The Effect of Biofilters on Water Quality Parameters and Efficiency in Aquaponic System

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ABSTRACT

Aquaponic systems are ecological systems suitable for sustainable agriculture. With the reuse of water in the system, the fertilizer needs of plants are met withnatural fish waste and water consumption is minimized. In our project, a control and experiment group consisting of 2 pilot aquaponic systems consisting of a fish tank and a hydroponic vegetable tank working in parallel has been established. In addition, Biofilters is designed for the Experimental group. Koi fish was used in the fish tank and Kale was used in the vegetable tank. Blue LEDs were used due to insufficient sunlight.

Key words: *Aquaponics, Biofilter, Water quality, Koi, Black cabbage*

1 Introduction

In today's world, a lot of inorganic fertilizer is given to the environment to get more products from the unit area to meet the nutritional needs. However, the introduction of chemical fertilizers has caused environmental pollution and serious health problems. Organic fertilizers used as a solution provide significant efficiency increase in yield and quality(Badr ve Fekry, 1998; Arisha ve ark., 2003).

Aquaponic systems are an ecological system conducive to sustainable agriculture. By reusing water in the system, natural fish waste meets the fertilizer needs of plants and water consumption is minimized. 2 Pilot akuaponic systems were operated simultaneously and in parallel with each other, including control and experimental group. During the process of our project, 3 different contents filter were prepared. Our aim is to investigate the effect of 3 filters with different contents on water quality and efficiency in the aquaponic system.

Water quality is the sum of all physical, chemical, biological and aesthetic properties that affect the beneficial use of water.(Tepe ve Boyd, 2002). It is important to identify various factors that change the quality of water in terms of aquaculture. Fish are stressed when exposed to situations other than these values. Water quality parameters followed during the project process temperature, pH, dissolved oxygen, total hardness and alkalinity, salinity, conductivity, oxidation ORP, TDS, TAN.

Akdogan (2014) reported that fish farm water increases yields in the aquaculture system. Güzel et al. (2014), in a research project on the cultivation of carp and lettuce in the aquaponic system; they stated that fish and lettuce can be grown together, water is cleaned and reuse and provides better performance according to the system. Tyson (2007) stated that the appropriate pH range is 7.5-8.0 in his study on determining the appropriate pH range in biological filtration of ammonia in aquaponic environment. Trang and Brix, (2012) examined the function of the biofilter placed in the integrated aquaponic system within the system. Lorena et al. (2008) in her study for the production of sturgeon and lettuce in an aquaponic system reported that throughout the entire study, water parameters remained within optimal limits to ensure optimal growth.

2 Methods

The trial assembly of our project was created in August 2021 in Giresun Science High School Biology laboratory and ended on January 15, 2021. Made with 3 repeaters.

Fig. 1: Pilot-1 and Pilot-2 aquaponic systems

In the aquaponic system; In the pilot-2 group designated as the experimental group, the effect of 3 biofilters on water quality parameters and efficiency was investigated in different characteristics in which wastewater from the fish tank was filtered. In our project, an aquaponic system was created for the fish tank using koi fish (Cyprinus rubrofuscus) and vegetable bed Cabbage (Brassica oleracea) plant. In the trial groups, a total of 30 pieces weighing an average of 5-6 g were placed in each fish tank (2 in total, 1 control, 1 experimental group) (Fig.2).

Fig. 2: Koi fish and Cabbage

In our project, Filled Environment, Tank System was preferred from aquaponic designs. The equipment used in this system is small and the resulting product is lower (Fig.3).

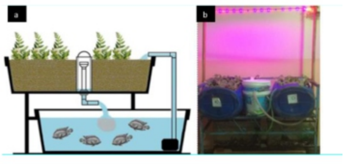


Fig. 3: Filled Media Tank System

2- 1 Fish Tanks and Vegetable Tanks

Pilot-1 control group (Fish tank and vegetable tank) akuaponic system was accepted, while pilot-2 system was determined as Experimental group (Fish tank, vegetable tank and Biofilters) (Fig. 4) (Table 1).

