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Study of the effects of different monosex Nile tilapia (*Oreochromis niloticus*) fingerlings densitieson Lettuce (*Lactuca sativa*) and water quality in a low-techrecirculation aquaponic system

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ABSTRACT

The sustainable food initiatives and awareness amongst development interest has increased rapidly the technology of aquaponics in recent years due to widespread interest in local agencies that aquaponics may allow for the production of both vegetables and fish in water-deficient or soil-deficient zones. The present study aimed to compare rearing of three different fish (*Oreochromis niloticus*) fingerlings densities on the growth of lettuce (*Lactuca sativa* var. *capitata*) and water quality in a shallow water low-tech recirculation aquaponic system. The experimental aquaria were designed in 12 longitudinal aquaria of equal volum of 105L.^{3}The treatments (Aquaponic *vs* Hydroponic) in this study were set-up for 56 days under 4treatments with three replications. T1, control (lettuce plant only using Hoagland solution), T2, T3, and T4 where stocking density of tilapia were 150(15 fish/ aquar.), 175(17 fish/ aquar.) and 200(20 fish/ aquar.) fish/m^3 with Lettuce plants, respectively. Fish was fed up to satiation twice a day with commercially available floating pellet with 30% protein level. The wastewater from the fish aquarium was irrigated to the vegetable bed by a 40 watt submersible water pump. During the experimental period different water quality parameters were monitored regularly. Growth and yield of Lettuce were measured by means of fresh weight, dry weight (g), leaf area (cm^2), and Chlorophyll (SPAD). The range of water temperature was 27 to 29^o C (av. 28 ^{o} C), dissolve oxygen 6.8 to 7.4 mg/l (av. 7.1 mg/l), pH 7.10 to 7.4(av. 7.25), total ammonia (mg/l) 0.10 to 12.0 mg/l (av. 0.11 mg/l), nitrite (mg/l) 0.003 to0.005 (av. 0.004 mg/l) and nitrate (mg/l) 140 to 180 (average 160 mg/l). At the end of the experiment, the study suggests that stocking density of 20 fish/aquarium for tilapia, i.e.200 fish/m^3 with Lettuce plants, is suitable for production of both plant and fish in a recirculating aquaponic system because of higher nutrient availability in this aquaponic trough.

Keywords: Aquaponic, Lettuce (*Lactuca sativa*), Tilapia (*O. niloticus*) density, water quality, Production

INTRODUCTION

In Egypt, fish production was modeled to reach 1.65 million tones, while the production of aquaculture will be 1.3 million tones and food fish supply will reach 2.45million tones in 2025 based on fish production data from 2013–2015 [(1)].

Aquaponic is the sustainable integrated system consists of aquaculture (fish in a recirculating system) and hydroponics (plants without soil) [2, 3]. In aquaponics, wastewater fish tank is used to fertilize hydroponics production beds beside plant roots and associated rhizosphere bacteria clean up the water from nutrients, especially ammonia as a toxic element to fish [4 - 6]. Aquaponics is an eco-friendly and natural food cultivating method that allows the most noteworthy advances of aquaculture and hydroponics through recirculation of water without the necessity to discard any water [7].

Many studies have turned aquaponics into a practical model of sustainable food production by improving the water quality of aquaculture effluent and maximizing the usage of the fish farming resources for vegetable, fruit, or herb production [8-9]. The integration between fish and plants represent a good system for the recycling of essential elements in the environment [10].

Since aquaponic systems are designed as enclosed recirculating systems, their agricultural waste and environmental footprints decrease, compared to conventional agriculture practices. Furthermore, utilization of plants as a secondary crop reduces the pollution load through nutrient uptake and assimilation [11]. Nitrate accumulation has been shown to be reduced by 97% within aquaponic systems compared to regular recirculating aquaculture systems [12]. Since water within systems is recirculated, the quantity of water needed to run the system is minute compared to most fish and crop production systems. On average, 98% of the water in aquaponic systems is recycled for the duration of operation[4]. Hydroponicsis simple and rapidly developing technique of growing plants in enriched nutrient solutions, instead of soil[13-14]. Hydroponics is the practice to grow plants in a controlled environment (*i.e.*, temperature, humidity, light intensity) to meet the needs of crops under greenhouses or indoor farming conditions[15-16]. Hydroponics is classified into water (hydroponics) and substrate cultures (soilless culture; e.g., gravel and sand cultures) while the latter culture includes both organic and inertsubstrates to provide mechanical support and an chorplant roots[17]. The developed hydroponics systems are competitive in cost-benefit with the production systems of open field agriculture[18].

