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Impact of Fish Stocking Density and Aeration Rate on The Performance of Mint (*Mentha Spicata L.*) and Nile Tilapia (*Oreochromis Niloticus*) in Aquaponic System

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Abstract

The main aim of this study is to determine the effect of fish stocking density and aeration rate on the performance of mint (*Mentha spicata L.*) and Nile tilapia (*Oreochromis niloticus*) in aquaponic system. To achieve that, the effects of different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) on plant growth and fish biological parameters. The results indicated that, the root and shoot length of mint plant increases with increasing fish stocking density, aeration rate and plant age. The highest values of root and shoot length (25.75 and 32.40 cm) were found at 15 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate. The highest values of fresh and dry weight of shoot (132.71 and 26.05 g $plant^{-1}$) were found at 15 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate. The total weight gain, fish growth rate, specific growth rate feed conversion ratio and feed efficiency ratio of tilapia fish decreases with increasing fish stocking density and decreasing aeration rate. The highest values of the total weight gain, fish growth rate, specific growth rate feed conversion ratio and feed efficiency ratio of tilapia fish (40.83 g, 1.36 g day^{-1}, 1.60 % day^{-1}, 1.11 g feed g^{-1} fish and 1.18 g fish g^{-1}feed) were found at 5 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate.

Keywords: Aquaponic, Aquaculture, Hydroponic, Fish, mint plant, Shoot, Root, weight gain, Specific growth rate, Fish conversion rate

Introduction

Aquaponic system is an integrated fish and plant system. The water is used to rare fish is useful for plant growth. Plants serve as biofilter which converts the harmful to harmless. Nutrients which are removed by plants improve the water quality and enhance the fish production. The amount of nitrate produced in fish culture is affected by fish density, protein content in feed and fish species **(Endut *et al.*, 2010 and Khater *et al.*, 2023)**. Aquaponics is the integration between the hydroponic cropping systems and the recirculating aquaculture systems. In this system, the dissolved nutrients in fish tank are used to supply crops with nutrients. The potential benefits of integrated production include increased revenue from the combination of fish and plant sales, minimized reliance on synthetically derived fertilizers, and both location independent and season-independent protein and vegetable production in food deserts **(Krastanova *et al.*, 2022 and Tetreault *et al.*, 2023)**.

Aquaponics has several advantages over aquaculture and hydroponics. This system reduces the need for formulated fertilizers, eliminates the possibility of agricultural run-off, and cleanses the water through biofilter treatments **(Rakocy et al., 2006)**. The nutrients released from fish excreta and microbial breakdown of organic wastes are used by plants in aquaponic systems **(Roosta and Hamidpour, 2011)**. Therefore, the aquaponic systems develop an economically advantageous symbiotic system, where aquatic species and the plant component benefit each other and the grower receives two marketable products. In contrast, the crop plant is the only marketable product in hydroponics and it is devoid of the commercial aquatic species and associated nutrient supply. Aquaponics can also be a strategy to combat water scarcity, as it has been shown to lower overall water consumption and prolong the useful life of water by reducing turnover rates and subsequently the environmental pollution, with improved economic return **(Rakocy *et al.*, 2006)**.

Since in intensive aquaculture system, ponds are heavily stocked with fish as well as with high feed supply and in these artificially fed fish ponds, many problems like organic pollution, deficiency of oxygen, increased level of free carbon dioxide and total increase in ammonia-nitrogen, nitrite-nitrogen ratio are frequently occurring. However, the problem of oxygen depletion in rearing of freshwater fish species is a major threat and main limiting factor in intensive aquaculture because it leads to hypoxia which affects fish growth, food conversion levels and feeding efficiency etc. **(Mallya, 2007)** and fish always show high feed efficiency when they are fed at required DO in water **(Boyd, 1998)**.

The productivity of water plants and the quality of water for culturing are influenced, among others, by the stocking density ratio in the culture media, in order to achieve an ideal combination for a useful biological control. The results of fish metabolism in forms of ammonium ($NH4^+$), nitrate ($NO3^-$) and phosphate can be utilized by the water plants to reduce the percentage of nitrogen in the media **(Rakocy 2007)**, as well as to increase the growth level of the water plants.

Culturing plants hydroponically is considered because of their productivity and other associated benefits **(Lennard and Ward, 2019)**. As we head towards the commercialization of aquaponics, necessary quality standards must be maintained to ensure quality fish and vegetable production. Productivity in aquaponic systems is often considered similar to that of a hydroponic unit **(Søberg, 2016)**. The amount of nutrients produced in a fish culture system is affected by several factors; the key among them is the amount of feed given to the fish according to the density of fish stocked in the system **(Ani *et al.* 2022 and Khater *et al.* 2024)**.

Selection of plants for soilless systems is critical. Mint is widely used in the aquaponics system because it can be harvested in a short time (three to four weeks in the system), and relatively has fewer problems with pests than fruity plants. It has low to medium nutritional needs and can be customized with aquaponics system **(Diver, 2006)**. Romaine lettuce is a vegetable that is favored because of its aroma and crispiness **(Zhan *et al.*, 2013)**.

Water is very important to satisfy the fish and plant requirements from oxygen and nutrients. Effective stock density and aeration rate are very important to achieve optimal growth for both fish and plants in the integrated aquaculture and hydroponics systems, therefore, the main aim of this work is to determine the effect of fish stocking density and aeration rate on the performance of mint (*Mentha spicata L.*) and Nile tilapia (*Oreochromis niloticus*) in aquaponic system.