Table 1: Group symbols and contents

Trial Group symbols	Trial group contents
KS-1	Control Vegetable Tank
KB-1	Control Fish Tank
DB-2	Experimental Fish Tank
DS-2	Experimental Vegetable Tank
F-2	Experimental Biofilter

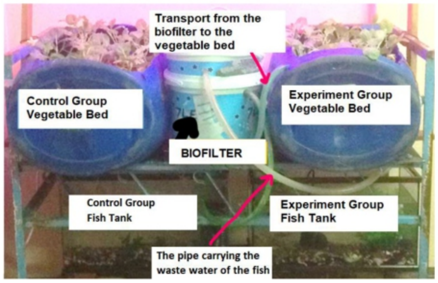


Fig. 4. Our aquaponic system

In the design of the aquaponic system, the rack system is used in the profile iron structure (Fig. 5)

Fig.5 : Metal Rack system

In our aquaponic system, vegetable bed 1 and 2 were obtained by using 50 liter volume PE canisters $(60x35x25)cm^3$ for vegetable growing environment (Fig. 6).

Fig. 6.: Vegetable Tank design

For fish tanks, 2 50x20x30 cm^3 and 30L volume aquariums were used (Fig.7).

Fig.7: Internal Filter and Fish tank

Waste water is sent to the biofilter with the aquarium internal filter motor in fish tanks (Fig. 8).

Fig.8: Hydrotone

Styrofoam was used for the placement of violas (Fig.9).

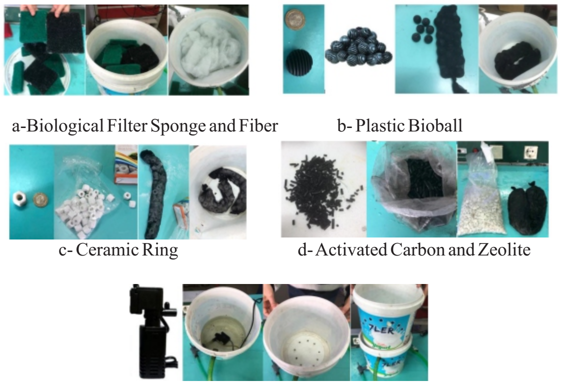
Fig.9: Styrofoam

2-2 Biofilter Design

In addition to Figure(10) and Table (2), Sponge, Fiber, Activated Carbon, internal filter motor was used when preparing biofilters.

Table 2: Types and Contents of Biofilters

Symbol	Biological External Filter
Biofilter-1	Plastic Bioball
Biofilter-2	Plastic Bioball and Zeolite
Biofilter-3	Ceramic Ring and Zeolite



a-Biological Filter Sponge and Fiber b- Plastic Bioball
c- Ceramic Ring d- Activated Carbon and Zeolite
e- internal filter and biofilters

Fig.10: External filter materials (a,b,c,d,e)

2-3 Operation of the Aquaponic System

In our project, two simultaneous and parallel pilot akuaponic systems were operated. In the Pilot-1 aquaponic system, the wastewater control group is pumped into the vegetable tank with the help of an internal filter motor from the control group fish tank. In the Pilot-2 aquaphonic system, the experimental group fish tank waste water is sent to the biofilter system designed with the help of the internal filter engine and the filtered water is transferred to the experimental group vegetable tank with the help of the biofilter motor and after being used by Cabbage, it is transmitted back to the fish tank with the pipe system and the turnover is ensured.

2-4 Oxygen Requirement

Oxygen in air motor and air stone are saturated in the fish tank and vegetable bed (Fig.11).

2-5 Light Source and Feeding of Fish

A blue strip LED was used as the light source. Daily feed was given as 3% of the weight of the fish (Fig.12).

Fig.11: Air motor and Air Stone

Fig.12: Strip Led and Fish Food

2-6 Ardunio System

With the Ardunio system, pH, temperature and water level were measured daily. If the data from the sensors is appropriate, the green LED will light up and alert if not.

2.1.2. Dissolved Oxygen, Saturation, ORP, TDS, E.C. and Salinity measurement. Orp, TDS, E.C. and Salinity were measured with The Hach brand measuring device with Dissolved Oxygen, Saturation and YSI pro1030 multiparameter device (Fig.13).

Fig.13:TU-1810 UV-VIS Spectrophotometer

2-7 TAN Analysis

TAN 1 and TAN 2 solutions were used to determine total ammonia nitrogen. 635 nm wavelength reading was made. TU-1810 UV-VIS model Spectrophotometer was used .

2- 8 Height Tracking in a Vegetable Tank

A total of 40 cabbages were grown and height measurements were made for 20 control and 20 experimental groups in vegetable tanks.

2-9 One-Way Variance Analysis (ANOVA)

It was made with ANOVA in SPSS 22 program in comparison of plant sizes.