Craver *et al.* [19] stated that hydroponics is contributed to enhancing agriculture productivity by avoiding the environmental limitations at a large-scale over the world. In the same manner, ecological factors like temperature, humidity, and light intensity can be maintained or manipulated in a hydroponics system to avoid the decrease in the yield of plants due to unsuitable environmental conditions [20,21]. Hydroponics allows the control of air, and temperature, light, water, plant available nutrients besides it protects the growing plants against the changes of climatic conditions [13].

There are wide arrays of plants and aquatic species that can be grown together within an aquaponic system. Some popular fish species include Nile tilapia (*Oreochromis niloticus*), channel catfish *(Ictalurus punctatus)*, rainbow trout *(Oncorhynchus mykiss)*, and various carp species *(Cyprinus* sp.*)*. Some popular plants grown in an aquaponic system are various lettuce (*Lactuca* spp.), tomato (*Solanum* spp.), and herb species including sweet basil (*Ocimum basilicum*)[22].

Tilapia fish are favorable for their rapid growth, beneficial of a wide variety of natural and artificial foods, tolerance for a wide range of environmental conditions, resistance for diseases and stresses, and proliferation in capture [(23)]. Also, the Nile tilapia *Oreochromis niloticus* is an important species for freshwater aquaculture, and the improving of its culture and diseases resistance is a major challenge facing fish culturists[(24)]. *Lactuca sativa* L. is one of the most important leafy vegetable crops globally in terms of production [(25)].

The present research aims to investigate the effect of rearing different *Oreochromis niloticus* fingerlings densities on the growth of lettuce (*Lactuca sativa* var. *capitata*) and water quality in a shallow water low-tech recirculation aquaponic system.

MATERIALS AND METHODS

Study Area:

The experiment was conducted in aquaponic system in a greenhouse at Animal production department farm, Faculty of Agriculture, AL- Azhar University, Cairo, Egypt.

Layout of the experiment:

This investigation (Aquaponic *vs* Hydroponic) in this study was designed according to a randomized complete block design (RCBD)for four treatments with three replicates as follow:

Treatment 1: lettuce plant only (using Hoagland solution).
Treatment 2, fish culture with density 150 fish/m^3 and Lettuce plants.
Treatment 3, fish culture with density 175 fish/m^3 and Lettuce plants.
Treatment 4, fish culture with density 200 fish/m^3 and Lettuce plants.

The period of experiment:

The trial lasted for 56 days started at the 18th of January 2018 and harvested at 14th March 2018.

Description of the experiment:

The experimental aquaria were designed in 21 longitudinal aquarium of equal volum of one 105 $L.^3$ each. Each aquarium was longitudinal in shape (70 length x 30 width and 50 cm height) and has volum of water 100 L^3.

The nutrient film technique (NFT) is a hydroponic method using horizontal pipes each one with a shallow stream of nutrient-rich aquaponic water flowing through it. Plants are placed within holes in the top of the pipes to use this thin film of nutrient-rich water.

The type of pipes used within experiment was PVC which colour white duo to reflects the sun's rays, thereby keeping the inside of the pipes cool. The diameter of pipes was about 4 inch (4″),4m length and the holes drilled into the hydroponic pipe was 8 cm in diameter and 22 cm between the centre of each plant hole to allow adequate plant space.

Components of Aquaponic System

The aquaponic system consisted of the following components:

1. longitudinal aquarium tank (105 $L.^3$) for rearing tilapia.
2. Pipes hydroponics system.
3. Mechanical and Biological filter of each aquarium.
4. Aeration system for the fish tank and hydroponics pipes.
5. The aquarium pump for water recirculation in the designed aquaponics system.
6. The oxygen pump.
7. LED Lighting System (working for 3 hours per day every night).

Water Management of the experimental aquarium:

Each aquarium has water of about 100 $L.^3$and stocked by mono-sex Nile tilapia fingerlings. During the experimental period; water in treatment (T1) was replaced with new water at a rate 25% of the water column daily, while water in treatments (T2, T3 and T4) was was only compensate for consumption using plants.

Experimental fish:

Mono sex of fingerlings Nile tilapia (*Oreochromis niloticus*) were obtained from Egyptian aquaculture center for training and applied research in Hamoul city, Kafr El-Sheikh governorate, Egypt in January 2018. Fish were adapted to the experimental system condition for 7 days before starting the experiment. Fingerlings were stocked at an average initial total body weight of 32.20 g./fish and an average initial total body length of 12.10 cm/fish for all treatments. Fish were taken weekly and weighed to readjusting feeding rate according the new weights, then fish were returned back to the corresponding aquarium after recording the body weight and body length.

Stocking rate: During the experimental period; aquaria of treatments 2, 3 and 4 were stocked with 15, 17 and 20 , respectively of mono sex Nile tilapia (*O. niloticus*) fingerlings.