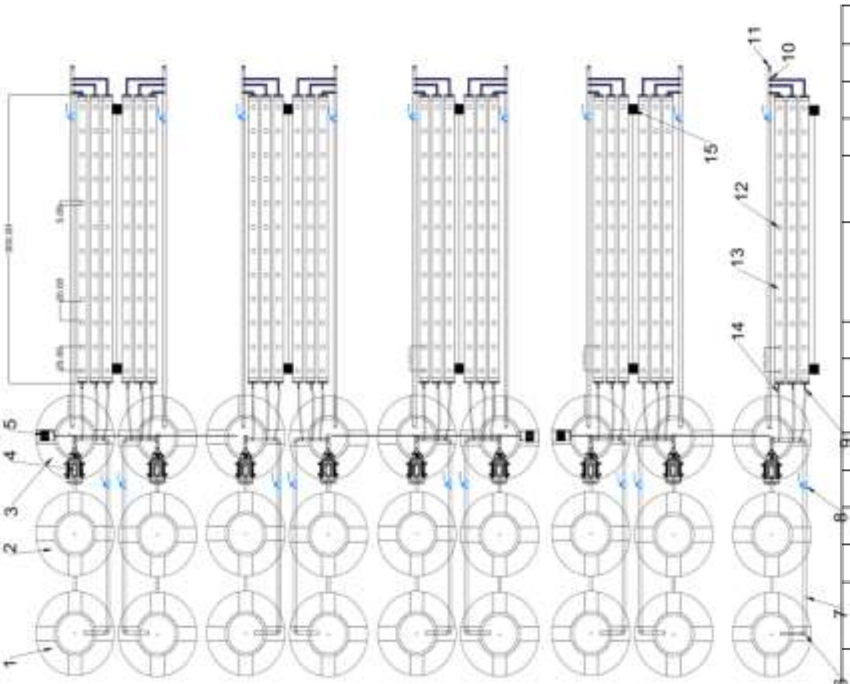
Materials and methods

The main experiment was carried out in a greenhouse at Fish Farms and Protected Houses Center, Faculty of Agriculture Moshtohor, Benha University, Egypt (latitude 30° 21` N and 31° 13` E). During the period of Sep. and Oct., 2024 season.

1. Materials

1.1. System description

The recirculating aquaponic system which consists of fiberglass fish tanks, bio-sump tank, hydroponic units, air blower, pumps, water holding tank and reservoir, pipelines made of polyvinyl chloride were installed to connect the culture tank and hydroponic trough to recirculate the water (Fig 1).



System Components

Number	Name
1	Fish tank
2	Bio tank
3	water holding and aeration tank
4	Air compressor including hose for each tank
5	Water pump 0.5HP
6	UPVC elbow
7	UPVC Pipe (32 mm)
8	Ball valve (1 inch)
9	Inlet (16 mm)
10	Outlet (16 mm)
11	End Cap (32 mm)
12	holes for plants (diameter 50 mm)
13	UPVC PIPE (110 mm)
14	P.E Pipe (16 mm)
15	A Shape Stand

Fig. 1. The experimental setup.

The system consists of nine circular fiberglass tanks for fish culture, with dimensions of each tank are 1.0 m diameter and 1.0 m height. The water volume in each tank was 0.60 m³. There are other nine circular fiberglass tanks (Bio-sump) were used in this system for solid wastes removal with dimensions of each tank are 0.75 m height and 0.70 m diameter. The water volume used in each tank was 0.25 m³. Polyethylene sheets were used as a media for solids removal and carry bacteria (Nitrosomonas and Nitrobacter) in the system to improve the water quality.

The five A shape system consists of three stands made of iron. Dimensions of each stand are 1.2 m wide and 1.7 m high. Each A shape consists six polyvinyl chloride (PVC) pipe, the dimensions of pipe are 110 mm in diameter and 2.0 m long. The slope of pipes was 2 %. Small tubes (16 mm) were used to provide tanks with solution in a closed system. Fig. (2) shows the A shape system.

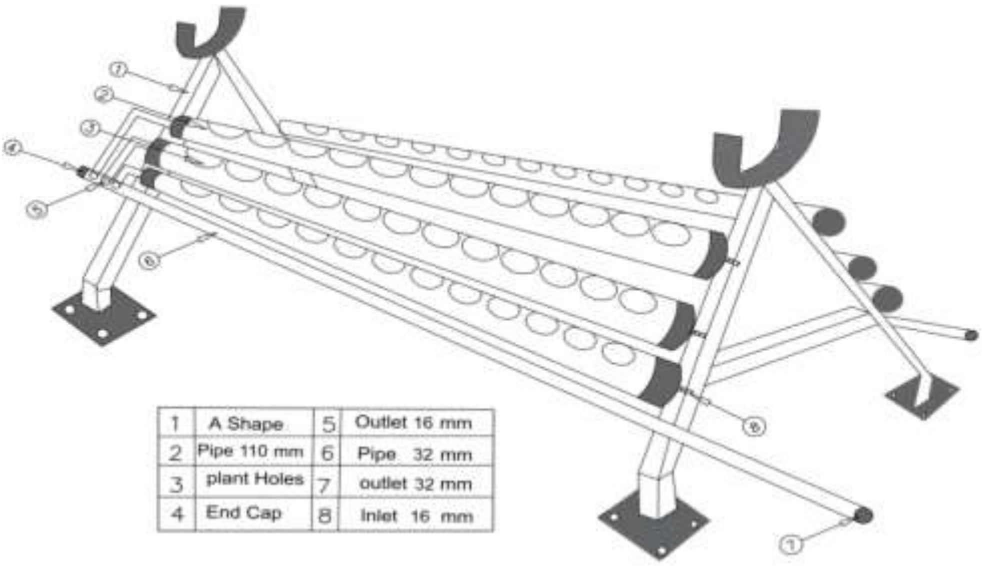


Fig. (2): A shape system.

Irrigation water and solution were supplied to plants from water tank with the proper nutrient solution by 0.5 hp pump (Model First QB60 – Flow Rate 30 L min^{-1} – Head 25 m – Power 0.5 hp, China). The air was pumped to the fish tanks and hydroponic units by using an air blower (Model C.C.P. Parma – Flow Rate 10 m^3 h^{-1} – Head 2.7 bar – Power 1.0 kW, Italy), under various pressures through air stones.

