



Survival and Productivity of Culinary Herb Species in a Nutrient Film Technique-type Aquaponic System with Nile Tilapia

Carlos Valdez-Sandoval^{1*}, Dennis Guerra-Centeno¹, Manuel Lepe-López¹, Mercedes Díaz-Rodríguez¹ and Lariza Pineda-Alvizuris²

¹Instituto de Investigación en Ciencia Animal y Ecosalud, Facultad de Medicina Veterinaria y Zootecnia (FMVZ), Universidad de San Carlos de Guatemala (USAC), Ciudad Universitaria zona 12, 01012, Guatemala City, Guatemala.

²Escuela de Estudios de Postgrado, FMVZ, USAC, Ciudad Universitaria zona 12, 01012, Guatemala City, Guatemala.

*Corresponding author's Email: zoovaldez@gmail.com; ORCID: 0000-0002-8742-1320

ABSTRACT

Aquaponics is an evolving technology for producing plants and fish (or other aquatic organisms) in an integrated water recirculating system. However, the survival and productivity of terrestrial plants in aquaponic systems have not been evaluated for most plant species. The present study aimed to analyze the survival rate, growth, and biomass production of eight culinary herbs, commonly used in Guatemala, in a Nutrient Film Technique-type (NFT) aquaponic system with Nile tilapia (*Oreochromis niloticus*). The investigated herbs included coriander (*Coriandrum sativum*), parsley (*Petroselinum crispum*), peppermint (*Mentha spicata*), thyme (*Thymus vulgaris*), samat (*Eryngium foetidum*), oregano (*Plectranthus amboinicus*), dill (*Anethum graveolens*), and basil (*Ocimum basilicum*). A total of 50 individuals of each herb species and 150 juvenile Nile tilapias were distributed in 5 aquaponic modules. The survival rate, growth, and biomass production were measured for herbs and tilapias. All the herb species survived against the NFT aquaponic conditions. The findings indicated that the herb survival was species-dependent and ranged 42-98%. There was a significant effect of the herb species both on height and biomass gains. Post hoc comparison showed interspecific differential abilities to grow biomass in NFT aquaponics conditions. Among the investigated herbs, *M. spicata* and *O. basilicum* were the most productive species. Refinement in the selection of initial plants and aquaponic management could improve plant performance.

Keywords: Ecological production, Hydroponics, *Oreochromis*, Recirculating water, Sustainable aquaculture

INTRODUCTION

Aquaponics is an evolving technique to tackle climate change challenges in the agriculture industry (Tyson et al., 2011; König et al., 2018; Palm et al., 2018). In contrast to traditional agricultural resource management, an aquaponic system saves water and reduces waste, costs, and environmental contamination (Lennard and Leonard, 2006; Rizal et al., 2018). The reutilization of water and the use of waste from aquatic organisms to feed the plants in a closed system makes aquaponics a social, ecological, and healthier alternative to meet the sustainable development goals proposed by United Nations (United Nations, 2015; Li et al., 2018; Rizal et al., 2018). Regardless of the fact that aquaponics has been criticized by organic farmers for the industrial origin of the substrate and the absence of soil (Kledal et al., 2019), this form of producing has also been considered the agriculture of the future (Shafeena, 2016).

Although aquaponics has demonstrated to be effective and efficient for small and large scale productions of lettuce, tomatoes, and other salad greens (Somerville et al., 2014; Love et al., 2015), it seems that it is not possible for all plant species to survive and grow in aquatic conditions (Guerra-Centeno et al., 2016). Therefore, it is necessary to identify plant species that can be grown and produced in aquaponic conditions.

Guatemala is a megadiverse country, where many plant species are traditionally used for feeding, spicing, medicinal, and other cultural purposes (Cáceres, 1996; Villar-Anleu, 1998; Knapp and Davidse, 2006). However, there is a dearth of research addressing the productivity of Guatemalan plant species in aquaponic conditions (Guerra-Centeno et al., 2016). Since biomass production is a function of survival and growth, the aim of the current study was to examine these features in eight culinary herb species mainly used in Guatemala (coriander [*Coriandrum sativum* L.], parsley [*Petroselinum crispum* (Mill.) Fuss], peppermint [*Mentha spicata* L.], thyme [*Thymus vulgaris*, L.], samat [*Eryngium foetidum*, L.], oregano [*Plectranthus amboinicus* (Lour.) Spreng], dill [*Anethum graveolens* L.] and basil [*Ocimum basilicum* L.]) using a Nutrient Film Technique-type (NFT) aquaponic system with Nile tilapia (*Oreochromis niloticus* L.).

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MATERIALS AND METHODS

Ethical approval

This study was reviewed and approved by the Graduate School Bioethics Committee of the Faculty of Veterinary Medicine and Animal Husbandry of the University of San Carlos of Guatemala, Guatemala City.

Study site

The study was performed inside a greenhouse, in the facilities of the *Instituto de Investigación en Ciencia Animal y Ecosalud* (IICAE) at the Veterinary and Animal Husbandry Faculty, University of San Carlos of Guatemala, located in Guatemala City.

