Scientific Papers. Series D. Animal Science. Vol. LXV, No. 1, 2022
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

COMPARATIVE STUDY ON THE GROWTH AND DEVELOPMENT OF THYME AND BASIL HERBS IN AQUAPONIC SYSTEM AND HYDROPONIC SYSTEM

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Abstract

This experiment aimed to compare the growth and development of two aromatic herbs, thyme (Thymus vulgaris) and basil (Ocimum basilicum var Aristotle) in an aquaponic system with Carassius auratus, versus a hydroponic system. The experiment took place at the pilot system from University Dunărea de Jos, Galați, Faculty of Food Science and Engineering. The system consists of six rearing units for fish and twelve units for plants (filled with substrate light expanded clay aggregate L.E.C.A.), led lamps for plants with purple light (36 W), biological and mechanical filters, and pumps for water recirculation. Three rearing units were populated with Carassius auratus at a stocking density of 20.93± 0.11 kg m^{-3} and the other three were left without fish. For the hydroponic treatment, a nutritive solution was added daily to support plant growth. Plants units were populated with seedlings of thyme and basil. The physico-chemical parameters of water were measured twice per week during the trial. At the end of the trial, the fresh weight of the plants was measured, and it was concluded that the productivity of the plants was higher in the aquaponics units comparing the hydroponic units.

Keywords*: aromatic herbs, Integrated aquaculture, nutrient supplementation, plant productivity.*

INTRODUCTION

The world's population is continuously growing, that`s because in the future satisfying consumers' demands only by classic agriculture will lead to more intense competition for natural resources. Thus, the adoption of technologies for the sustainable farming system can release environmental pressure, reduce gas emissions and implicitly reduce their contribution to environmental impact (Schwitzguébel & Wang, 2007; Kloas et al., 2015; Rizal et al., 2018). Lately, hydroponic and aquaponic farming became popular and are the most innovative methods in the agricultural sector. Generally, hydroponics refers to the production of plants without soil, only with the addition of nutrient solutions to support growth (Pantanella, 2008; Panda et al., 2016). Aquaponics combines hydroponics and aquaculture (fish culture), plants being grown together with aquatic species in a soilless water-based system (Rakocy et al., 2006; Timmons and Ebeling, 2013). In an aquaponic system, fish waste supplies the nutrients for plant growth. Both growing systems are suitable for urban areas, highly productive, and can address the shortage of land concerning growing demand for food production (Medina et al., 2016). In this context, aquaponics can be a sustainable farming technique, because offers many advantages in terms of environmental impact (Ghamkhar et al., 2022), recycling nutrients (Graber and Junge et al., 2009), and reducing water consumption (Rakocy & Hargreaves, 1993; Turcios & Papenbrock, 2014; Yigit et al., 2016) being at the same time more profitable, because both plant (vegetables) and animal (fish) production are obtained. Aromatic herbs (e. g. basil, thyme, coriander, spearmint, sage, etc.) are among the

most used in aquaponics, mainly because have a fast harvest rate, and due to the higher applicability of these plants in various fields (cosmetics, medicinal, or food industry), making them the most economically important herbs worldwide. Thyme (*Thymus vulgaris*) and basil (*Ocimum basilicum* var. *Aristotle*) are between the most appreciated aromatic plants by consumers as culinary herbs, but also with multiple uses in the pharmaceutical, cosmetic industry, or the food industry for meat bio-preservation (Mihailović et al., 2013; Grespan et al., 2014; Fratianni et al., 2010; Sandulachi et al., 2021).
In this context, this study aimed to compare the growth performances of basil (*O. basilicum* var. Aristotle) and thyme (*Thymus vulgaris*) in an aquaponic system with *Carassius auratus,* versus a hydroponic system, with the addition of plant fertilizers. The plant and fish growth performance were analyzed and discussed together with the physicochemical parameters of water.

