Yuzuncu Yil University
Journal of Agricultural Sciences
(Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi)
https://dergipark.org.tr/en/pub/yyutbd

ISSN: 1308-7576 e-ISSN: 1308-7584

Research Article

Investigation on Basil (*Ocimum basilicum* L.) and Lavender (*Lavandula angustifolia*) Cultivation in Aquaponic Aquaculture (Carp, *Cyprinus carpio* L.)

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Article Info

Received: 25.04.2023
Accepted: 25.09.2023
Online published: 15.12.2023
DOI: 10.29133/yyutbd.1286610

Keywords

Aquaponics,
Basil,
Carp,
Lavender,
Sustainable Agriculture

Abstract: Aquaponic production system, which creates a sustainable production ecosystem by bringing water, fish, and plants together in a closed system, is a reflection of sustainable economic activities in aquaculture. In this context, the aim of the study was to investigate the cultivation possibilities of carp, lavender, and basil in two different grow beds (water and mollusc shell) created in the aquaponic production system. Basil and lavender as plant material and carp as fish material were used in the study. The experimental design was formed from 12 pots of 90 L volume, and the experiment was continued for 60 days with 3 replications. In the study, reasonably high values for specific growth rate (1.96±0.01 g), condition factor (1.5), and survival rate (97.05%) were obtained in carp. While basil (23.5 cm, 23.5 cm, and 16.5 cm) and lavender (16.57 cm, 15.14 cm end 9.73 cm) grown in water media performed better in terms of plant height, root length, and dry herb yield, the green herb yields of basil (49 cm) and Levander (19 cm) were found to be high for both plants in the mollusc shell media. The maximum NH_4, NO_3+NO_2, and PO4 values were determined as 1.30 mg L^{-1} (in 3. quarter and fish tank), 40.07 mg/L (in 3. quarter and Levander shell group), and 0.37 mg L^{-1} (in 1. quarter and basil shell group) respectively.

To Cite: Ertaş, İ, Gökçe, M A, Saygı, H, Ertaş, A. 2023. Investigation on Basil (*Ocimum basilicum* L.) and Lavender (*Lavandula angustifolia*) Cultivation in Aquaponic Aquaculture (Carp, *Cyprinus carpio* L.). *Yuzuncu Yil University Journal of Agricultural Sciences*, 33(4): 618-633. DOI: https://doi.org/10.29133/yyutbd.1286610

1. Introduction

Increasing world population has also increased the demand for food needs (Struik and Kuyper, 2017; van Dijk et al., 2021). This increasing need for food has led to an increase in the development of techniques that can get the most efficiency from the unit area (Kara Öztürk et al.2021) in both vegetable and animal production due to the limited agricultural areas and resources (Struik and Kuyper, 2017; Oliveira et al., 2022). Some of these developed techniques have started to raise problems such as the use of more fertilizers and pesticides with the increase in yield (Oliveira et al., 2022).

Various soilless farming techniques such as Hydroponics, Aquaponics, and Aeroponics have been started to be used in recent years and these techniques allow crop farming to be carried out on balconies, roofs, areas not suitable for agriculture, and in greenhouses (El-Kazzaz and El-Kazzaz, 2017).

Aquaculture, on the other hand, is the cultivation of aquatic animal organisms, usually fish, in a controlled or semi-controlled aquatic environment. The main need to grow healthy fish in aquaculture is clean water providing optimal conditions. However, waste products generated during aquaculture activities also create a pollution load that cannot be ignored in the aquatic environment. Non-consumable feeds, undigested feed compounds, and dissolved metabolic discharge products are important wastes in the aquaculture systems (Tekinay et al., 2006; Munguti et al., 2021). The water used in the aquaculture is contaminated under these three effects over time and the amount of phosphorus, ammonia, and suspended solids increases, and the amount of dissolved oxygen decreases. Aquaponic systems have been developed to reduce these effects (Somerville et al., 2014; Eltez and Taşkavak, 2016). Aquaponic is an application based on the use of wastewater coming from aquaculture in hydroponic systems (Sfetcu et al., 2008; Atique et al., 2022). The main purpose of this system is to reduce the pollution load of water used in aquaculture or to eliminate it completely (Atique et al., 2022). The water used in fish farming is very rich in nutritious elements and plants using this water in hydroponic systems benefit from them (Nguyen et al., 2016). Thus, the water is filtered through the use of these nutrients by the plants (Atique et al., 2022). The pollution load of the water treated by plants is reduced and water that provides optimal conditions is returned to the aquaculture system.

The selection of fish and plants to be used in the aquaponic farming system is very important (Yavuzcanet al. 2017). In the literature, the most commonly used fish species for this purpose are *Maccullochella peelii peelii* (Cod Fish), *Bidyanus bidyanus* (Silver Perch), *Macquaria ambigua* (Golden Perch), *Salmo trutta fario* (Stream trout), *Salmo salar* (Atlantic salmon), *Perca fluviatilis* (Freshwater perch), *Oncorhynchus mykiss* (Rainbow trout), *Ctenopharyngodon idella* (Grass carp), *Hypophthalmichthys molitrix* (Silver carp), *Cyprinus carpio* (Koi) and *Oreochromis* sp. (Tilapia) (Rakocy et al., 2006; Kerim and Tırıl, 2009; Türker, 2018). Carp is a preferred species for breeding because it can live in almost all fresh waters except Antarctica (Rahman, 2015; Fadiloglu and Çoban, 2019)), can easily adapt to sudden temperature changes, is suitable for intensive aquaculture, maintains product quality during the production process, reproduces quickly, has a high survival rate, low aquaculture costs and has a high economic value (Yılmaz, 2004). Plants, on the other hand, are widely used in aquaponic systems in the literature; Lettuce-salad, tomato, cucumber, pepper, spinach, zucchini, parsley, basil, many cultural vegetables, and various ornamental plants (Kargın and Bilgüven, 2018; Türker, 2018). In the study, a medicinal and aromatic plant with high economic value (basil, which is widely used in the aquaponic system, and lavender, which is not used much in the literature) was preferred. Lavender is an important medicinal and aromatic plant that produces essential oils with the highest commercial value in the world (estimated $38 million in 2020) (BAKA, 2020; Crişan et al., 2023). Lavender is used as an input in various production processes such as perfumery, food, cosmetics, health, aromatherapy, and landscaping (BAKA, 2020). With these features, lavender creates a good income opportunity for producers, and its cultivation is preferred (Crişan et al. 2023).