Experimental lettuce:

Lettuce (*Lactuca sativa*) was obtained from Bakker Brothers company.The number of seedling of each trait was 14 plants with three replicats.

Experimental diet and Feeding rate:

Fish were fed during the whole experimental period (56 days) on a commercial fish diet purchased from the Koudijs and Kapo feed Company located in 4th Indust. Zone,Block 37, land nr's.11to14, Borg EL Arab, Alexandria, Egypt. The experimental diet was in the form of pelleted floating diets with a diameter 3mm. The experimental diets containing 30.63% crude protein and 4250 Kcal/kg gross energy (Table 1).The ingredients of the experimental diet were corn, soybean meal 48%, wheat bran, fish meal, fish oil, soy oil, Di-calcium phosphate, salt, premix, minerals and vitamins mixtures, Di- methionin, Llysine, HCL,Choline chloride 60%.

Fish in all treatments were fed on the commercial diet six days per week at feeding rate of 3% of the fish biomass. Feeding for fish was three times daily at 9.00 am,12.00 am and 3.00 pm during the whole experimental period.

Table (1): Proximate chemical analysis (%) of the experimental diet used in the present experiment.

Parameter	% of dry weight
Moisture	9.46
Dry matter	90.54
Crude protein	30.63
Ether extract	2.99
Ash	8.24
Crude fiber	3.61
*Nitrogen free extract	54.53
** Gross energy(Kcal/kg)	4250.97

*Nitrogen Free Extract calculated as: 100-% (Protein + Lipid + Ash + Crude fiber).
**GE (gross energy) calculated using the values 5.64, 9.44 and 4.11 Kcal GE/g DM of protein, fat and carbohydrate respectively [26].

Water quality measurements:

During the experimental period; no water was exchanged except adding losing water caused by transpiration and evaporation in treatments (T2, T3 and T4). Water samples were taken twice each week during the experimental period from 9.00 to 9.30 am.

The samples were collected at 25 cm of water coloumn surface at each tank. The samples were analyzed within one hours after collection. Some parameters such as (dissolved oxygen, pH, water temperature and salinity) were measured daily. Five milliters of chloroform were added to each bottle sample as a conserving for laboratory analysis (Ammonia, Nitrite and Nitrate).

Field analysis

Dissolved oxygen (DO mg/L), PH values and Water temperature (°C) were measured in *situ* (between 9.00 to 9.30am) daily using the Orion Portable pH Meter (Thermo Scientific Orion 5-Star Plus, Thermo Fisher Scientific Inc., Beverly, MA, USA) [27].

Salinity was measured daily by using Milwaukee Salinity Refract meter Model (MR32ATC - Brix Refractometer) range from (0-32 Brix) [28].

Ammonia (NH3-N)

Ammonia was measured by using Ammonia (Low Range) Martini Instruments (Mi 407) range from (0.00 – 3.00 mg/l)[29].

Laboratory analysis

A sample of water (1litre) from each aquarium was taken (at 9.00 to 10.00 am) weekly and transferred to Central laboratory, Desert Research Center.

Nitrite (NO2 -N mg/L)

Nitrite was measured by (nitricol) model LP-55 code 3274 Lamotte company range from 0.2 - 0.8 ppm.

Nitrate (NO3-N mg/L)

Nitrate-nitrogen was measured by using phenoldisulphonic acid method, using spectrophotometer (Model Milton Roy 21D), at a wavelength of 410 nm according to [(30)].

Biological evaluation of fish growth performance:

Fish from each aquarium were measured separately for weight and length weekly during the experimental period. Growth performance parameters and feed utilization for each treatment at the end of the culture period were calculated as described by Sveier ***et al.***[(31)].

Measurements of Plant growth:

Characteristics of plant growth were measured as follow:

1) Fresh weight per plant was taken in (g/plant) after harvest by using a digital balance.

2) Dry weight per plant [the samples dried in oven at 70 ^{o}C for 48 hours and weighed by sensitive balance (g/plant)].

3) Leaf area (cm^2) was measured using the fresh weight method [(32)]. The sixth leaf was chosen as constant leaf. Five leaves were taken from each treatment and weighed in addition to 5disks from the previous leaves were taken and also weighed. The leaf area was calculated according to the following formula:

Leaf area (cm^2) = (Fresh weight of leaves/ Fresh weight of disks) × Area of the disk

4) Amount of chlorophyll (SPAD units) was measured using chlorophyll Meter SPAD-502 [(33)].

5) Determination of nitrogen, phosphorus and potassium:

N was estimated using the Kjeldahl method [(34)].

P and K contents (g/kg) were determined according to Cottenie *et al.* [(35)]. A spectrophotometer at a 430 nm wavelength was used to estimate P content; while K was estimated using a flame photometer.