MATERIALS AND METHODS

Design and components of the aquaponics/hydroponic system. The study was conducted for 45 days at the Aquaponics unit of the Research Center for Modelling Recirculating Aquaculture Systems (MoRAS) of Faculty of Food Science and Engineering, Dunărea de Jos, University of Galați, Romania. The system consists of six rearing units for fish (1) and twelve units for plants (5), led lamps (6) with purple light, biological filter (4), mechanical filter (5), and pumps for water recirculation (2) (Figure 1).

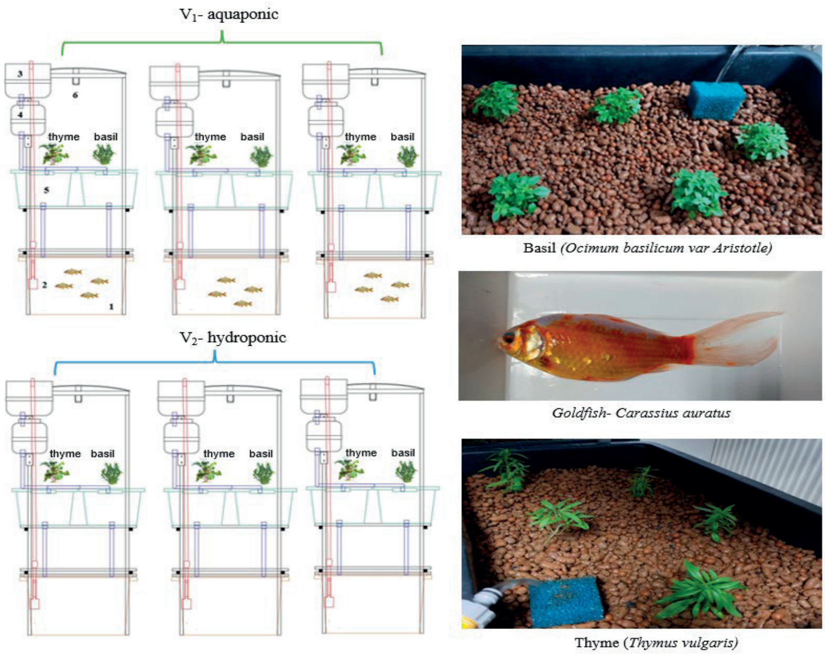

Figure 1. The scheme of the aquaponic and hydroponic systems
1-fish rearing unit; 2- recirculation pump; 3- mechanical filter; 4- biological filter; 5- aquaponic units; 6- led lamp

The LED lamps – pink color (36 Watts, model YQ-88012-36, China) were located at 0.8-meter above the plant's units to maintain the optimal illumination for the growing and were scheduled to work for 12 hours per day.
From each fish tank water was recirculated to the plant's units using a submersible pump (Aqua Zonic Evo E05, EVO PUMPS, Latvia), with a flow rate of 3000 liters per hour. The pump is submerged in the fish rearing unit from where it pumps the water up through a polypropylene pipe into the mechanical filtration unit. From the mechanical filter, the water moves gravitationally through the rest of the system. From the mechanical filtration unit to the biological filtration unit, through

distribution pipes to the two plant units (of each module), and from there back into the fish rearing unit (Figure 1). The mechanical filter uses sponges of two different densities, housed inside a plastic container, while the biological filtration consists of hundreds of small plastic media beads on which naturally-occurring bacteria (mainly *Nitrosomonas* sp. and *Nitrobacter* sp.) can develop. Weekly, 1 % of rearing water from the aquaponics system was replaced to remove settable solids. Also, weekly freshwater was added to compensate for its evaporation.

Experimental design. Two treatments in three replicates per experimental variant were performed. Therefore, three rearing units (V1-aquaponic) were populated with *Carassius auratus* (mean weight of 62.95±0.35 g) at a stocking density of 20.93± 0.11 kg m^{-3} and the other three were left without fish (V2-hydroponic). For the hydroponic treatment, a nutritive solution (0.27% Fe, 0.07% Mn, 0.05% Zn, 0.04% B, 0.009% Cu, and 0.006% Mo) was added daily to support plant growth (2 mL solution/L water).