Chemical fertilizers and pesticides, which are considered to be harmful to plants and fish, are not used in aquaponic systems. Thus, it is possible to produce organic products in these systems. The water change is avoided unless it is necessary for the aquaponic system, hence, water, fertilizer, and chemicals are saved, and environmental pollution is prevented (Diver, 2000; Somerville et al., 2014; Olanrewaju et al., 2022).

However, for the elimination of the wastes released by the fish and recirculation of the water, it is very important for the sustainability of the system to determine and optimization of the fish species, fish size, stocking density, plant bed, plant variety, and amount.

This study was conducted to investigate the aquaponics culture potential of common carp, lavender, and basil plants using two different (water and shell) plant mediums. In the study, it was aimed to determine the realization possibilities of aquaponic production, which is a different type of cultivation than traditional production, which may be an alternative to agricultural production in the Mediterranean region of Turkey. Waste, consisting of feed leftovers, fish faeces, and algae from fish tanks rich in nutrients has been used to feed plants in the aquaponic system. These wastes coming from fish tanks, which have a polluting effect above certain levels for the environment are intended to be used by plants that act as biofilters in hydroponic and aquaponic systems, through plant beds, and to help eliminate ammonia, nitrate, nitrite, and phosphorus. Thus, the possibilities of reuse of the water discharged from the fish tanks have been revealed.

2. Material and Methods

2.1. Fish and plant materials

As fish material, Cyprinus species carp juveniles in the Cyprinidae family from Teleostei (bony fishes) order from the Pisces (fish) class were used. Carp has been preferred because of its characteristics that are mostly grown in hot climatic conditions, can be easily transported to long distances with a minimum loss, can withstand low temperatures, and can be monocultured and polycultured (Váradi, 2022).

As plant material, Lavender（*Lavandula angustifolia*）and Basil (*Ocimum basilicum* L.) from the Lamiaceae family were used. Within the scope of the research, basil seedlings of one (1) month and lavender seedlings of one (1) year were used. Lavender, one of the medicinal and aromatic plants, has been preferred because it is one of the 15 most traded essential oils in the world and because of its high economic value (Georgieva et al. 2021) in terms of the use of lavender in cosmetics, perfume, and pharmaceutical industries (Daneshvar Royandazagh et al., 2022). The other one, Basil, was preferred because of its high economic value in terms of using its essential oils in food flavoring, oral and dental health products, perfumery, and industry as a source of anthocyanins (Günay and Telci, 2017).

2.2. Plant and fish cultivation

This research was carried out at Çukurova University, Adana-Turkey Freshwater Fish Research Station between 01.05.2019 and 30.06.2019. The trial setup and observation of the results were carried out in a greenhouse sheltered against external influences. Day length during the 60-day period in which the experiment was conducted varied between 13:00 and 14:39 h. The 3 pieces of 500 L fish tanks were used in the experiment and air stones in each tank were placed to maintain oxygen level above 5 ppm. The water drained from the fish tanks was transferred to a 1000 L storage tank to capture suspended solids and homogenized water was given to the pots. Twelve plastic pots of 86x40x29 cm were used for plant cultivation. Irrigation water obtained from the fish tanks was used in two different plant types cultivated in two different bedding materials. In the study, the experimental groups were arranged in three replications (Figure 1).

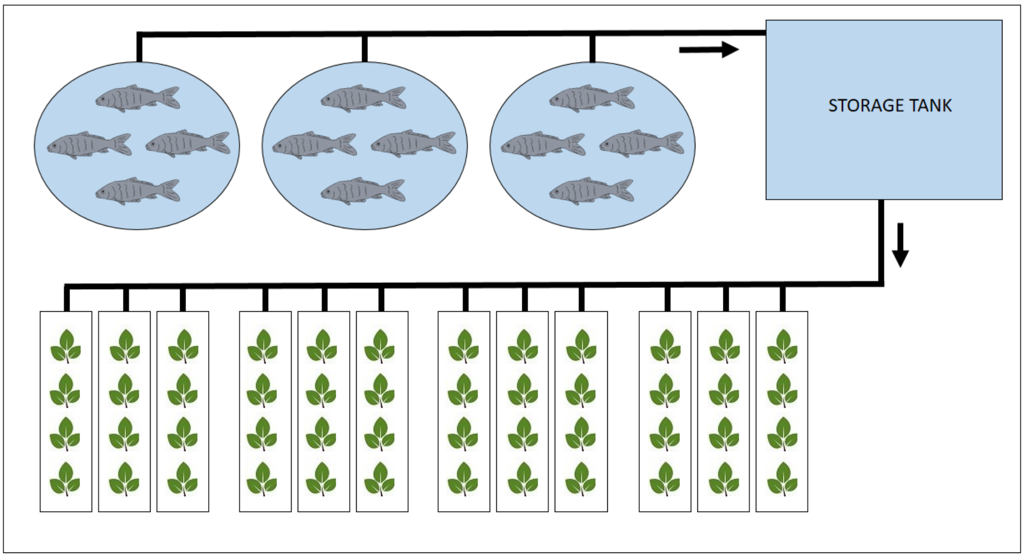

Figure 1. The experimental setup.

