in both tube and raft cultures over a 37-day cropping cycle. Freshly harvested leaves were subjected to laboratory analysis to determine concentrations of iron (Fe), zinc (Zn), and vitamin A, which are commonly deficient in the Filipino diet. Results showed that iron content in basil leaves from both tube (5.70 mg) and raft (9.70 mg) cultures exceeded the standard reference value of 3.17 mg, demonstrating enhanced accumulation despite undetected iron in the nutrient solution. In contrast, zinc concentrations were lower than the reference standard (0.81 mg), with values of 0.30 mg and 0.50 mg from tube and raft cultures, respectively, suggesting competitive interactions with iron uptake. Vitamin A levels, determined from beta-carotene analysis, were 6,635 IU in tube culture and 5,175 IU in raft culture, compared to the standard 5,275 IU. The elevated vitamin A content in tube-grown basil is attributed to reduced sunlight exposure and increased carotenoid accumulation. These findings underscore the nutritional potential of hydroponically grown basil, particularly as a rich source of iron and vitamin A, while highlighting the need for nutrient solution adjustments to improve zinc uptake.

Keywords: hydroponics, sweet basil, nutrient composition

1. Introduction

Hydroponics is a soiless method of growing food that has been embraced by several countries, including the United States, Mexico, Canada, British Columbia, China and the Philippines. The soiless system of growing fruits and vegetables offers distinct advantages such as better control of pests, increased efficiency in managing the level of nutrients in the system, higher yields and better utilization of available space. The overall production cycle is also shortened by reducing the period needed to complete the seedling development cycle (FAO, 2015). Hydroponics also offers a way to produce better yields without having to depend too much on naturally scarce resources such as land and water. These two particular resources have always been scarce and the trend is not going to reverse especially in the face of high demand (Licamele, 2009). World hydroponic production has increased exponentially since its formal introduction in 1980s. Production has increased to 62,500 acres in 2001 from a meager 15,000 acres in the eighties (Resh, 2013). Hydroponic systems can be used for a variety of crops, including indigenous plants and commercially viable herbs.

In the Philippines, there has been an impetus to increase research and development of indigenous plants to promote conservation, biodiversity and increase production for functional food and raw materials for different industries such as the pharmaceutical industry. The Department of Science and Technology

(DOST) are now focusing on the possibility of exploring, studying and developing indigenous plant life for the purpose increasing food security, enhancing pharmaceutical production through the discovery of healing/restorative compounds and of course, to spark the possibility of entrepreneurship among the social classes that require additional income streams. One such Philippine herb that is perfect for hydroponics is the balanoi or sweet basil *(Ocimum basilicum* L.*),* which is used as food and is processed for fragrances, traditional medicine and even cosmetics. Traditionally, balanoi is used in the Philippines as a repellant and as a natural remedy for cold sores, headaches and even anxiety. It is common for manufacturers to process balanoi leaves to extract its essential oil (Alvarez, 2016). However, there is still a palpable scarcity in the number of studies that explored the potential of growing herbs and spices using innovative and cost-effective agricultural methods such as hydroponic systems (Eleazar, 2010). Hydroponics is an alternative method of growing food that has been embraced by different scientific institutions and even amateur hydroponic farmers alike.

One of the major factors that will determine the success of any hydroponics system is its nutrient dynamics, which can be easily quantified through the regular measurement of the nutrient solution used in the system. The nutrient solution has a large impact not only on the growth rate of plants in a soiless system but also size of the projected yield. Water quality and nutrient solution quality are such important aspects of soiless systems because these two determine not only the physical availability of nutrients to the plants but they also influence nutrient bio-availability and uptake values. A nutrient solution for plants should ideally contain target minerals (the majority of which are classified as inorganic ions) and also various types of salts that are utilized by plants as macronutrient and micronutrients.

Nutrient Film Technique (NFT)

The nutrient film technique (NFT) was developed by Dr. Allan Cooper in England in the 1960's and is considered today as most rapidly evolving type of hydroponics system used due to refinements in design made by growers worldwide. NFT is an example of closed hydroponic system where a tank or nutrient solution reservoir has pump which supplies nutrient through the system. The plants are contained into a plastic lined troughs where a thin film of nutrient solution flows through the roots of the plants for nutrient uptake. Nutrients are pumped into the higher areas of the channel system and gravity aids the travel of the solution from the catchment pipes and a sump (Jensen & Malter, Protected Agriculture: A Global Review, 1995).

The advantage of NFT lies mainly on the efficient use nutrient solution because it requires less and appears easier to manage particularly during winter months when nutrient solution heating is needed. However, the length of the system employing NFT should be carefully designed because as the nutrient travels a distance from the nutrient solution source, it changes significantly. Consequently, the amount of dissolved oxygen and elemental concentration in a nutrient solution tends to dissipate as it travel through the system (Jones, 2005).