2.12. Plant and fish species

2.1.2.1. Mint plants

Mint (*Mentha spicata L.*) seedlings were gown in the plastic cups (7 cm diameter and 7 cm height) filled with peat moss. The cups were irrigated daily using water with nutrient solution. Two weeks old Mint seedlings were planted at 25.0 plant m^{-2} in the experimental tanks **(Khater and Ali, 2015)**.

2.1.2.2. Nile Tilapia fish

Tilapia nilotica fingerlings (an individual weight of 60 g), which were used in the beginning of experiment. The fish was weighed every ten days and the flow rate and aeration rate were adjusted according to the growth rate. The daily feed rates at different fish sizes were applied according to **Rakocy (1989)** as shown in table 1 and the feed pellet diameter was prepared according to **Jauncey and Ross (1982)**. Feeding was stopped during weighing process.

2.2. Methods

2.2.1. Treatments

In this study, three fish stock densities are 5, 10 and 15 kg m^{-3} and three aeration rates are 0.2, 0.3 and 0.4 g O_2 per kg fish.hr. The experimental design was a split-split plot with three replicates.

2.2.2. Measurements

2.2.2.1. Plant samples

Root length was measured every ten days. To study the behavior of root growth, their mass production and assess to which extent their roots could be grown in the growing solution. Shoot length of mint plant was measured every ten days.

The fresh and dry weight of shoot and root were measured at the end of the experiment. Dry weight the plants were measured by using oven dryer at 65 ºC until constant weight was reached.

2.2.2.2. Biological factors of fish

Fish sample were taken every ten days to determine the biological parameters which include: weight gain, fish growth rate, specific growth rate, feed conversion ratio and feed efficiency ratio using the following equations according to{ **Sveier, Raae and Lied (2000)**}:

$$WG = W_f - W_i \quad (1)$$

$$FGR = \frac{WG}{t} \quad (2)$$

$$SGR = \frac{\ln W_f - \ln W_i}{t} \times 100 \quad (3)$$

$$FCR = \frac{FI}{WG.n_t} \quad (4)$$

$$FER = \frac{WG.n_t}{FI} \quad (5)$$

Where:

WG is the mass gained, g, W_f is the mean final fish mass, g, W_i is the mean initial fish mass, g, FGR is the fish growth rate, g day^{-1}, SGR is the specific growth rate, (% or g day^{-1}), t is the time, day, FCR is the feed conversion ratio, g feed g^{-1} fish, FER is the feed Efficiency ratio, g fish g^{-1} feed, FI is the feed intake, g, n_t is the final number of fish in the tank.

Results and discussion

3.1. Plant growth parameters

3.1.1. Root length

Table (1) shows the effect of different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) on the root length of mint plants during the growth period. The results indicate that the root length of mint plant increases with increasing fish stocking density, aeration rate and plant age. It could be seen that the root length of mint plants increased from 5.37 to 22.65, 5.84 to 23.11 and 6.42 to 23.80 cm, when the mint plant age increased from 10 to 30 days, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of fish.hr^{-1}, for 5 kg m^{-3} fish stock density. For 10 kg m^{-3} fish stock density, the root length of mint plants increased from 5.88 to 23.39, 6.17 to 24.28 and 6.90 to 24.73 cm, when the mint plant age increased from 10 to 30 days, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of fish.hr^{-1}. For 15 kg m^{-3} fish stock density, the root length of mint plants increased from 6.13 to 24.01, 7.21 to 25.12 and 7.55 to 25.75 cm, when the mint plant age increased from 10 to 30 days, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of fish.hr^{-1}. It was noticed that there was not any overlapping (interference) between roots of the growing plants as a result of choosing a suitable distance (25 cm) apart between plants during different growth stages. If there is any overlapping existed it was very limited (not more than 3.0%). These results were in agreement with **Khater and Ali (2015)** found that the plant spacing for lettuce was (20-25 cm).

Table 1. The root length of mint plants grown in different fish stocking density and aeration rate.

Experimental Period, day	Fish Density, kg m^{-3}	Aeration Rate, g O_2 kg^{-1} of fish.hr^{-1}		
		0.2	0.3	0.4
		Mint Root Length, cm		
10	5	5.37	5.84	6.42
	10	5.88	6.17	6.90
	15	6.13	7.21	7.55
20	5	17.77	18.60	19.46
	10	18.33	18.98	19.93
	15	18.90	19.55	20.21
30	5	22.65	23.11	23.80
	10	23.39	24.28	24.73
	15	24.01	25.12	25.75

Regarding the fish stocking density, the results indicate that the root length increases with increasing fish stocking density. It observed that when the fish stocking density increased from 5 to 15 kg m^{-3}, the length of root increased from 5.88 to 6.96, 18.6 to 19.55 and 23.19 to 24.96 cm after 10, 20 and 30 days, respectively, from transplanting. Also, the results indicate that the mint root length increases with increasing aeration rate. It observed that when the aeration rate increased from 0.2 to 0.4 g O_2 kg^{-1} of fish.hr^{-1}, the length of root increased from 5.79 to 6.96, 18.33 to 19.87 and 23.35 to 24.76 cm after 10, 20 and 30 days, respectively, from transplanting. Generally, the growth of root system of the plant in a solution has optimum conditions depending on the amount of nutrients available to the roots its oxygen supply, the osmotic pressure of solution and its temperature. These results agreed with those obtained by **Khater *et al.* (2015), Khater (2016)** and **Saha *et al.* (2016)**.