Sampling for the water quality parameters and plant growth measurements were made at 15-day intervals in the study. The fish were hand-fed twice a day to apparent satiation from the beginning and a commercial feed with 37% raw protein was used. Two different materials were used as plant growing beds, water, and marine snail (*Buccinum undatum*) shells. During the experiment, dissolved oxygen, temperature, and pH were measured and recorded in fish tanks. Carp (*Cyprinus carpio* L.) fry which had an initial average weight of 2.1 ± 0.30 g were stocked with a 0.826 mg kg^{-1} stocking ratio in the tanks. The lavender (*L. agustifolis*) and basil (*O.basilicum*) plant species were cultivated as 40 root basil and 15 root lavender in separate pots.

While the basil was arranged to have 30 cm between rows, 20 cm above the rows, and 40 plants per parcel, lavenders were arranged so that there are 90 cm between rows, 60 cm above the rows, and 15 plants per parcel. No additional fertilizer was used for the production of lavender and basil during the experiment.

2.3. Physicochemical parameters

Water temperature (T ºC) and dissolved oxygen (DO) were measured daily with AZ 8402 oxygen meter. The electrical conductivity (EC) and acid or alkaline value (pH) of the water were measured at 15-day intervals by using the WTW Series Cond 720 conductivity meter. Fenat method for ammonium nitrogen (NH_4-N), cadmium reduction method for nitrate + nitrite nitrogen (NO_3 + NO_2-N), ascorbic acid method for orthophosphate phosphorus (PO_4-P) were used for the water samples taken (APHA, 2005). Spectrophotometer readings were also carried out with Shimadzu UV at 15-day intervals.

2.4. Plant and fish measurements

In the basil, the plant height (cm) was measured by averaging 10 plants randomly selected from each pot before harvest. The root lengths (cm) of 5 plants at each replication were measured removing the plants without any damage at the end of the harvest.

The plant length (cm) of the Lavender and Basil was determined by measuring the distance of each plant from the water surface to the top point during the harvest period. Flower Stalk Length (cm) was found by measuring the length of the plant flower stalk to the top point, including the flower spike (Sönmez et al., 2018). Flower Spike Length (cm) was measured as the length of the plant flower spike (Sönmez et al., 2018).

The live weights of the fish were made with a 0.1 gram measurement precision scale and total length measurements were made with a 1 mm precision measuring board. The growth parameters of fish were determined based on the daily live weight gain (Wotten, 1990; Rahman and Arifuzzaman, 2021a), the live weight gain (WG) (%) (Heydarnejad, 2012), the specific growth rate (SGR) (De Silva and Anderson, 1995; Hoşsu et al., 2003; Rahman et al., 2022), the condition factor (CF) (Ricker, 1975; Çelik, 2005; Yazıcıoğlu and Yazıcı, 2023), the survival rate (SR) (Çelik, 2005; Opiyo et al., 2017) and the feed conversion rate (FCR) of fish (Santinha et al., 1996).

2.5. Data analysis

SPSS 17.0 (2008) statistics program was used to evaluate the data obtained. The average values and standard errors of the data were calculated, and whether there was a significant difference in the data of the experimental groups was determined by variance analysis (ONE WAY ANOVA) and Duncan test ($P \leq 0.05$) (Düzgüneş et al., 1993).

3. Results

The study was carried out to investigate the aquaponic growing potentials of carp, lavender, and basil plants in two different environments (water and water + mollusk shell). For this purpose, fish population (WG, SGR, CF, SR, and FCR), plant morphological characteristics (plant height, plant root length, plant green herb yield, and plant dry herb yield), and water physicochemical properties (NH_4, NO_3 + NO_2, and PO_4) parameters were examined.

3.1. Fish population

Regarding the fish population findings examined within the scope of the study, the daily live weight gain was determined as 0.7609 g while the WG was determined to be 217.40 g carp juveniles at the end of the experiment in the present study. Eltez and Taşkavak (2016) investigated the possibilities of lettuce cultivation at different doses of fish feeding in aquaponic culture and reported an average fish weight of 49.82 g at 4% feeding (based on live fish weight ratio) over a period of approximately 90 days. Deer et al. (2021) reported the standard average fish weight of 600 g in carp during 6-8 months. The daily live weight gain is a study-specific value due to factors specific to the studies and individuals studied. However, since SGR is a relatively standardizable value, it is considered to be more appropriate to compare it with other studies. In this study, the SGR was found to be 1.96±0.01 g for a 60-day trial. İzci et al. (2020) reported a standard mean SGR of 14.14 g (initial weight: 25-30 g) in carp over a 35-day period. On the other hand, the CF value obtained from the present study is 1.5, and the SR rate of 97.05% was determined. Setiadi et al. (2018) reported a 96% SR of red carp in the aquaponic culture of lettuce cultivation. Yılmaz et al. (2010) reported that the condition factor in carp ranged from 1.34 to 2.29. The average FCR, which is an important tool for calculating the acceptability and feeding efficiency of artificial feed was 1.91 in this study. Hager et al. (2021) reported that the ideal FCR is 1 pound (453.59 g) (1 pound growth of fish fed 1 pound of feed), but in practice, this ratio is 1.4-1.8.

3.2. Plant morphological characteristics

Our findings regarding the findings of Lavender and Basil's plant examined within the scope of the study. The findings related to plant height, root length, green and dry herb productivity, and plant bed of Basil and Lavender are shown in Figure 2.

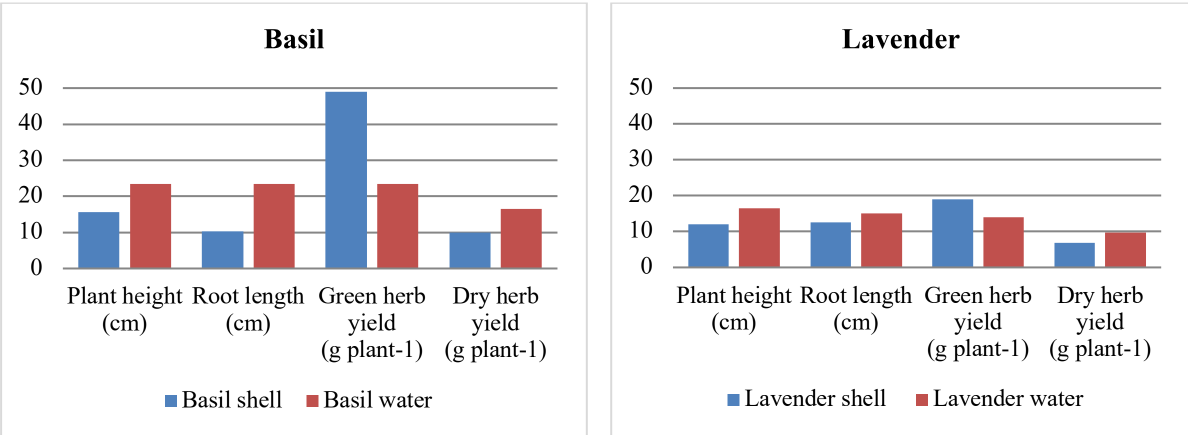

Figure 2. The yields of Basil and Lavender in different plant beds.