Fish were fed manually with extruded pellets (34 % protein, 15 % lipids, 1.4 % crude fibre, 6.80 % ash). The daily feed ratio was adjusted to 2% from fish biomass. The daily feeding amount was divided into three meals (at 8:00 AM, 12:00 PM, and 5:00 PM). Plants units were populated with seedlings of thyme (*Thymus vulgaris*) and basil (*Ocimum basilicum* var. *Aristotle*), at a density of five plants per tank (0.17 plants/m^2). Plants units were filled with lightweight expanded clay aggregate (LECA).

Water quality. During the trial, the temperature (°C), dissolved oxygen (mg L^{-1}), and pH (pH units) were daily monitored, with the Pro1020 (YSI Incorporated, USA), pH-meter WTW (InoLab pH 7110, Xylem Analytics, Germany), while the nitrogen compounds: nitrates, nitrites, and ammonium concentration (mg L^{-1}), were measured twice per week, using Merck kits and the Merck Spectroquant Nova 400 spectrophotometer (Merck Chemicals GmbH, Germany). The sampling points of the water samples were established as follows: after mechanical and biological filtration (M+B), after evacuation of water from thyme growing units (T), after evacuation of water from basil growing units (B), and from the fish basins (F), respectively from the hydroponic units (H). The luminous intensity (lx) was measured with TESTO 545 light meter (Testo Co. United States) once per week.

Determinations of nitrogen, phosphorus, and chlorophylls. After weighing and measuring, the plants were oven-dried at 60ºC until constant weight, and then, their dry biomasses were determined. From dry plants, we determinate the nitrogen, according to the Dumas method by combustion of dry samples at 1100°C (Primacs SNC 100, Skalar Analytical B.V., The Netherlands). The nitrite and nitrate levels in plants were determined using the Griess method (STAS 9065:2002).

The amount of phosphorus was determined colorimetric using the San^{series} of Automated Wet Chemistry Analyzers (SAN^{series} Skalar Analytical B.V., The Netherlands). The method of phosphate determination is based on the reaction of ammonium hepta molybdate and potassium antimony (III) oxide tartrate in an acidic medium with diluted solutions of phosphate to form an antimony-phospho-molybdate complex. This complex is reduced by L(+) ascorbic acid to an intensely blue-coloured complex which is measured spectrometrically at 660 nm. The chlorophyll content indexes were determined. Chlorophylls were extracted from the tissues of leaves with ethanol according to the protocol of Castle et al. (2011). Absorbance was measured at adequate wavelengths characteristic for chlorophyll a, b, and total chlorophyll respectively 649 and 665 nm.

Growth parameters. At the beginning of the experiment, and the end, basil and thyme seedlings were measured for plant height (cm), plant weight (g), and roots height (cm). Fish growth parameters, including initial weight (g), final weight (g), weight gain (g), initial biomass (g), final biomass (g), feed conversion ratio (FCR), specific growth rate (SGR), and protein efficiency ratio (PER) were calculated:

- Weight Gain (WG) = Final Weight (Wt) (g) – Initial Weight (W0) (g);
- Food Conversion Ratio (FCR) = fish feed quantity (g)/WG (g) (g/g);
- Specific Growth Rate (SGR) = (ln Wt − ln W0)/t × 100 (% BW/day), where t- duration of the experiment;
- Protein efficiency ratio (PER) = Total weight gain (W) / amount of protein fed (g).

Statistical analysis. All collected data were analysed with the SPSS 21.0 (SPSS Company Inc., Chicago, IL. USA) statistical software package and Microsoft Excel. Statistically significant differences were reported at $p<0.05$.

RESULTS AND DISCUSSIONS

Water. The daily values of temperature, dissolved oxygen, and pH are presented in Figure 2. During the experimental period, water temperature registered a mean value of 23.03±4.31°C in the aquaponic system respectively 23.33±3.36°C in the hydroponic system, with no statistical differences ($p>0.05$). Regarding the dissolved oxygen, significantly higher values were registered in the hydroponic system (8.79±0.12 mg L^{-1}) in comparison with the aquaponic system (7.47±0.14 mg L^{-1}). The pH values were statistically lower ($p<0.05$) in the hydroponic system (6.75±0.24) in comparison with the aquaponic system (7.12±0.31).