Multiple regression analysis was carried out to obtain a relationship between the root length of mint plants as dependent variable and different both of fish stocking densities (5, 10 and 15 kg m^{-3}), different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) and experimental period (1 to 30 days) as independent variables. The best fit for this relationship is presented in the following equation:-

$$RL = -4.51 + 0.89t + 6.84AR + 0.13SD$$

$$R^2 = 0.93 \qquad (6)$$

Where:

RL is the root length of mint plant, cm
t is the mint plant age, day
AR is the aeration rate, g O_2 kg^{-1} of $fish.hr^{-1}$
SD is the fish stocking density, kg m^{-3}

3.1.2. Shoot Length

Table 2 shows the effect of different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) on the shoot length of mint plants during the growth period. The results indicate that the shoot length of mint plant increases with increasing fish stocking density, aeration rate and plant age. It could be seen that the shoot length of mint plants increased from 12.05 to 28.62, 13.01 to 29.50 and 13.76 to 30.54 cm, when the mint plant age increased from 10 to 30 days, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$, for 5 kg m^{-3} fish stock density. For 10 kg m^{-3} fish stock density, the shoot length of mint plants increased from 12.88 to 29.17, 13.73 to 30.78 and 14.52 to 31.39 cm, when the mint plant age increased from 10 to 30 days, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$. For 15 kg m^{-3} fish stock density, the shoot length of mint plants increased from 13.71 to 30.72, 14.50 to 31.26 and 15.63 to 32.40 cm, when the mint plant age increased from 10 to 30 days, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$. The growth of mint plant in a solution has optimum conditions depending on the amount of nutrients available to the plants and their balance in addition to sufficient, oxygen supply, the appropriate osmotic pressure of solution and its temperature. These results were in agreement with **(Maucieri *et al.*, 2019)**.

Table (2): The shoot length of mint plants grown in different fish stocking density and aeration rate.

Experimental Period, day	Fish Density, kg m^{-3}	Aeration Rate, g O_2 kg^{-1} of $fish.hr^{-1}$		
		0.2	0.3	0.4
		Mint Shoot Length, cm		
10	5	12.05	13.01	13.76
	10	12.88	13.73	14.52
	15	13.71	14.50	15.63
20	5	20.82	22.34	24.05
	10	22.05	24.16	25.32
	15	23.79	25.02	26.11
30	5	28.62	29.50	30.54
	10	29.17	30.78	31.39
	15	30.72	31.26	32.40

Regarding the fish stocking density, the results indicate that the shoot length increases with increasing fish stocking density. It observed that when the fish stocking density increased from 5 to 15 kg m^{-3}, the length of shoot increased from 12.94 to 14.61, 22.40 to 24.97 and 29.55 to 31.46 cm after 10, 20 and 30 days, respectively, from transplanting. Also, the results indicate that the mint shoot length increases with increasing aeration rate. It observed that when the aeration rate increased from 0.2 to 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$, the length of shoot increased from 12.88 to 14.64, 22.22 to 25.16 and 29.50 to 31.44 cm after 10, 20 and 30 days, respectively, from transplanting. These results agreed with those obtained by **Nuwansi *et al.* (2020) and Amin *et al.* (2022)**.

Multiple regression analysis was carried out to obtain a relationship between the shoot length of mint plants as dependent variable and different both of fish stocking densities (5, 10 and 15 kg m^{-3}), different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) and experimental period (1 to 30 days) as independent variables. The best fit for this relationship is presented in the following equation:-

$$SL = 0.56 + 0.84t + 11.06AR + 0.21SD$$

$$R^2 = 0.98 \qquad (7)$$

Where:

SL is the shoot length of mint plant, cm
t is the mint plant age, day
AR is the aeration rate, g O_2 kg^{-1} of $fish.hr^{-1}$
SD is the fish stocking density, kg m^{-3}

3.1.3. Fresh and dry weight of shoot

Figs. 3 and 4 show the fresh and dry weight of shoot of mint plants grown in different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the fresh and dry of shoot of mint plant increases with increasing fish stocking density and aeration rate. It could be seen that, the fresh weight of shoot increased from 121.05 to 126.36, 123.37 to 128.32 and 127.05 to 132.71 g plant^{-1}, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate. The results also indicate that, the dry weight of shoot increased from 21.13 to 22.79, 22.54 to 23.06 and 22.81 to 26.05 g plant^{-1}, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate.

The results indicate that the highest values of fresh and dry weight of shoot (132.71 and 26.05 g plant^{-1}) were found at 15 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate, while, the lowest values of fresh and dry weight of shoot (121.05 and 21.13 g plant^{-1}) were found at 5 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of fish.hr^{-1} aeration rate.

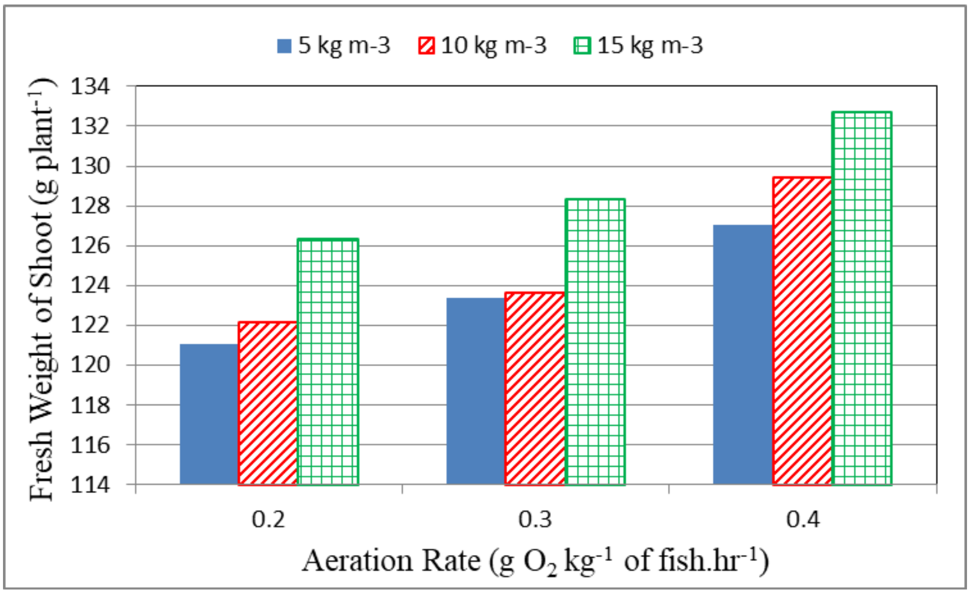


Fig. 4. Fresh weight of shoot of mint plants.