3 Results

3-1 Temperature, Dissolved O2 and Saturation

The findings of pilot-1 and pilot-2 system are given below.

According to the results of 93 measurements, Biofilters caused an increase in Dissolved O2 and an increase in Biofilter-1 and Biofilter-2 Dissolved O2 in Fish tanks (Table 3). The water temperature was found to be between 16.18 and 16.28. It is seen that there is an inverse ratio between temperature and Dissolved O2. Saturation Pilot-2 gave the highest result of Filter-2 in both vegetable tank and fish tank. Accordingly, according to the water pollution control regulation, the quality of the water is 1st class (Fig. 14-17).

Table 3: Dissolved O2 and Saturation

Biofilter-1 Process				
Name	Akuaponic component	Temperature	ÇO	% Saturation
Pilot-1	Control Group Vegetable Tank	16,70	9,28	97,88
Pilot-1	Control Group Fish Tank	16,65	9,10	95,63
Pilot-2	Biofilter-1 Mounted Experimental Group Fish Tank	16,85	9,50	100,05
Pilot-2	Biofilter-1 Mounted Experimental Group Vegetable Bed	16,90	9,61	100,75
Biofilter-2 Process				
Name	Akuaponic component	Temperature	ÇO	% Saturation
Pilot-1	Control Group Fish Tank	15,89	10,24	103,35
Pilot-2	Biofilter-2 Mounted Experimental Group Fish Tank	15,94	10,29	104,47
Pilot-2	Biofilter-2 Mounted Experimental Group Vegetable Bed	16,08	10,37	105,39
Biofilter-3 Process				
Name	Akuaponic component	Temperature	ÇO	Saturation
Pilot-1	Control Group Vegetable Tank	16,38	10,13	101,20
Pilot-1	Control Group Fish Tank	16,35	10,10	100,75
Pilot-2	Biofilter-3 Mounted Experimental Group Fish Tank	16,28	10,10	104,10
Pilot-2	Biofilter-3 Mounted Experimental Group Vegetable Bed	16,03	10,25	104,20
Measurement of water samples from Biofilter Output				
Name	Akuaponic component	Temperature	ÇO	% Saturation
Pilot-2	Biyofilter 1	16,65	9,87	102,40
Pilot-2	Biyofilter 2	15,91	10,43	105,58
Pilot-2	Biyofilter 3	15,95	10,25	104,15

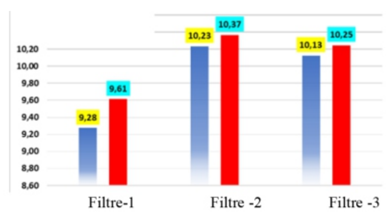


Fig. 14: A Control Group Vegetable Tank Trial Group Vegetable Tank

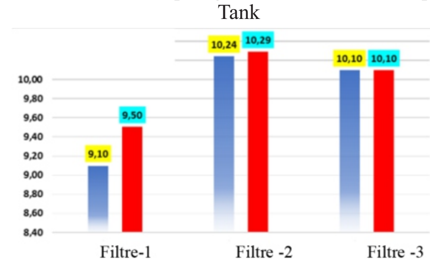


Fig. 15:B Control Group Fish Tank Trial Group Fish Tank

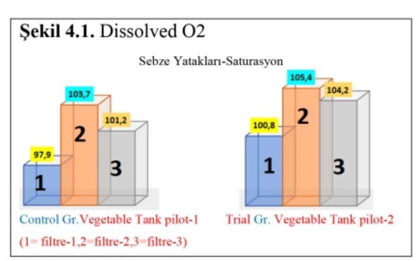


Fig. 16: Dissolved O2

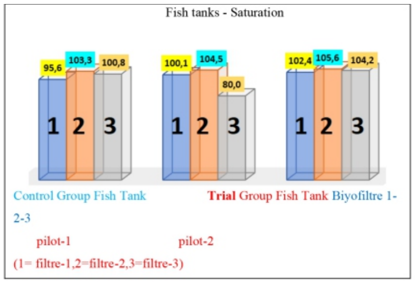


Fig. 17: Saturation

3-2 Alkalinite, Hardness and pH

Filter-3, Pilot-2 While increasing alkalinite in the vegetable tank and fish tank; Filter-2 increased hardness in the Vegetable tank and Fish tank (Table 4, Fig.18). The Alkalinity and Hardness values of the biofilter output water samples are smaller than the values of the Experimental group Vegetable tanks from which this water is poured. Filter-3 has been shown to cause the pH values of the Vegetable tank and Fish tank to decrease. During Filter-2, the pilot-2 pH value was found to average 7.84 and pilot-1 pH averaged 7.79, but during Filter-3, the pilot-2 pH value was 7.65 and pilot-1 pH averaged 7.60 (Figure 4.3). In the light of these results, it shows that the quality of the water is 1st class according to the water pollution control regulation.