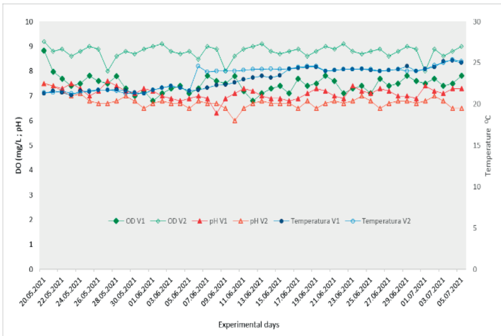

Figure 2. Daily values of temperature, pH, and dissolved oxygen during the experimental period

To obtain higher production of plants and fish in aquaponics systems plant and fish species must correspond as closely as possible for water temperature and pH requirements. For basil and thyme, the optimum temperature is reported between 20-25°C (Somerville et al., 2014; Abdelrazzaq et al., 2016), while the pH values must be between 6 and 8. According to some authors (Dong et al., 2001), high-temperature levels have a negative impact on the roots because reduce the absorption of N and inhibit the assimilation of K and P.

Also, for optimum growth, it is necessary to ensure plants higher nitrogen concentrations. In the Figures 2, 3, 4 and 5 are presented the minimum, mean and maximum values during the whole experimental period.

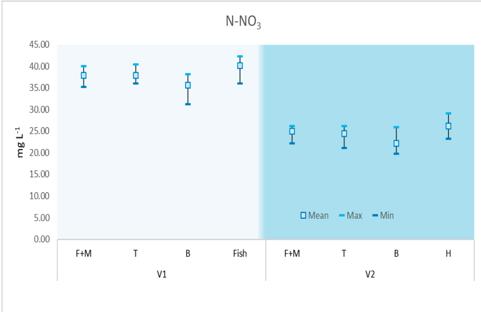

Figure 3. Values of nitrate during the experimental period

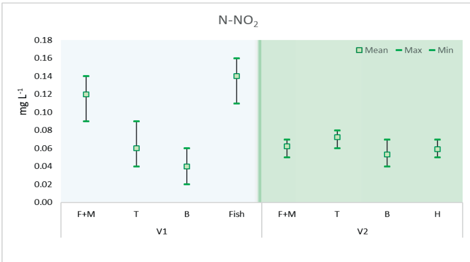

Figure 4. Values of nitrite during the experimental period

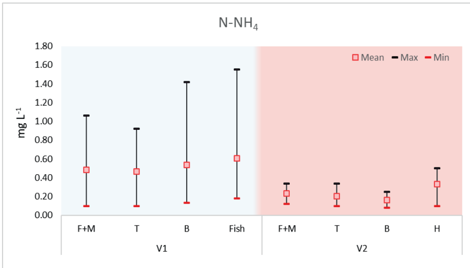

Figure 5. Values of ammonium during the experimental period

Significant higher ($p<0.05$) concentration of nitrogen compounds was recorded in the aquaponic system. The average N-NO_3^-, N-NO_2^- and N-NH_4^+ concentrations in the effluent water after removal from the plant units, showed a better removal rate capacity in the case of basil in comparation with thyme. Also, during the experimental trial the nitrate concentration gradually increase, and at the end of the experiment we registered a higher nitrate concentration comparing with the beginning of the experiment. Nitrogen is the element that is required in the greatest amounts by several crops (Lavres et al., 2005), principally because nitrogen contributes in the synthesis of proteins. The ammonium ($N\text{-}NH_4^+$) represents the major source of inorganic nitrogen used for growth plants (Vaillant et al. 2004), while the concentration of nitrate is relatively harmless, and it is the preferred form of nitrogen for plant growing (Rakocy et al., 2006). Concentration of nitrogen compounds were found to be in nontoxic range for fish (Eding & Kamstra, 2002; Timmons & Ebeling, 2013), but in the recommended values to sustain plants life in the aquaponic system (Bittsanszky et al., 2016; Mulay & Reddy, 2021). According to some authors nitrate (NO_3) is not toxic to fish even at high concentrations of up to 150-300 mg L^{-1} (Graber & Junge, 2009; Yildiz et al., 2017). Wongkiew et al. (2017) reported nitrate values around 16-50 mg L^{-1} in an aquaponic system using Common carp (*Cyprinus carpio*) and Pak choi (*Brassica chinensis*), respectively values of 26.7-54.7 mg L^{-1} for Tilapia (*Oreochromis* sp.) and Basil (*Ocimum basilicum*).