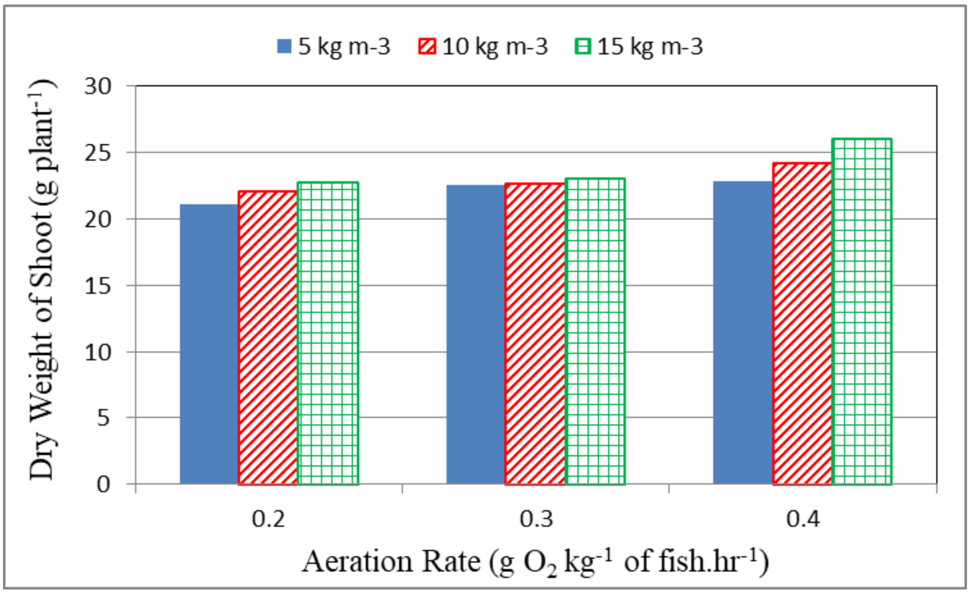


Fig. 4. Dry weight of shoot of mint plants.

3.1.4. Fresh and dry weight of root

Figs. 5 and 6 show the fresh and dry weight of root of mint plants grown in different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the fresh and dry of root of mint plant increases with increasing fish stocking density and aeration rate. It could be seen that, the fresh weight of root increased from 86.93 to 92.51, 89.94 to 95.66 and 93.73 to

97.35 g $plant^{-1}$, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate. The results also indicate that, the dry weight of root increased from 13.92 to 14.21, 14.06 to 15.02 and 14.30 to 15.92 g $plant^{-1}$, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate.

The results indicate that the highest values of fresh and dry weight of root (97.35 and 15.92 g $plant^{-1}$) were found at 15 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate, while, the lowest values of fresh and dry weight of root (86.93 and 13.92 g $plant^{-1}$) were found at 5 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate.

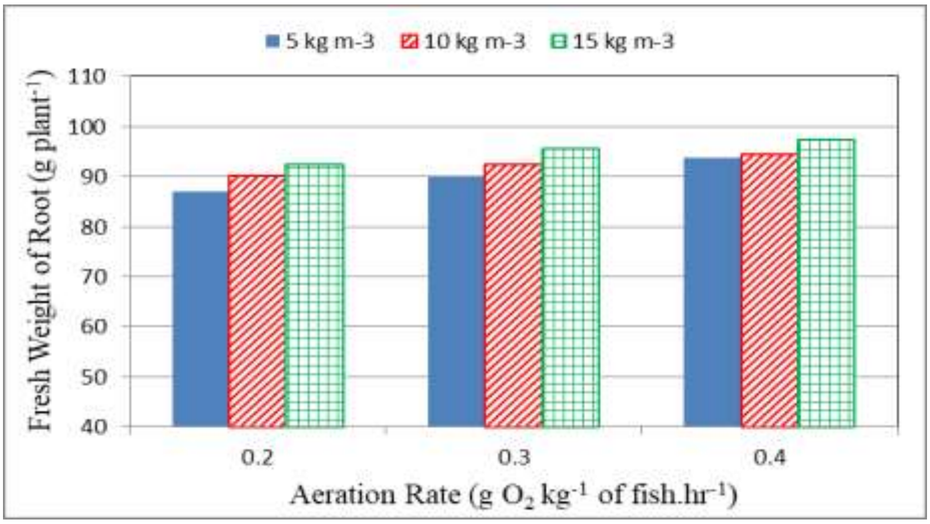


Fig. 5. Fresh weight of root of mint plants.

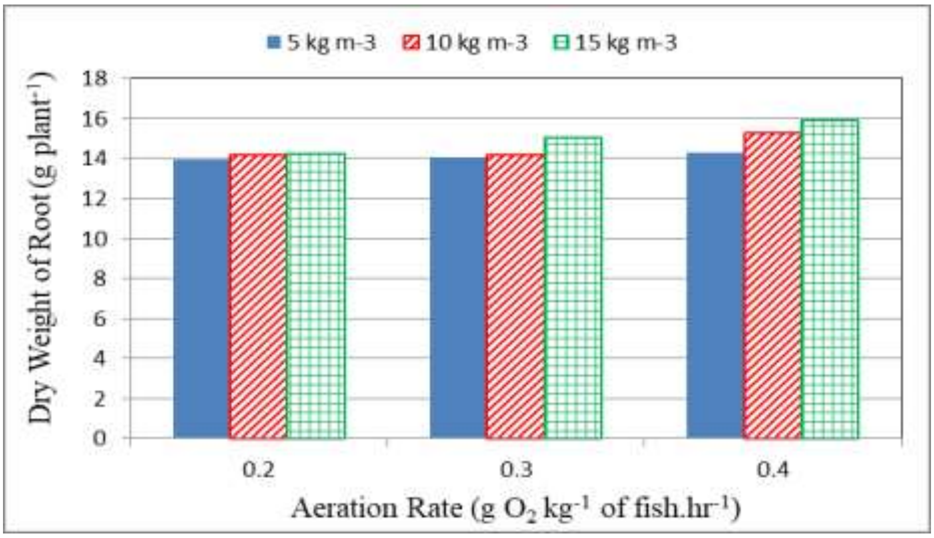


Fig. 6. Dry weight of root of mint plants.