The plant height, root length, and dry herb yield values of the basil plant were better in the water plant bed while the basil-shell group was found to have a higher value in green herb fertility (Figure 2). İzci et al. (2020) examined mint cultivation in the aquaponic system and reported a 50% increase in plant roots. In the evaluation made in terms of plant height, the maximum plant height from the basil-water plant bed was measured as 23.50±1.50 cm. Green herb yield was 49 gr for basil and dry herb yield was 16.50 g. İzci et al. (2020) reported that the growth rate of plant leaves increased by 100% and the plant weight growth rate increased by more than 100% in mint cultivation in the aquaponic system. It was determined that the plant height, root length, and dry branched flower productivity of the lavender plant were better in the water plant bed while the lavender group in the shell bed had higher values in fresh branched flower productivity. There were significant differences in the yield of freshly branched flowers in lavender grown in different plant beds. In the experiment, the highest fresh branch flower yield was obtained from the lavender-shell plant bed (19.00±2.00 g plant^{-1}). As a result, it can be speculated that plant beds have a significant effect on plant yield.

3.2. Water physicochemical properties

The physical and chemical parameters (pH, EC, temperature, and DO) measured in the study are shown in Table 1.

Table 1. Physical and chemical parameters measured during the study period

Periods	Cultivation Media	pH	EC (mS/m)	Temperature ºC	DO (mg L^{-1})*
15.05.2019	Fish tank	7.20	719	23.80	6.91
	Lavender shell	7.09	761	23.30	-
	Lavender water	7.21	709	23.10	-
	Basil shell	7.12	795	23.00	-
	Basil water	7.10	768	23.10	-
30.05.2019	Fish tank	6.99	775	26.10	6.38
	Lavender shell	7.02	767	26.30	-
	Lavender water	7.11	735	25.90	-
	Basil shell	7.07	783	25.80	-
	Basil water	7.04	779	25.80	-
15.06.2019	Fish tank	7.67	779	25.90	6.35
	Lavender shell	7.69	756	25.10	-
	Lavender water	7.64	761	25.40	-
	Basil shell	7.59	790	25.30	-
	Basil water	7.53	787	25.10	-
30.06.2019	Fish tank	7.91	813	26.80	6.32
	Lavender shell	8.04	808	27.00	-
	Lavender water	8.00	815	27.10	-
	Basil shell	7.94	820	27.20	-
	Basil water	7.93	820	27.00	-

*1 mg L^{-1} (milligram $liter^{-1}$) = 1 ppm (parts per million). pH, Acid or Alkaline Value; EC, Electrical Conductivity, DO, Amount of Dissolved Oxygen in Water.

Standard deviation, mean, and range values of the physical parameters measured on all sampling dates are given in Figure 3.

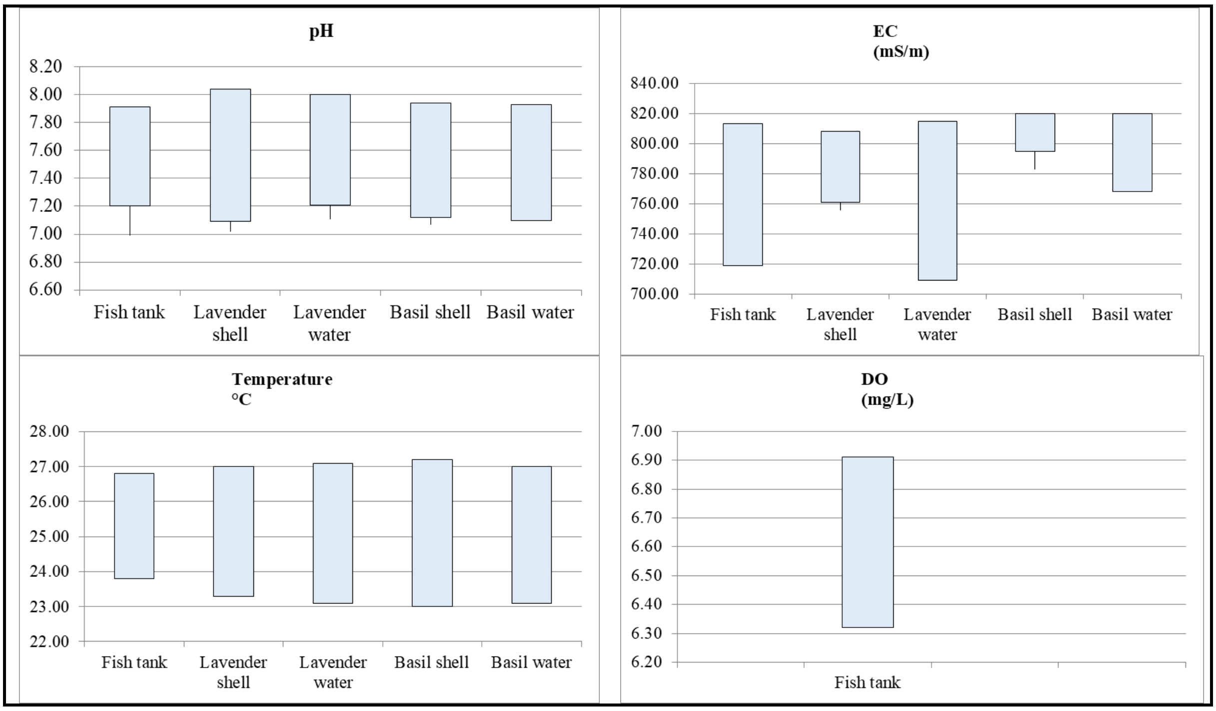

Figure 3. The range of pH, EC, temperature and DO values measured in this study.