Table 4: Alkalinity and Hardness

	Filter 2-Alkalinite	Filter 3-Alkalinite	Filter 2-Hardness	Filter 3-Hardness
Control Gr. Vegetable tank pilot-1	208	192	287	338
Trial Gr. vegetable tank pilot-2	208	198	309	312
control Gr. Fish tank pilot-1	207	209	294	342
Trial Group Fish Tank pilot-2	199	218	308	335
BiyoFilter pilot-2	199	177	305	302

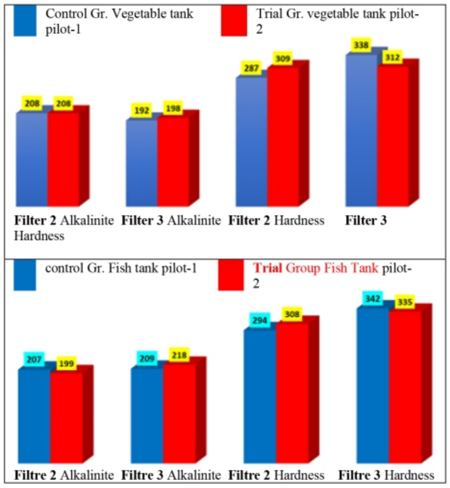


Fig. 18: Alkalinite and hardness results

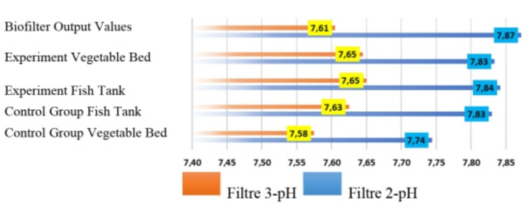


Fig. 19: pH results

3-3 TAN

Biofilter-2, control group vegetable tank TAN value was found to be 30.6% lower than Control Group Fish Tank and reduced vegetable tank TAN value. Biofilter-2 reduced the experimental group Fish Tank TAN from 0.121 mgL-1 to 0.115 mgL-1, but the Vegetable tank TAN increased to 0.153 mgL-1. In the biofilter-3 process, the Control Group Vegetable tank TAN value is 91.2% lower than the Control Group Fish Tank and the vegetable tank decreases the TAN value. Biofilter-2 Experimental group Fish Tank increased the value from 0.188 mgL-1 to 0.193 mgL-1 and the Vegetable tank reduced the TAN value by 38.03% to 0.140 mgL-1 (Table 5 and Fig. 20).

Table 5: Alkalinite and Hardness results

		TAN ORTALAMALARI	
		BİYOFİLTRE-2	BİYOFİLTRE-3
Pilot-1	Kontrol Grubu Balık Tankı	0,136	0,224
Pilot-1	Kontrol Grubu Sebze Yatağı	0,104	0,117
Pilot-2	Biyofiltre takılan Deney Grubu Balık Tankı	0,121	0,188
Pilot-2	Biyofiltre Çıkış Değerleri	0,115	0,193
Pilot-2	Biyofiltre takılan Deney Grubu Sebze Yatağı	0,153	0,140

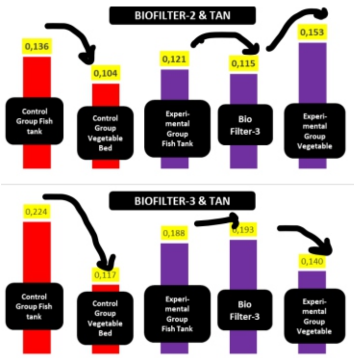


Fig. 20: Filter 2 and Filter 3

3-4 TAN result Electrical conductivity (E.C.), TDS, ORP and Salinity (Table 5).