3.2. Fish growth parameters

3.2.1. Total weight gain of tilapia fish

Fig. 7 shows the total weight gain of tilapia fish for different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the total weight gain of tilapia fish decreases with increasing fish stocking density and decreasing aeration rate. It could be seen that, the total weight gain of tilapia fish decreased from 35.22 to 29.76, 36.56 to 32.77 and 40.83 to 34.39 g, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate. These results were in agreement with **Rayhan *et al,* (2018) and Wang *et al.* (2019)**. **Pouey *et al.* (2011)** concluded that silver catfish had the highest growth rate when stocked at the lowest density.

The results indicate that the highest values of the total weight gain of tilapia fish (40.83 g) was found at 5 kg m^{-3} fish stocking density and 0.4 g O_2

kg^{-1} of $fish.hr^{-1}$ aeration rate, while, the lowest values of the total weight gain of tilapia fish (29.76 g) was found at 15 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate.

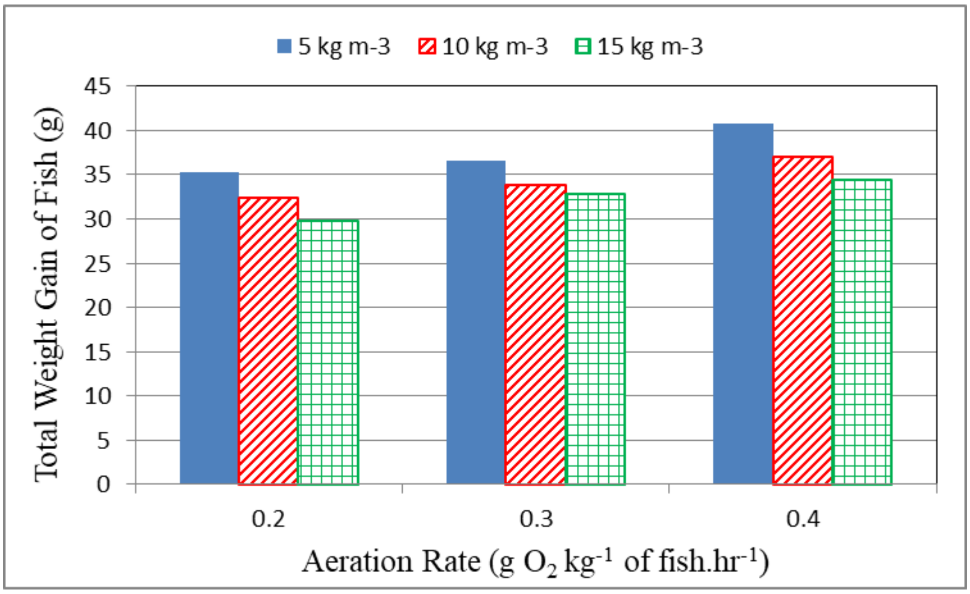


Fig. 7. Total weight gain of tilapia fish.

3.2.2. Fish growth rate

Fig. 8 shows the fish growth rate (FGR) for different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the fish growth rate (FGR) decreases with increasing fish stocking density and decreasing aeration rate. It could be seen that, the fish growth rate (FGR) decreased from 1.17 to 0.99, 1.22 to 1.09 and 1.36 to 1.15 g day^{-1}, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate. These results were in agreement with **Alzahran *et al.* (2023)**.

The results indicate that the highest values of the fish growth rate (1.36 g day^{-1}) was found at 5 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate, while, the lowest values of the fish growth rate (0.99 g day^{-1}) was found at 15 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate.

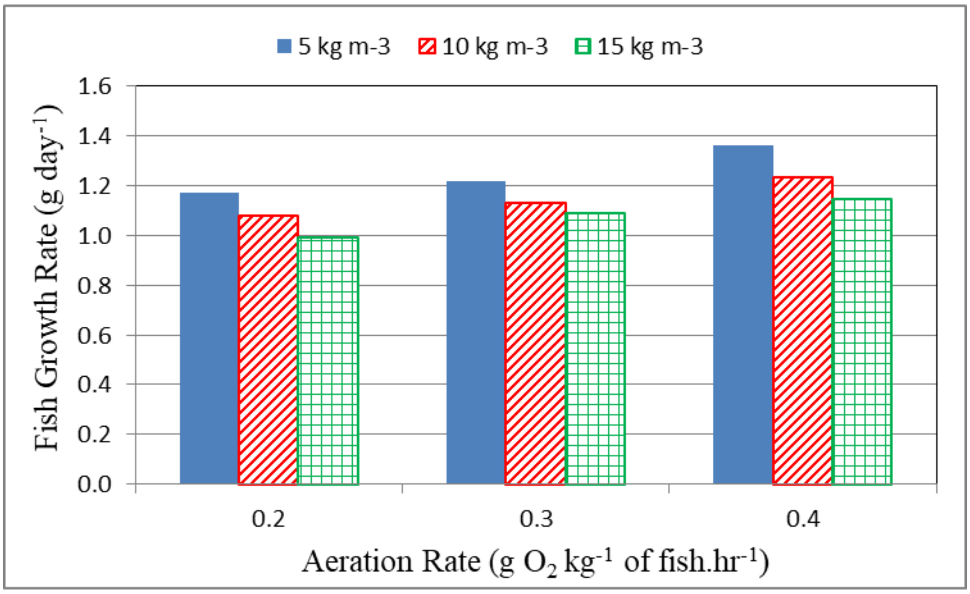


Fig. 8. Fish growth rate.