According to the study findings, the measured pH values are between 6.99 and 8.00. Deer et al. (2021) investigated the nitrogen cycle in aquaponic culture (with and without fish), and reported that the pH value in aquaponic culture should be in the range of 6.0-8.50 for fish (cold and hot water fish) and bacterial cycle, and 5.50-7.50 for plants. When the EC values in the applications were examined, the highest EC value was obtained from the basil peel and water application in the 4th quarter in the first 60-day period, and the lowest value was obtained from the lavender shell application in the 3rd quarter. Hager et al. (2021) reported that the ideal EC value in aquaculture should be 0.50-2.0 µS cm^{-1}. The water temperature values measured during the application were between 23-27.2 ºC. Sallenave (2016) reported that the appropriate water temperature required for maximum growth of carp in aquaponic culture should be 27-29 °C. Deer et al. (2021) reported the ideal water temperature in aquaponic culture (in warm water fish) in the range of 22-32 ºC. The dissolved oxygen values measured during the application were between 6.32 and 6.91 mg L^{-1}. Sallenave (2016) reported that the amount of dissolved oxygen should be 5 ppm and above for the healthy development of carp in aquaponic culture. Deer et al. (2021) reported the ideal amount of dissolved oxygen in aquaponic culture (in hot water fish) in the range of 4-6 mg L^{-1}.

During the study, NH4, NO3+NO2, and PO4 measurements were made at the $P \leq 0.05$ significance level in the application environments every 15 days in fish tanks and all plant experimental groups, and the results are presented in Table 2.

Table 2. Effect of applications on the NO3 + NO2, PO4 and NH4

Periods	Cultivation Media	NO3+NO2	PO4	NH4
15.05.2019	Fish tank	35.22±0.71^{ab}	0.06±0.01^{b}	0.25±0.06^{a*}
	Lavender shell	39.30±1.01^{a*}	0.17±0.12^{b}	0.09±0.02^{c}
	Lavender water	37.91±3.32^{ab}	0.04±0.01^{b}	0.14±0.03^{bc}
	Basil shell	24.10±1.79^{c}	0.37±0.14^{a*}	0.12±0.02^{bc}
	Basil water	34.21±3.18^{b}	0.04±0.01^{b}	0.20±0.03^{ab}
30.05.2019	Fish tank	17.44±1.30^{b}	0.11±0.01^{ab}	0.25±0.04 ^{a}
	Lavender shell	29.24±0.33^{a}	0.31±0.24^{a}	0.18±0.04^{b}
	Lavender water	27.53±1.92^{a}	0.03±0.01^{b}	0.17±0.03^{b}
	Basil shell	28.79±1.00^{a}	0.24±0.13^{ab}	0.17±0.04^{b}
	Basil water	27.29±2.21^{a}	0.05±0.01^{b}	0.12±0.02^{b}
15.06.2019	Fish tank	27.18±1.39^{b}	0.08±0.01^{a}	1.30±0.05 ^{a}
	Lavender shell	40.07±3.44^{a}	0.06±0.04^{abc}	0.58±0.26^{b}
	Lavender water	34.16±1.51^{ab}	0.04±0.01^{c}	0.71±0.08^{b}
	Basil shell	36.19±8.99^{ab}	0.08±0.03^{ab}	0.70±0.22^{b}
	Basil water	34.14±3.86^{ab}	0.04±0.01^{cb}	0.53±0.05^{b}
30.06.2019	Fish tank	33.82±1.19 ^{a}	0.06±0.01^{a}	0.15±0.04^{b}
	Lavender shell	30.65±1.60^{a}	0.12±0.06^{a}	0.53±0.21^{ab}
	Lavender water	33.16±0.47^{a}	0.05±0.01^{a}	0.59±0.06^{ab}
	Basil shell	33.51±5.43^{a}	0.08±0.01^{a}	0.79±0.38^{a}
	Basil water	31.99±1.04^{a}	0.23±0.29^{a}	0.51±0.32^{ab}

NO_3, Nitrate; NO_2, Nitrogen Dioxide; PO_4, Phosphate ; NH_4, Ammonium. Differences between applications were statistically evaluated at the significance level of $P \leq 0.05$. The differences between the table values of the applications are symbolized by the letters a, b, and c, the highest value with the letter a(*) and the other values represent the lower values in alphabetical order, and there is no difference between the applications expressed with the same letter.

When the effects of the applications on NH_4 values were examined, the highest NH_4 value was obtained from the fish tank in the first quarter in the first 60-day period, and the lowest value was obtained from the lavender shell application in the second quarter (Figure 4).

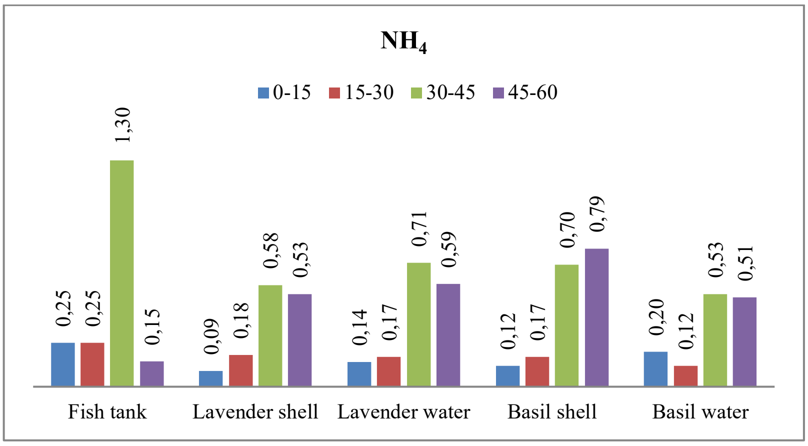

Figure 4. The NH_4 values for all experimental groups.