Plants. Plant productivity is shown in Table 1. No significant differences ($p>0.05$) in the plants' weight, plant biomass, total heights, and root length were registered at the initial moment when the aquaponic and hydroponic systems were populated. After 45-days, the obtained results indicate a significant ($p<0.05$) higher plant biomass in the aquaponic system, both in the case of thyme and basil. From Table 1 it could be seen that the thyme and basil weight, total fresh biomass, and the total heights from the aquaponic system are significantly higher than those from the hydroponic system. In terms of plant roots, the statistical analysis revealed that the thyme roots from the aquaponic system (15.13±4.77 cm/plant) are significantly lower ($p<0.05$) compared to those from the hydroponic system (26.31±15.63 cm/plant), while no significant differences ($p>0.05$) were not highlighted between the lengths of the basil roots.

Table 1. Plant growth data in an aquaponic system vs. hydroponic system

Plant	Growing method	Experimental moment	Plant weight (g/plant)	Plant biomass (g)	Total heights (cm/plant)	Root length (cm/plant)
Thyme	Aquaponic	Initial	4.02±0.33	20.11±1.33	12.66±1.98	8.53±1.06
		Final	49.13±24.76	245.64±2.18	48.21±16.11	15.13±4.77
	Hydroponic	Initial	3.63±0.78	18.14±1.45	11.95±2.56	7.91±1.40
		Final	28.44±8.75	142.21±43.73	29.41±19.11	26.31±15.63
Basil	Aquaponic	Initial	6.48±0.96	32.38±1.42	9.55±1.15	1.06±0.72
		Final	50.67±9.09	253.36±3.22	48.84±12.11	16.98±4.21
	Hydroponic	Initial	6.12±0.61	30.61±3.06	10.15±0.64	7.63±0.35
		Final	24.32±9.62	121.62±32.94	45.18±11.91	17.67±2.87

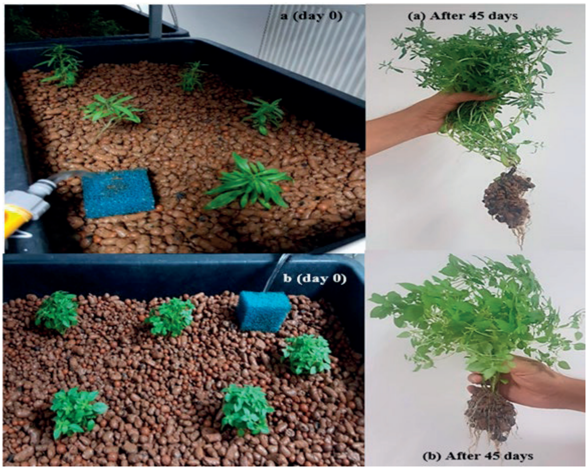

Figure 6. Thyme (a) and basil (b) cultivated in LECA substrate
(Day 0 of cultivation and after 45-days)

Fish growth performance is presented in Table 2. Survival rate was 98.33±2.36 % in experimental fish during the trial. The final individual weight of fish (mean±SD) was 82.75±5.56 g, with no significant differences ($p<0.05$) between the triplicates. The feed conversion ratio (FCR) was 1.15±0.07 and the specific growth rate (SGR) was 0.61±0.01 % day^{-1}.