3.2.3. Specific growth rate

Fig. 9 shows the specific growth rate (SGR) for different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the specific growth rate (SGR) decreases with increasing fish stocking density and decreasing aeration rate. It could be seen that, the specific growth rate (SGR) decreased from 1.54 to 1.34, 1.59 to 1.45 and 1.73 to 1.51 % day^{-1}, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate. These results were in agreement with **Alzahran *et al.* (2023)**.

The results indicate that the highest values of the specific growth rate (1.60 % day^{-1}) was found at 5 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate, while, the lowest values of the specific growth rate (1.34 % day^{-1}) was found at 15 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate.

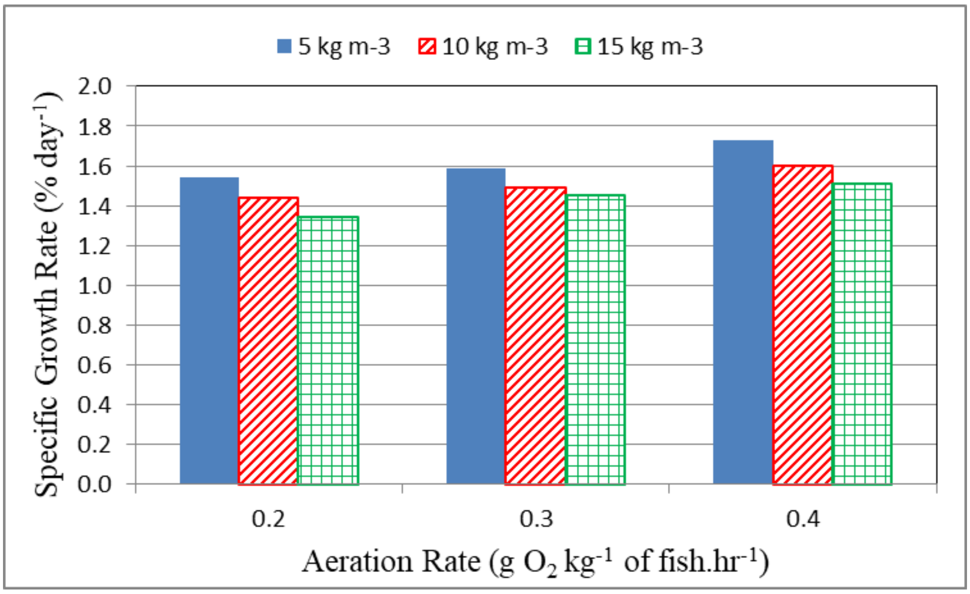


Fig. 9. Fish growth rate.

3.2.4. Feed conversion ratio

Fig. 10 shows the feed conversion ratio (FCR) for different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the feed conversion ratio (FCR) decreases with increasing fish stocking density and decreasing aeration rate. It could be seen that, the feed conversion ratio (FCR) decreased from 0.91 to 0.82, 0.93 to 0.85 and 1.11 to 0.87 g feed g^{-1} fish, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate. These results were in agreement with **Alzahran *et al.* (2023)**.

The results indicate that the highest values of the feed conversion ratio (1.11 g feed g^{-1} fish) was found at 5 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate, while, the lowest values of the feed conversion ratio (0.82 g feed g^{-1} fish) was found at 15 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of $fish.hr^{-1}$ aeration rate.

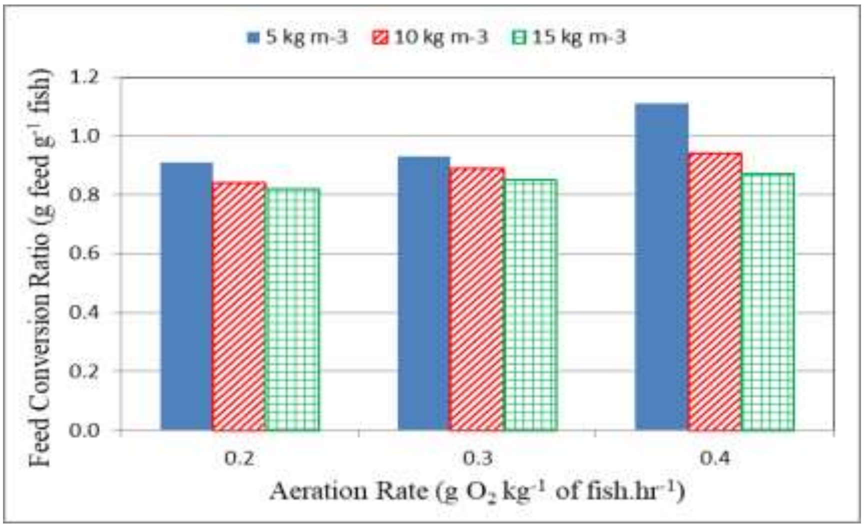


Fig. 10. Feed conversion ratio.

3.2.5. Feed efficiency ratio

Fig. 11 shows the feed efficiency ratio (FER) for different fish stocking densities (5, 10 and 15 kg m^{-3}) and different aeration rates (0.2, 0.3 and 0.4 g O_2 per kg fish.hr) at the end of growth period (30 days). The results indicate that the feed efficiency ratio (FER) increases with increasing fish stocking density and decreasing aeration rate. It could be seen that, the feed efficiency ratio (FER) increased from 1.11 to 1.18, 1.08 to 1.16 and 0.88 to 1.12 g fish g^{-1} feed, when the fish stocking density increased from 5 to 15 kg m^{-3}, respectively, at 0.2, 0.3 and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate.

The results indicate that the highest values of the feed efficiency ratio (1.18 g feed g^{-1} fish) was found at 15 kg m^{-3} fish stocking density and 0.2 g O_2 kg^{-1} of fish.hr^{-1} aeration rate, while, the lowest values of the feed efficiency ratio (0.88 g feed g^{-1} fish) was found at 5 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate.