Table 5: E.C. Results

GROUP	Filter 1	Filter 2	Filter 3
Control Group Vegetable Bed	473,0	522,6	563,0
Control Group Fish Tank	406,0	519,6	564,5
Experiment Fish Tank + Biofilter	489,3	549,0	583,5
Experiment Vegetable Bed +Biofilter	490,5	550,1	583,8
Biofilter Output Values	500,0	551,8	585,8

Table 4.6. TDS Results

GROUP	Filter 1	Filter 2	Filter 3
Control Group Vegetable Bed	365,0	407,5	449,5
Control Group Fish Tank	315,3	399,5	450,8
Experiment Fish Tank + Biofilter	377,5	422,4	463,6
Experiment Vegetable Bed +Biofilter	378,0	426,0	463,3
Biofilter Output Values	387,5	431,4	464,5

Table 4.7.ORP Results

GROUP	Filtre 1	Filter 2	Filter 3
Control Group Vegetable Bed	118,5	166,0	185,5
Control Group Fish Tank	116,0	159,1	192,3
Experiment Fish Tank + Biofilter	115,3	154,9	192,5
Experiment Vegetable Bed +Biofilter	114,5	152,6	192,8
Biofilter Output Values	117,5	149,3	188,8

Table 4.8. SAL Results

GROUP	Filtre 1	Filtre 2	Filtre 3
Control Group Vegetable Bed	0,3	0,3	0,3
Control Group Fish Tank	0,3	0,3	0,3
Experiment Fish Tank + Biofilter	0,3	0,3	0,3
Experiment Vegetable Bed +Biofilter	0,3	0,3	0,3
Biofilter Output Values	0,3	0,3	0,3

E.C., TDS, ORP values are highest in biofilter-3 and lowest result is seen in Biofilter-1. Salinity values were not changed in all ambient conditions and were 0.3. In light of these results, the quality of water according to the water pollution control regulation is 1st class (Table 5).

3-5 Cabbage Size Measurements

Control and experimental groups :There were 5 seedling losses in 7 experimental groups in the Control group of 20 cabbage seedlings preferred in the Vegetable tank. head of Project and end-of-project size measurements for each of the 28 seedlings are seen in Table (6).

Table 6: Cabbage Size Measurement results

	Control Group Vegetable Bed		Experiment Vegetable Bed	
	First measurement (cm)	Last measurement (cm)	First measurement (cm)	Last measurement (cm)
1.	13	13,5	15	24,5
2.	15	15,5	15	15,5
3.	14,5	14,5	17,5	19
4.	12	12,5	13	14
5.	17	20	13,5	14,5
6.	15	15,5	13	14
7.	16,5	18,5	17	20 1
8.	11	11	13	16
9.	16	17	12,5	16
10.	13,5	15	13	14
11.	12	14	14,5	14,5
12.	13	13	14	16
13.	14,5	16	14,5	16
14.			13,5	14
15.			14	15
Average	14,07	15,07	14,20	16,2

4 Discussions

In our project, in the Aquaponic system containing Koi fish and cabbage plant; In the pilot-2 group, the effect of 3 biofilters on water quality parameters and efficiency was investigated in different characteristics in which wastewater from the fish tank was filtered. Pilot-1 aquaponic system While the control group (fish tank and vegetable tank), Pilot-2 aquaponic system Experimental group (fish tank, vegetable tank and Biofilter) was accepted. When the temperature results were evaluated, the ideal water temperature values for Koi fish in aquaponic systems were 15-20 degrees and a total of 93 measurements were made during our project and the water temperature was determined to be between 16.18 and 16.28. Unsuitable water temperature conditions regrow the growth of fish, larvae can not get feed or feed. Dissolved oxygen is one of the important parameters for aquaponic systems. In the measurements, it was seen that ventilation was sufficient. Pilot-2 All Biofilters in vegetable tanks led to an increase in Dissolved O2 and an increase in Biofilter-1 and Biofilter-2 Dissolved O2 in Fish tanks. According to the saturation results, Pilot-2 gave the highest result of Filter-2 in both vegetable tanks and fish tanks. In the light of these results, it shows that the quality of the water is 1st class according to the water pollution control regulation.

The appropriate pH range for plants and fish in aquaponic systems is 7-8. In the Pilot-2 Aquaponic system, Filter-3 increases alkalinite, while Filter-2 increases hardness. When looking at the pH results, it is seen that Filter-3 causes the pH to decrease. During Filter-2 for Pilot-1 and Pilot-2, the pH value was 7.84 and 7.79, respectively, but Filter-3 was 7.65 and 7.60. According to the measurements made, the pH range in the system is suitable. When we look at the studies in the literature, the pH value of an aquatic environment should not endanger living life and should not exceed the limit value of 6.5-8.5 in order for this water source to be used for fish farming purposes (Kara and Potteryoglu, 2004). Passing water through activated carbon filters reduces pH and hardness. The total alkalinite desired in the aquaculture environment is between 20-300 mg/L as CaCO3. Low alkaline waters with a total alkalinite of less than 20 mg/L and high alkaline waters of more than 300 mg/L are not conductive. Alkalinite; plays a role in increasing the effect of toxic substances in terms of aquaculture (Göksu, 2003). From this point of view, alkalinite and hardness values were appropriate for fish life (Boyd, 1990). literature.