Sweet basil is also being grown hydroponically primarily in the focus of efforts to improve the product yield and quality, using the NFT technique (Salachas *et al.,* 2015). One study showed that hydroponically-grown basil cultivars such as sweet basil and osmin purple yielded a total of ten identifiable essential oils such as 8-cineole, methyl chavicol and methyl eugenol. Both major and minor essential oil components were identified, yielding a total of three chemotypes: linalool & eugenol, linalool & chavicol and neral & geranial (Huang *et al.,* 2011).

Sweet basil is known for thriving in water-rich environments with little to no competition for basic nutrients. Due to its sensitivity to frost, care must be taken when it is propagated in temperate areas. This particular cultivar thrives well in tropical climes due to the absence of frost and full exposure to a healthy amount of sunshine every day. While sweet basic prefers very moist media, excessive watering should also be avoided as this can easily predispose this cultivar to fungal disease (Sullivan, 2009).

In hydroponic setups for sweet basil, nutrient solutions that are also rich in nitrogen (NO_3-N) are used solely to supply the cultivar's appetite for this nutrient. In a research conducted by Olfati et al. (2012), basil requires low concentrations of ammonium in the nutrient solution and responds better to nitrate than ammonium. Replenishment of the nutrient solution may be done once a week. Table 1 showed the recommended nutrient levels for hydroponic basil growing.

Table 1. Recommended Nutrient Concentration for Basil

NUTRIENT CONCENTRATION	(mg/L)
Nitrogen (N)	210
Phosphorus (P)	80
Potassium (K)	275
Calcium (Ca)	180
Magnesium (Mg)	80
Sulfur (S)	200
Manganese (Mn)	0.25
Iron (Fe)	3.75
Copper (Cu)	0.26
Boron (B)	0.6
Zinc (Zn)	0.25
Molybdenum (Mo)	0.06

Source: (Organic Fertilization of Fresh Market Sweet Basil in a Greenhouse, Succop & Newman, 2004)

Plant nutrition is the basis for the success of a hydroponic system. The proper management of the nutrient solution, the available nutrients for the uptake of plants is the key to an effective hydroponic system. Maintenance of available nutrients to optimum levels is essential to prevent rapid starvation or other adverse effect on the plants which could occur swiftly in a hydroponic set-up and could ultimately limit growth (Resh, 2013).

The Hydroponics Growing System

A 35-watt AC submersible pump was installed for the purpose of circulating water that contains essential plant nutrients. The pump distributes water from a mixing tank where daily measurement and replenishment of water and nutrient solution were made. The hydroponic growing system has 3 components.

The mixing tank which acts as the reservoir for the nutrient solution recirculated through the whole system. The PVC growing tubes consisting of 8 tubes at each side, 3 of which lies stacked above the mixing tank. The 5 remaining tubes lies horizontally above the third component which were the raft system. The raft system was composed of styrofoam sheets with holes. This was replicated twice. The first to be reached by the nutrient solution was the tube culture which employs an NFT system where water flows through

the aid of gravity down to the raft culture. The raft culture had the plants suspended from the styrofoam sheets with the roots remain submerged into the water. The nutrient solution which flowed from the PVC tubes falls down to the raft system and causes the movement of water back to the reservoir for recirculation.

Media Preparation

The growing media was composed of equal parts of rice hull, carbonized rice hull and fine sand and was treated with fungicide and nematicide. The prepared media was soaked in approximately 30 grams of Funguran OH® dissolved in 20 liters of water for 1 hour. The media was drained thoroughly and a ratio of 1 gram of Carbomax 3G® insecticide/nematicide was used for every 1 kilogram of media was added. It was solarized to prevent contamination and disease occurrence.

Planting of Sweet Basil (*Ocimum basilicum* L.) Seeds

Basil seeds were acquired from an existing herb garden in the facilities. The seeds were sown directly into a small rectangular foam cut accordingly to the size of the plastic cups to promote constant moisture in the plant roots upon emergence. The foam which contained the seeds was placed one by one into perforated plastic cups and covered with the prepared growing media. The cups were then placed in modified PVC tubes and styrofoam rafts (Sace & Natividad, 2015) inside the greenhouse. The prepared PVC tubes were painted white to reduce heat build-up (Jensen, Hydroponic Culture for the Tropics: Opportunities and Alternatives, 1991). The Styrofoam rafts measuring 60cm x 50cm were equipped with equidistant holes, 5 cm from each other. This ensured balanced growth for all the plants.

Nutrient Solution Management

The nutrient solution was a special formulation consisting of solutions A and B (Appendix Figure 5. C). Solutions A and B were mixed only when the tank has been filled with water as these cannot be introduced to the system beforehand. This prevents the inactivation of the nutritive elements contained in each of the solutions (FAO, 1993). The components of solutions A and B were listed in Table 3. The macronutrients were grouped in solution A while solution B was composed of the micronutrients.