Effendi et al. (2017) investigated the development of Nile carp in lettuce cultivation in aquaponic culture and reported the amount of NH_4 as 3.10-4.72 mg L^{-1}. Zahidah et al. (2018) investigated the effect of Red Water System (RWS) probiotic applications on water quality in aquaponic culture and reported the highest NH_4 value of 0.77 ppm at 20 days, and the lowest value of 0.28 ppm at 10 days.

When the effects of the applications on NO_3+NO_2 values are examined, the highest NO_3+NO_2 value in the first 60-day period was obtained from the lavender shell application in the first quarter, and the lowest value was obtained from the fish tank in the second quarter (Figure 5).

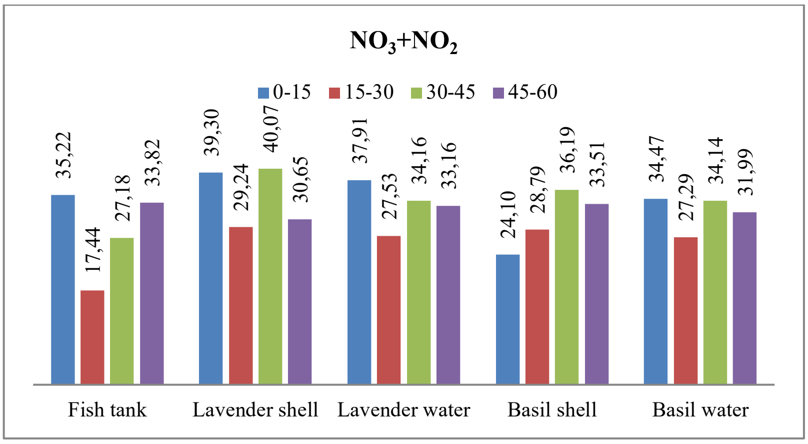

Figure 5. The NO_3 + NO_2 values for all experimental groups.

Effendi et al. (2017) investigated the development of Nile carp in lettuce cultivation in aquaponic culture and reported the NO_3+NO_2 amount in the range of 0.94 (0.91+0.03) - 2.45 (1.52+0.93) mg L^{-1}. While İzci et al. (2020) reported the lowest Ammonium and Nitrite values as 0.061 mg L^{-1} and the highest as 0.226 mg L^{-1} in mint cultivation in the aquaponic system, they reported the lowest Nitrate value as 3.6 and the highest as 110.80.

When the effects of the applications on PO_4 values were examined, the highest PO_4 value was obtained from the basil shell application in the first quarter in the first 60-day period, and the lowest value was obtained from the lavender water application in the third quarter. (Figure 6).

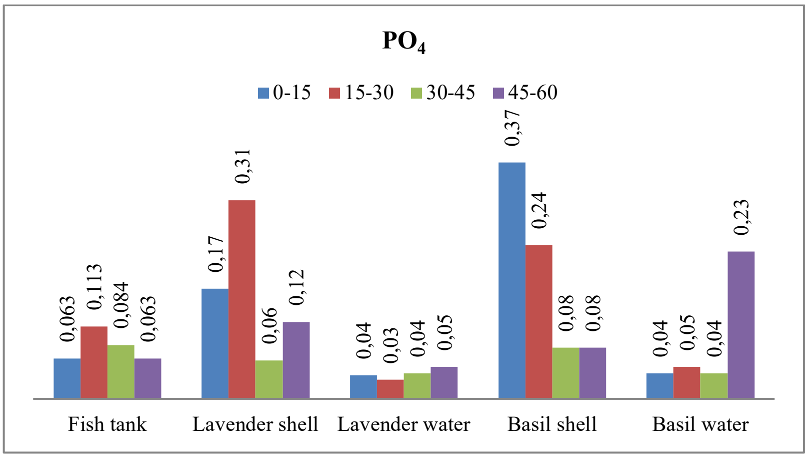

Figure 6. The PO_4 values for all experimental groups.

Türker (2018) investigated the effect of growing different plant species in aquaponic culture on water quality, and in lettuce, he reported the amount of PO_4 as 2.05-2.88 mg L^{-1} for the water entering the system and 0.89-2.25 mg L^{-1} for the water leaving the system. In addition, Türker (2018) reported the amount of PO_4 as 1.78-2.35 mg L^{-1} for the water entering the system and 0.98 mg L^{-1} for the water leaving the system in strawberry. Zahidah et al. (2018) reported that the ideal amount of NO_4 in aquaponic culture should be in the range of 0.20-1.00 ppm.

4. Discussion

In the study, aquaponic cultivation potentials of carp, lavender, and basil plants in two different media (water and water + mollusk shell) were evaluated in terms of fish population (WG, SGR, CF, SR, and FCR), plant morphological characteristics (plant height, plant root length, plant herb yield, and plant dry herb yield) and water physicochemical properties (NH_4, NO_3 + NO_2 and PO_4) parameters.

4.1. Fish population

In the study, fish population characteristics were evaluated in terms of WG, SGR, CF, SR, and FCR parameters.

Regarding WG, the conversion of the nutrients in the feed taken by the fish into live weight and growth is an indicator used to determine the amount of marketable product in fish farming (Gençer and Doğankaya, 2022). Regarding WG, Rahman et al. (2012) tried 4 different protein levels in their feeding study with carp, and they found the growth rate of the WG to be a minimum of 42.7 g and a maximum of 129.2 g. According to Sultana et al. (2001), the WG growth rate of at least 218.91 g in carp where they applied different feeding frequencies, the highest was 334.30 gr during the 45-day trial. Heydarnejad (2012) determined the growth rates of carp at different pH levels between 13.1 and 80. Rahman and Arifuzzaman (2021b) reported the WG value in the range of 36.49±4.09 - 125.19±1.29 g in their study examining the growth performance and survival rate of rohu (Labeo rohita) and tilapia (*Oreochromis niloticus*). As a result, it is seen that quite different data were obtained in the studies conducted. Likely, the genotype of fish, the character and objectives of the studies, and the fish size and environmental factors may be considered to be effective in these differences.