Total ammonia nitrogen (TAN) is the sum of ionized ammonium with non-ionized ammonia found in water. When tan results were evaluated, in the biofilter-2 process, on average, the Control Group reduced the value of vegetable bed TAN from 0.136 to 0.104, despite falling from 0.121 to 0.153. However, during biofilter-3, it decreased from 0.188 to 0.140. In light of these results, it shows that the nitrorification process was more successful in the Biofilter-3 (Ceramic Ring and Zeolite) process. In addition, the lack of oxygen in the Biofilter-3 process compared to Biofilter-3 indicates that dissolved oxygen is used by microorganisms in the nitrorification process. Pilot-1 The decrease of the average of the fish tank TAN by 30.5% in the Biofilter-2 process and by 91.2% in the Biofilter-3 process indicates that there is a cost-free removal by Cabbage in the aquaponic system. Pilot-2 Fish tank TAN average decreases by 33.92% in biofilter-3 process indicates a cost-free removal by Cabbage in aquaponic system.

Electrical conductivity is an important parameter in studies related to water quality. In the Pilot-1 aquaponic system, the average electrical conductivity values were 519.5 mS/cm in the Vegetable Bed and 496.7 in the fish tank. In the Pilot-2 aquaponic system, the values of Biofiltre1, Biofiltre2, Biofiltre3 were 489 mS/cm, 549 mS/cm, 584 mS/cm and 490.5 mS/cm, 550.1 mS/cm, 583.8 mS/cm, respectively, in the Fish Tank. Biofilter3 containing Ceramic Ring and Zeolite gave the best result with an average of 583.8 mS/cm. It is reported that there are no fish shelter in waters with an electrical conductivity value exceeding 1000 µS/cm at 25°C, and the conductivity of the water to be grown should be in the range of approximately 12.50-1800 µS/cm (Göksu2003).

In the pilot-1 aquaponic system, the mean TDS values were 407.3 mg/L in the Vegetable Bed and 388.5 mg/L in the fish tank. TDS values of Pilot-2 aquaponic system Biofiltre1, Biofiltre2, Biofiltre3 were 377.5 mg/L,422.4mg/L, 463.6 mg/L and 378 mg/L, 426 mg/L, 463.3 mg/L for vegetable bed, respectively for Fish Tank. Biofilter3 containing Ceramic Ring and Zeolite gave the best result with an average of 463 mS/cm. The highest results of E.C., TDS, ORP values are seen in Biofilter-3 and lowest results are in Biofilter-1Salinity values were not changed in all ambient conditions and were 0.3. It has an inverse relationship between salinity concentration of water and oxygen solubility, and as salinity increases, the amount of dissolved oxygen decreases (Tepe and Mutlu, 2004). In the light of these results, it shows that the quality of the water is 1st class according to the water pollution control regulation.

According to the results of cabbage size measurement of 28 seedlings in vegetable tanks, pilot-1 vegetable tanks (control group) averaged 14.07 cm in initial height and harvest size average was 15.07 cm; Pilot-2 Vegetable tanks (Experimental group) was found to have an average initial height of 14.2 cm and a harvest size average of 16.2 cm. In the aquaponic system where biofilter is applied, cabbage lengthening is thought to be greater, but in the absence of sufficient elongation, ambient temperature and lack of sunlight due to winter season negatively affect. As a result of the one-way variance analysis, no significant difference was found between stations statistically ($p<0.05$).

Our project tyson (2007) stated that the appropriate pH range in biological filtration of ammonia in a aquaponic environment is 7.5-8.0, Trang and Brix, (2012) examined the function of the biofilter placed in the integrated aqua aquaponic system, Lorena et al. (2008) reported that water parameters remained within optimal limits to ensure optimal growth throughout the aquaponic system study, and Graber and Junge (2009) reported that aquaculture waste it supports its work, which shows that it can be used in ebze cultivation, and the study of Güzel et al. (2014), which the aquaponic system states allows water to be cleaned and reused.

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