Table 3. Components of Nutrient Solutions A and B

SOLUTION A (MACRONUTRIENTS)	SOLUTION B (MICRONUTRIENTS)
Nitrogen (N)	Iron (Fe)
Phosphorus (P)	Zinc (Zn)
Potassium (K)	Manganese (Mn)
Sulfur (S)	Copper (Cu)
Calcium (Ca)	Molybdenum (Mo)
Magnesium (Mg)	Boron (B)

The water loss from the tank was replenished and maintained at a depth of 53 cm with a total of 458 L of water every morning. The amount of nutrient solution combined to the tank was based on the required EC of the sweet basil. The electrical conductivity was maintained at 2.0 mS/cm (Hassanpouraghdam *et al.,* 2010) while the TDS was at 700-1120 ppm (Roberto, 2003) as per sweet basil requirement. The pH was

maintained at 5.5-6.5 through the addition of an automotive battery acid which was 30-50% sulfuric acid (H_2SO_4) in water.

Composite Sampling

Composite sampling of the leaves was done on each side of both tube and raft culture plants. The leaves were sent to the Food and Nutrition Research Institute (FNRI) laboratory for chemical analysis of nutrient content that is widely deficient in the Philippines such as iron and zinc and vitamin A (World Health Organization, 2015). Results of tissue analysis in the tube and raft cultures were compared to the USDA National Nutrient Database for Standard Reference.

Tissue Analysis of Basil Leaves

Fresh harvested basil leaves from the tube and raft cultures were sent to the Food and Nutrition Research Institute for iron, zinc and vitamin A content analysis. These elements were chosen based on the WHO study on the common nutrients that are deficient in the Philippine diet in the hopes of introducing basil to the common masses. Table 6 shows the values of fresh leaves obtained by composite sampling from the two different cultures.

Table 6. Tissue Analysis of Sweet Basil Leaves for selected nutrients

ELEMENTS	STANDARD VALUES	TUBE CULTURE	RAFT CULTURE
Iron (Fe) (mg)	3.17	5.70	9.70
Zinc (Zn) (mg)	0.81	0.30	0.50
Vitamin A (IU)	5275	6635	5175

The concentration of iron in the leaves from the raft culture were 9.70 mg which was higher than the standard concentration by 6.53 mg. the iron content from the tube culture was also higher than the standard by 4 mg. These results showed that hydroponically grown sweet basil contain high iron concentration in the leaves despite undetected iron concentration levels in the hydroponic set-up. Cianzo (1991) reported that some plants have the ability to release substances such as siderophores from their roots to enhance ion chelation and uptake. These were commonly observed in plants where iron is obtained under adverse conditions and are called iron-efficient plants. In dicots, plants respond to iron deprivation by morphological and physiological changes. These include the development of lateral roots and differentiation of specialized transfer cells to increase the surface area for reduction and transport of iron (Guerinot & Yi, 1994).

The zinc content of basil from both tube and raft culture were lower than the standard with 0.3 mg and 0.5 mg respectively. These results are congruent with the nutrient analysis of the water where low zinc content was determined. Moreover, zinc exhibit antagonistic effect to iron where zinc deficient plants had significantly higher concentration of iron (Imtiaz, et al., 2003). The decrease in zinc concentration is due to competitive interactions with iron occurring in the plant roots (Samreen *et al.,* 2013).

The vitamin A content was determined by the analysis of the beta-carotene of the leaves. Beta-carotene is a provitamin of vitamin A where absorption in animals is facilitated by dietary fat and bile salts in the small intestines (Mandal, 2014). The values of beta-carotene in micrograms were divided by 0.6 to convert the microgram to vitamin A in international units (USDA, 2015). The analyte from the tube culture contained the highest amount of vitamin A with 6,635 IU and was higher than the standard by 1,360 IU.

The vitamin A of the raft culture was 5,175 IU and was 100 IU lower than the standard. This is attributed to the location of the plants in the tube culture where less sunlight was received. Beta-carotene is a carotenoid and an antioxidant which is an essential component of photosynthetic membranes in all plants (Cunningham & Gantt, 1998). Beta-carotene is a carotenoid pigment in the chloroplasts that absorbs light in the blue region of the visible spectrum and is produced by the plant to protect their stems and leaves from the sunlight. Ultraviolet wavelengths generate unstable molecules known as free radicals thereby prompting the plant to produce carotenoids to serve as antioxidant by donating electrons to quench or neutralize the oxidant radicals (Sims & Odle, 2005).

Conclusion

The tissue analysis of hydroponically grown *Ocimum basilicum* L. revealed important insights into its nutritional profile and potential contribution to addressing micronutrient deficiencies. The results demonstrated that basil cultivated in both tube and raft cultures accumulated iron (Fe) at levels significantly higher than the standard reference values, underscoring its potential as a dietary source of this essential micronutrient. In contrast, zinc (Zn) concentrations were consistently below the reference standard, suggesting antagonistic interactions with iron uptake that limited its bioavailability. Vitamin A levels, measured through beta-carotene content, were above or near reference standards, with tube-cultured basil exhibiting notably higher concentrations.

These findings suggest that hydroponically grown basil can serve as a functional food, particularly in combating iron and vitamin A deficiencies common in the Filipino diet. However, the low zinc content highlights the need for careful nutrient solution management to improve balanced micronutrient uptake. Overall, the study demonstrates that household hydroponic systems can be optimized not only for yield but also for enhanced nutritional value, contributing to food security and public health.

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