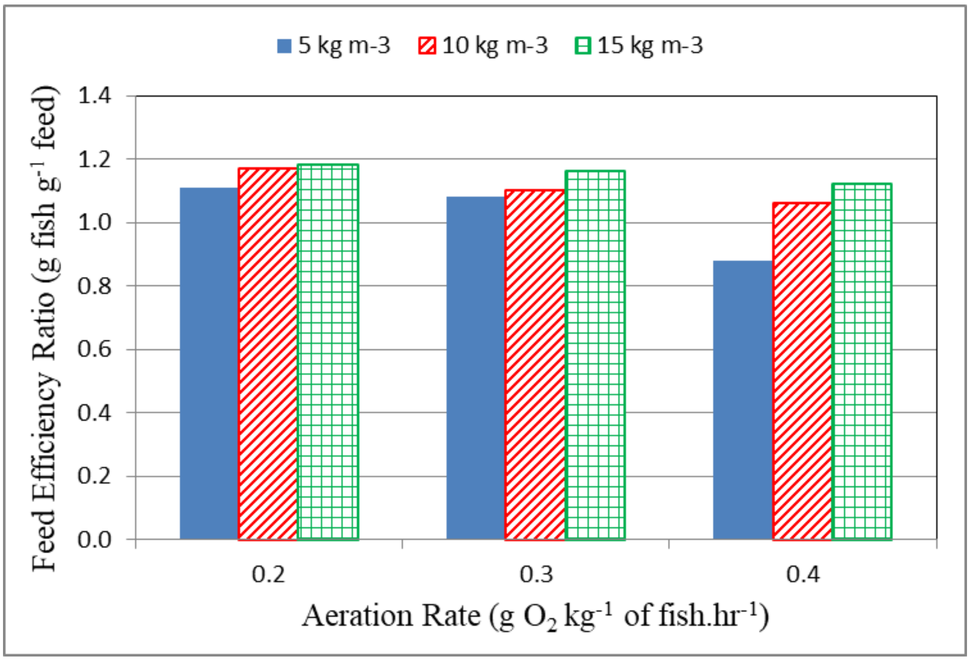


Fig. 11. Feed efficiency ratio.

Conclusions

The experiment was carried out to study is to determine the effect of fish stocking density and aeration rate on the performance of mint (*Mentha spicata L.*) and Nile tilapia (*Oreochromis niloticus*) in aquaponic system. It is concluded that, the highest values of root and shoot length (25.75 and 32.40 cm) were found at 15 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate. The highest values of fresh and dry weight of shoot (132.71 and 26.05 g $plant^{-1}$) were found at 15 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate. The total weight gain, fish growth rate, specific growth rate feed conversion ratio and feed efficiency ratio of tilapia fish decreases with increasing fish stocking density and decreasing aeration rate. The highest values of the total weight gain, fish growth rate, specific growth rate feed conversion ratio and feed efficiency ratio of tilapia fish (40.83 g, 1.36 g day^{-1}, 1.60 % day^{-1}, 1.11 g feed g^{-1} fish and 1.18 g fish g^{-1}feed) were found at 5 kg m^{-3} fish stocking density and 0.4 g O_2 kg^{-1} of fish.hr^{-1} aeration rate.

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تأثير كثافة الاسماك ومعدل التهوية على معدل اداء كلا من نبات النعناع واسماك البلطى النيلى فى نظام الزراعة المائية التكاملى

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يهدف هذا البحث إلى دراسة تأثير كلا من كثافة الاسماك ومعدل التهوية على معدل اداء كلا من نبات النعناع واسماك البلطى النيلى فى نظام الزراعة المائية التكاملى. وتم إجراء هذه التجربة فى وحدة المزرعة السكمية والبيوت المحمية – كلية الزراعة بمشتهر – جامعة بنها – محافظة القليوبية لدراسة تأثير كثافة الاسماك (5 و 10 و 15 كجم م$^{-3}$) وثلاثة معدلات تهوية (0.2 و 0.3 و0.4 جم اكسجين لكل كجم اسماك فى الساعة) على معدل نمو نبات النعناع والعوامل البيولوجية للاسماك. وكانت أهم النتائج المتحصل عليها كما يلى: زاد معدل طول المجموع الجذرى والمجموع الخضرى بزيادة الكثافة التحميلية للاسماك ومعدل التهوية، حيث كانت اعلى قيمة لطول المجموع الخضرى والمجموع الجذرى (25.75 و32.40 سم) مع 15 كجم م$^{-3}$ كثافة تحميلية للاسماك ومعدل تهوية 0.4 جم اكسجين لكل كجم اسماك فى الساعة. كانت اعلى قيمة للوزن الطازج والجاف للمجموع الخضرى لنباتات النعناع هى 132.71 و 26.05 جم لكل نبات مع 15 كجم م$^{-3}$ كثافة تحميلية للاسماك ومعدل تهوية 0.4 جم اكسجين لكل كجم اسماك فى الساعة. انخفض كلا من الوزن المكتسب ومعدل نمو الاسماك ومعدل النمو النوعى ومعدل التحويل الغذائى ومعدل الكفاءة الغذائية بزيادة الكثافة التحميلية للاسماك ومعدل التهوية. وكانت اعلى قيمة كلا من الوزن المكتسب ومعدل نمو الاسماك ومعدل النمو النوعى ومعدل التحويل الغذائى ومعدل الكفاءة الغذائية هى 40.83 جم و1.36 جم لكل يوم و1.60% % لكل يوم و1.11 جم عليقة لكل جم اسماك و 1.18 جم اسماك لكل جم عليقة) مع 5 كجم م$^{-3}$ كثافة تحميلية للاسماك ومعدل تهوية 0.4 جم اكسجين لكل كجم اسماك فى الساعة.

الكلمات المفتاحية: الزراعة المائية – الاسماك – النعناع – طول الجذر – المجموع الخضرى – المجموع الجذرى – الوزن المكتسب