Regarding SGR, which should be known primarily in fish farming, it is used to accurately estimate the growth potential of fish stocked in a certain breeding condition and to calculate the energy or feed amount to be given per day (Korkut et al., 2007). Rahman et al. (2012) found the SGR lowest and the highest values as 0.72 and 1.71 in their seven-week study. Nasır et al. (2016) reported the SGR data for the same species between 0.34 and 0.93 in their 60-day trial. The values obtained in both studies are considerably lower than our values. In contrast, Heydarnejad (2012) found highly variable values between 0.9 and 8.4 partially higher than the values of the present study. However, it can be said that both WG and SGR values obtained from this study are within reasonable limits when compared with previous studies.

Regarding CF, it refers to the best control of morphological structure in assessing nutritional and development criteria in fish, reflecting knowledge of the physiological state of the fish in relation to the welfare of the fish (Korkut et al., 2007). Sac and Okgerman (2016) reached very different CF values varied between 1.33 and 2.66 in their study on carp, which were caught from various lakes. The K value obtained from this study is relatively low compared to other values may be associated with the smaller size of the fish. It is known that one of the most important factors affecting the CF factor is the age of the fish, as well as factors such as nutritional conditions and maturation period (Korkut et al., 2007). Ujjania et al. (2022) reported that the CF value of carp grown in the village pond varied between 1.29 and 1.77 and these values were considered good. Therefore, it can be accepted that the CF factor value (1.5) revealing the health and feeding conditions of fish obtained from this experiment is within the optimum limits.

Regarding SR, it is a parameter that reflects the effect of the suitability of the growing medium on the yield amount in fish farming. In studies on SR, Rahman et al (2012) found a rate between 70% and 93.33%, while Nasir and Hamed (2016) found this rate as 100%. It can be stated that the SR rate of 97.05% determined in our study is satisfactorily high.

Regarding FCR, it is one of the most used indicators to determine the growth performance of fish, both for economical production and providing better conditions (Korkut et al., 2007). While Sultana et al. (2001) determined the FCR as the lowest 1.22. Nasir and Hamed (2016) determined the FCR as 2.21 in their feeding frequency study with carp. A relatively higher FCR value obtained in this study can be considered a more anticipated situation, especially in the fast-growing juvenile fish.

When the fish population characteristics parameters (WG, SGR, K, SR, and FCR) examined in the study are evaluated, the practices are compatible with previous studies in all parameters except WG and provide acceptable aquaponic farming conditions for carp.

4.2. Plant morphological characteristics

In the study, plant morphological characteristics were evaluated in terms of plant height, plant root length, plant green herb yield, and plant herb yield parameters.

Plant growth performance is one of the important criteria in these studies. Serin (1996) recorded the basil plant height values as 52.67-68.37 cm in his study on Adana and Osmaniye basin populations. Simon et al. (1999), on the other hand, determined the plant height values of *Ocimum basilicum* species as 29-49 cm in their studies. According to Nacar (1997), basil plant height values were found to be between 48.39 and 67.17 cm. Telci (2005) reported the height values of basil plants between 32.30-45.70 cm in 2001 and 28.70-40.60 cm in 2002. In a study conducted on basil growth in aquaponic and hydroponic conditions, a remarkable plant height of 89.9 cm was taken from the aquaponic system (Saha et al. 2016). The basil plant height values obtained from this study were lower than the results obtained in previous studies.

Ceylan et al. (1996) stated that the plant height of lavender is 41.3 cm. Arabacı and Bayram (2005) reported that the plant height in the lavender variety used in the study varied between 43.7-69.5 cm, while in another study Karık et al. (2017) reported that the height was determined between 39.50 – 79.25 cm in different lavender cultivars. Akçay et al. (2021) stated that the plant height of lavender is between 49.55 and 54.13 cm. Considering the results obtained from the plant height of lavender in the present study, the lower values were observed compared to the values reported in previous studies. Although plant height is affected by different environmental factors, it is known that the determining factor is the genetic potential of the variety. Plant height also varies according to cultivars and environmental factors (Ceylan et al., 1996; Arabacı and Bayram, 2005). In the study, the dry herp yield value of the lavender plant taken from the lavender water medium was higher than the dry herb value taken from the lavender shell medium. This situation is related to the density of nitrogen forms (NO_3 and NH_4) that can be taken up by plants in the environment and the ease of uptake by the plant. Korkmaz and Alkan reported that when the amount of nitrogen in the environment is low and its uptake by plants is difficult, root development increases in plants, and on the contrary, stem development increases. In the study, The findings of Korkmaz and Alkan support the findings of the study (the root length is shorter in the lavender shell than in lavender water, and the fresh shoot length is longer than in lavender water).

In the study conducted by Saha et al. (2016) on basil grown in aquaponic and hydroponic systems, the green herb yield was 150.2 g and the dry herb yield was 15.9 g in aquaponic conditions.

The values we obtained as a result of the green herb yield were lower than the results obtained in this study. Based on the dry herb yield, the data was parallel to the findings of Saha et al. (2016). This study was carried out in a greenhouse environment. It is thought that one of the reasons for the lower values found in this study may be due to higher temperature and humidity in greenhouse conditions. Also, in this study, no other nutrients were added to the water that the plants can take from the soil in conventional farming practices. Although the wastewater from the fish tank has an important potential for plant nutrition, the conversion of organic matter into inorganic substances that plants can utilize may not have been sufficient. By applying a system where fish, algae, and plants are used together in a controlled environment, or in a system where these three elements are present and optimum environmental conditions are provided, much more effective results can be obtained and waste minimization can be achieved.