Table 2. Fish growth performance at the end of the trail

Parameters	V1
Initial weight (g)	62.95±0.35
Final weight (g)	82.75±5.56
Initial length (cm)	11.5±1.09
Final length (cm)	12.8±3.01
Individual weight gain (g/fish)	18.80±1.70
Food Conversion Ratio (g/g)	1.15±0.07
Specific Growth Rate (g day^{-1})	0.61±0.01
Protein efficiency ratio	2.56±0.09
Survival rate (%)	98.33±2.36

Table 3 presents the values of the dry matter content (%), Chlorophyll A and B, total nitrogen (%), nitrite (mg/kg), nitrate (mg/kg), and phosphorous (mg/kg) content from leaf plants.

Table 3. Plant analysis at the end of the trial

Parameter	Plant	V1	V2
Dry matter (%)	Thyme	15.14±1.39	17±4.87
	Basil	8.09±0.98	10.6±2.58
Chlorophyll A ($\mu g \times g^{-1}$)	Thyme	0.23±0.01	0.19±0.03
	Basil	0.35±0.03	0.29±0.03
Chlorophyll B ($\mu g \times g^{-1}$)	Thyme	2.23±0.02	2.06±0.24
	Basil	2.25±0.11	2.18±0.06
Total Nitrogen (%)	Thyme	5.59±1.2	5.80±0.60
	Basil	5.79±0.19	5.61±1.63
Nitrite (mg/kg)	Thyme	0.56±0.06	0.58±0.13
	Basil	0.32±0.02	0.36±0.09
Nitrate (mg/kg)	Thyme	4.32±0.37	4.27±0.15
	Basil	2.85±0.33	2.35±0.18
Phosphorous (mg/kg)	Thyme	2.12±0.36	2.04±0.83
	Basil	2.45±1.31	2.32±0.14

Significant higher ($p<0.05$) values of Chlorophyll A were recorded in the case of the aquaponic system, both in the case of thyme and basil. Also, higher values of Chlorophyll B were obtained in the case of the aquaponic system, but the values are not statistically different ($p>0.05$). The chlorophyll content of leaf provides valuable information about the physiological and the nutrient status of plants (Filella et al., 1995; Gitelson et al., 2008). In our experiment, the chlorophyll content was higher in the case of basil. The results obtained by us are contradictory with those obtained by Saha et al. (2016) and Rakocy and Hagreves (1993), who did not find any differences in chlorophyll content from basil and lettuce crop grown under aquaponic and hydroponic systems. According to Gang et al. (1992), the differential chlorophyll accumulation can be explained most probably with the higher biomass growth is positively correlated with the basil biomass growth.

The values of total nitrogen content (%) were higher in the case of the aquaponic system, but the differences were not statistically different ($p>0.05$). Also, although the total nitrogen content (%) was higher in the case of basil, no significant ($p>0.05$) differences were recorded in comparison with thyme.

Regarding the nitrite and nitrate values (mg/kg) recorded significant ($p<0.05$) higher values were recorded for thyme, with no significant ($p>0.05$) differences between the two growing systems, while the values of phosphorous (mg/kg) registered no significant differences ($p>0.05$) between the experimental plants and growing systems. According to Madar et al. (2019), higher nitrate and nitrite content in leafy vegetables result in lower quality. However, the values obtained in our experiment do not exceed the acceptable upper limits of nitrates and nitrites set up in Ordinance no. 438/2002.

CONCLUSIONS

In this experiment, we compare the growth of thyme and basil in two soilless cultures, aquaponic and hydroponic. Both aquaponic and hydroponic systems can produce significant crop with limited water and without soil. From our results, we can conclude that the production of thyme and basil is more profitable in the aquaponic system. The use of wastewater with the aquaponic system is more favorable for basil and thyme growing since also a profitable fish production is obtained.

ACKNOWLEDGEMENTS

The authors are grateful for the technical support offered by MoRAS through the Grant POSCCE

ID 1815, cod SMIS 48745 (www.moras.ugal.ro). The author, Rîmniceanu Cristian thanks to the “Dunărea de Jos” University of Galați, which through the University Degree Program, the doctoral studies contract has supported the achievement.

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