Study design

The samples in the current study consisted of eight herb species. Depending on the herb species, seedlings or cuttings were used as propagules (Table 1). The performance of each sample was examined using aquaponic modules (Figure 1). Each module had 8 perforated pipelines and each pipeline had 10 holes. Each pipeline was considered as a block and only housed individuals of a single herb species. Therefore, each aquaponic module held 80 plant individuals (10 per species). This arrangement was replicated in five aquaponic modules. The observation period in aquaponic conditions lasted 90 days, from June to August 2018.

Aquaponic system and modules

The aquaponic modules at the IICAE consisted of a water tank, a pump, a biofilter, and a pipeline circuit. For each module, one plastic 750 L water tank was used. For pumping the water, one submersible 0.5 horsepower pump (BOS Truper®, Mexico) was installed and a hose was coupled to conduct the water flow from the tank to a biofilter (Clear Choice PF-1, Tetra®, Blacksburg, VA, USA). Two 4' PVC pipeline circuits were installed in a zigzag arrangement (Figure 1). Water flow was regulated using a nutrient film technique-type (NFT) design.

Herb management

The herb materials were obtained from commercial suppliers (Superb Superseed S.A and Vivero Botanik, Guatemala City). Prior to the observation period in aquaponic conditions, coriander, parsley, samat, dill, and basil seeds as well as peppermint, thyme, and oregano cuttings were placed into seedbeds with fertilized soil where they remained for up to eight weeks. The herbs were then transplanted to the NFT modules. Only the propagules that had three to five leaflets were selected to be transplanted to the aquaponic conditions.

Tilapia management

While the plant material was in the seedbeds, 300 juvenile Nile tilapia, weighing about 1.5 g each, were obtained from a commercial farm (Cazali Tilapia Farm, Escuintla, Guatemala) and put under quarantine for 30 days in a plastic 1000 L water tank. After that period, 30 tilapia organisms, weighing 2-4 g each, were selected and placed in the water tank of each NFT module (i.e., a total of 150 fish) to start the aquaponic phase. All tilapia organisms were managed following the Food and Agriculture Organization recommendations for small-scale aquaponic food production (Somerville et al., 2014). During the first 30 days of the study, tilapias were fed 45% protein extruded food (Tilapia™, Alcon, Honduras), and from day 31 to day 90, tilapias were fed 32% protein extruded food (Tilapia™, Alcon, Honduras).

Measurements

The height/length and weight of each herb and tilapia organism were measured and recorded at days 0, 45, and 90 of the aquaponic observation period. The height of the plants was measured from the base of the stem to the tip of the apical meristem whilst the length of the tilapia organisms was measured from the tip of the snout, with mouth closed, to the extreme of the tail fin. Heights and lengths were measured in centimeters using a measuring tape and approximated to the nearest tenth. The weight was measured in grams using an electronic balance (iBalance 700™, My Weigh, AZ, USA) and approximated to the nearest tenth. Differences between initial and final measurements were recorded. Growth was considered as both height/length and weight (biomass) gains. The values related to water temperature, pH, electric conductivity, and total dissolved solids were measured every 15 days using a digital tester (HI 991300™, Hanna, RI, USA) and the mean values were calculated.

Statistical analyses

The descriptive statistics included the calculation of the mean and standard deviations for height/length and weight measurements of herbs and tilapia. Since the obtained data did not meet the assumptions of normality, the non-

parametric test of Kruskal-Wallis was used to compare the means values of plant longitudinal growth and biomass production. In this regard, the post hoc test of Mann-Whitney pairwise was run to determine the specific differences. The correlation between survival rate and herb species was analyzed using the Pearson's chi-squared test. Statistical analyses were performed using Past Program®, version 3.20 (Hammer et al., 2001). The significance level for the statistical tests was $p < 0.05$.



Figure 1. Components of a nutrient film technique (NFT) aquaponic module at the IICAE greenhouse, including (1) water container with a submersible pump; (2) hose to conduct the water from the tank to the biofilter; (3) biofilter; (4) PVC pipe circuits for water circulation and plant hosting.

Table 1. Descriptive statistics of experimental arrays of eight investigated herbs species in five aquaponics modules

Herb species	Number of individuals per pipeline, per module	Total number of individuals	Type of propagule
Coriander (<i>Coriandrum sativum</i>)	10	50	Seedling
Parsley (<i>Petroselinum crispum</i>)	10	50	Seedling
Peppermint (<i>Mentha spicata</i>)	10	50	Cutting
Thyme (<i>Thymus vulgaris</i>)	10	50	Cutting
Samat (<i>Eryngium foetidum</i>)	10	50	Seedling
Oregano (<i>Plectranthus amboinicus</i>)	10	50	Cutting
Dill (<i>Anethum graveolens</i>)	10	50	Seedling
Basil (<i>Ocimum basilicum</i>)	10	50	Seedling
Total	80	400	---

RESULTS

The findings of the current study indicated that all herb species survived to the NFT aquaponic conditions. Survival rates were within the range of 0.42-0.98 (Table 2) and were associated with herb species ($p < 0.01$). There was a significant effect of the herb species both on height ($p < 0.01$) and biomass ($p < 0.01$) gains. The obtained results of post hoc comparison were indicative of interspecific differential abilities to grow biomass in NFT aquaponics conditions (Table 3). Peppermint and basil were the most productive species. Regarding biomass production, the growth rate of plants varies according to their species (Figures 2 and 3). For most plant species, growth was marked by a slow initial phase, followed by an accelerated phase (Figure 4).