4.3. Water physicochemical properties

In the study, water physicochemical properties were evaluated in terms of pH, EC, temperature, DO, NH_4, NO_3 + NO_2 and PO_4 parameters.

In fish farming, the acceptable value in terms of pH ranges between 6.5 and 9.0 (Zweig et al., 1999). Tekelioğlu (2005) reported that DO should not be below 5-6 mg L^{-1} and the T °C should be between 20-34 ˚C (Abd El-Hack et al., 2022; Panicz et al., 2022) for the best growth. Stone et al. (2013) stated that it is desired to have EC between 60-2,000 µS cm^{-1} for fish farming. In this respect, it has been demonstrated that environmental conditions were suitable for carp farming during the experiment.

Generally in studies, the NH_3 (non-ionized ammonia) and NH_4 (ammonium) are evaluated together and given as TAN (total ammonia nitrogen). NH_3 has a high level of toxicity, however, NH_3 in the water is converted to NH_4 and is present at a certain rate depending on some factors. The presence rate of NH_3 is directly related to water temperature and pH. The fact that a higher level of one or both of these parameters is an important factor in the increase of NH_3 in the water. In the current study, the water temperature did not exceed 27.2 °C, and the pH above 8.04, revealed that the risk of NH_3 toxicity was not high in the fish tanks.

The most suitable value in the water quality chart prepared for freshwater fish farming; is given as <1 mg L^{-1} for NH_4, <50 mg L^{-1} for NO_3, 0.1 mg L^{-1} for NO_2, and <0.1 mg L^{-1} for PO_4 (Anonymous, 2019). In the current study, it was determined that NH_4 does not have a value above 0.79 mg L^{-1} and NO_3 + NO_2 is the highest as 41.3 mg L^{-1}. The values observed are far below the limits. Ten of the total 16 observation values were determined to be lower than the given values in terms of PO_4. In 6 of them, the values increased up to 0.443 mg L^{-1}. On the other hand, 7 of the low values are in the water bed. In the study, significant differences were found in PO_4 values for different plant beds of the same plant species. Therefore, the water bed is thought to be much more effective than the plant in the availability of PO_4.

Graber and Junge (2009) reported the water quality obtained by cultivating tomatoes and cucumber in the aquaponic system where tilapia are used as fish material. The values obtained reveal that the tomato plant's NH_4, NO_3, and NO_2 performance is quite good, but the results of the cucumber plants are lower than the results we obtained. Accordingly, this difference in the availability of chemical ingredients in plant beds can be explained by the extent to which these chemicals are used by different plant species or cultivars.

Boxman et al. (2018) used additional equipment such as biofilters, waterbed aeration systems, and solid separators while conducting their experiments with purslane and black cumin in a marine hydroponic system, therefore they reported that very low values were obtained not only in plant beds but also in fish tanks. As a finding, the researchers stated that plant growth rates are important in sizing plant beds.

Li et al. (2019) tested the performance of the biofilm plant bed using spinach as the plant material, and in this study, they aimed for the plants to absorb high levels of nutrients with the biofilm material. When the results they obtained (TAN, NO_2, and NO_3) are compared with those obtained in this study, it is seen that the values are close, although the results of this study are partially higher.

Cultivations of tilapia fish, bok choy, and green beans in an integrated aquaponic experiment with filter systems were carried out by Estim et al. (2019). When the results obtained by the researchers are compared with our findings, it is seen that the total nitrite and nitrate levels for all groups are lower than our findings, but the PO_4 levels are higher than those in our study. While it is possible to associate the high PO_4 level in the study of Estim et al. with the nutritional preferences of the plants, the very low NO_2 and NO_3 levels can be explained by the contribution of the filter system used.

Yang and Kim (2019) carried out their studies with a trial setup in which they added a biofilter and ventilation system in their study with Nile tilapia and various leafy vegetables in order to determine the effects of feeding regime on water quality, crop performance, and nitrogen (N) use efficiency. In their study, they experimented with increasing, uniform, and intermediate feeding rates containing the same amount of (120 g) N and feed (1800 g) instead of standard increasing feeding practices (some % of fish body weight) and they found that uniform feeding regime increases quality, yield, N use and photosynthetic performance of the plants and herbs. They stated that simple modification of the feeding regime and subsequent water chemistry changes in aquaponics were effective in improving plant growth and performance. However, in this present study, one of the standard feeding practices used in aquaculture named as ad libitum (to satiation) was applied. It can be speculated that there is a need for fish plant quantity optimization, most likely due to the feeding method in the study.

Calone et al. (2019) reported NH_4 and NO_3 values for their study using catfish and lutus, as lower values than the values obtained in this study. It can be thought that the use of solid matter sedimentation and biofilter methods in their systems is effective in reaching lower values in their studies.

When the findings regarding the physical and chemical properties of the water were evaluated, it was observed that the organic matter wastes in the water, which emerged from the fish and created environmental pollution for the fish, were used by the plants as a food source to improve the water quality for the fish.

5. Conclusion

As a result of the present study, juvenile carp revealed a growth performance similar to previous studies and it was within the optimum limits. These results showed that optimal conditions in which carp could develop were provided in the experiment. In the study, it was determined that a higher amount of basil and lavender which were grown in the water bed were produced and dry herbal yields were higher in the waterbed. However, plant yields obtained in the study were found to be quite low compared to those grown in terrestrial environments. It is thought that this is because the plants could not find some of the nutrient requirements that they could obtain from the soil in the aquatic environment of the experiment. It is thought that it will be beneficial to determine the fish stock ratio and the optimum ratio of fish/plants that can reveal the optimum water usage rates of the plants in question. In addition, according to the literature reports, it can be said that the increase in the waste produced by the fish due to the growth and the change in the consumption amounts of the plants during the production period can be balanced by the use of aquatic plants and algae which can be another by-product in aquponic systems or biofilters. Furthermore, it can be thought that the use of some supports for plant nutrition will have positive effects on plant productivity.

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