Survival and productive parameters of Tilapia

Tilapias survived and showed a growing response in the water tanks of the NFT aquaponic modules (Table 4).

Water parameters

The mean values related to water temperature, pH, electric conductivity, and total dissolved solids were 24.9 ± 1.2 °C, 7.8 ± 0.5 , 458.1 ± 309.7 μ S, 232.7 ± 157.4 ppm, respectively.

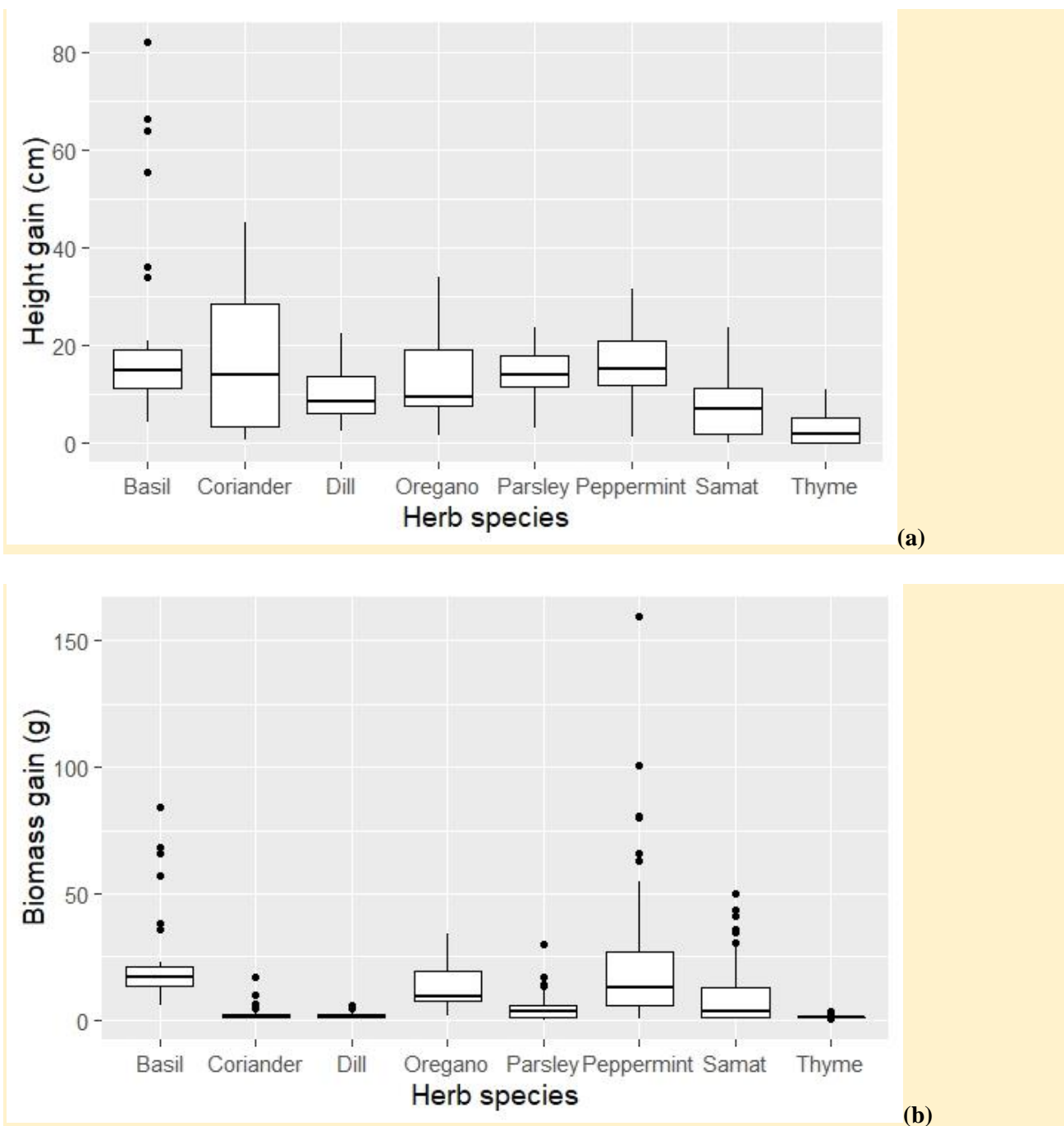


Figure 2. Variation in biomass production for survivors of eight herb species in NFT aquaponic conditions, by day 90 of observation: *a* = height gain; *b* = biomass gain.