Economic analysis:

It wasconducted to determine economic returns. The analysis was based on market prices in Egypt for harvested fishes and all other items, which were expressed in (LE) as was in season (2018). The following equation was used according to Asaduzzaman *et al.* [(36)].

R= I- (FC+ VC+ Ii) Where,

R= net return,

I= income from mono sex tilapia sale.

FC=fixed common costs.

VC= variable costs.

Ii=interest on inputs.

Statistical analysis:

Data were statistically analyzed using one way analysis variance (ANOVA)[(37)] to determine the signification of treatments. The comparison between means of all tested traits was carried out using Duncan's multiple range test. The statestical model was:

$$Y_{ij} = \mu + T_i + R_j + e_{ij}$$

Where :

Y_{ij} = the observation of the parameter measured.

μ = is the overall mean.

T_i = is the effect of treatment(source of nutrition solution).

R_j = is the effect of replicates.

e_{ij} = is the experimental error.

Data are presented as mean ± standard error (SE). The significant level for the differences between groups was calculated at $P < 0.05$.

RESULTS AND DISCUSSION

Water quality:

Results of water quality parameters during the experimental period as average values of the weekly samples are summarized in Table (2).The average values of dissolved oxygen ranged between 6.8 and 7.4 mg/l. Kamal[38] reported that 6.6-6.8 mg DO/l is suitable for growth of Nile tilapia (*O. niloticus*). In the present study, the average values of pH ranged between 7.1 and 7.4 in all treatments. Boyed[39] reported that water with a pH range 6.5-9 at dawn is the most suitable for fish production. Rakocy[40] considered these values high for a hydroponics system, but in an aquaponic system pH ranged must be maintained above 7.0 to promote nitrification. Water temperature ranged from 27 to 29°C during the experiment period. In this respect, Gui *et al.* [41] found that the average temperature of 28 °C was optimal for growth of Nile tilapia.

Table (2):Average values of water quality parameters during the experimental period.

Parameter	Aquaponics	
	Rang	Average
Water temperature (°C)	27-29	28
Dissolved oxygen (mg/l)	6.8-7.4	7.1
PH value degrees	7.10-7.4	7.25
Ammonia (NH3 mg/l)	0.10-12	0.11
Nitrite (mg/l)	0.003-0.005	0.004
Nitrate (mg/l)	0.140-0.180	0.160

Aquaponics =Fish culture + lettuce.

In the present study values of ammonia (NH_3), nitrite (NO_2-N) and nitrate (NO_3-N) ranged between 0.10-0.12 mg/l, 0.003-0.005 mg/l and 0.140-0.180 mg/l, respectively during the experimental period. These results were in accordance with the findings of Rocha *et al.* [42] Also, Selek *et al.*[43] found that the values of ammonia (NH_3), nitrite (NO_2-N) and nitrate (NO_3-N) ranged between 0.04-0.08 mg/l,0.05-0.021 mg/l and 0.11-0.106 mg/l, respectively.

Lettuce production:

Data presented in Table (3) showed that there were no significant differences between treatments in Phosphor, Potassium and Magnesium percentage for treatments (T2, T3 and T4) with the control (T1). On the other hand, there were significant differences between treatments and control in fresh weight, dry weight, leaf area, Nitrogen, Calcium percentage, chlorophyll and circumference. The range of average values of fresh weight, dry weight, leaf area, Nitrogen, Calcium, chlorophyll and circumference were 497.93-526.63 g, 14.98-15.98g, 345.31-364.56 cm^2, 4.24-4.28%, 1.603-1.616%, 18.46-18.80% and 54.20-56.53 cm for treatments T2, T3 and T4 respectively. While their respective average in control (T1) were 513.7g, 15.09g, 355.16cm^2, 4.22%, 1.603%, 18.56 and 55.36 cm^2. It was obvious that their average values at T4 were the highest, while their lowest average values were at T2.These results were in agreement with Sami[(44)] who studied the effluent water characterization of intensive tilapia culture units and its application in an integrated lettuce aquaponics production facility. He found that the range of fresh weight was 155.87-160.23 gm, dry weight 9.43-9.53gm, Nitrogen 4.09-4.21%, phosphor 0.62-0.66%, potassium 6.02-6.12%, Calcium 1.79-1.845%, Magnesium 0.61-0.67% and chlorophyll 30.95-31.21(SPAD). Also, these results were in accordance with that of El-Helaly[(45)].

Table (3):The effect of aquaponics treatments on fresh weight, dry weight, leaf area, nitrogen, phosphorus, potassium, calcium, Magnesium, Chlorophyll (SPAD) and Circumference of lettuce.

Item	Hydroponics	Aquaponics		
	T1	T2	T3	T4
Fresh weight (FW) (gm)	513.70 ± 0.43^c	497.93 ± 0.43^d	522.40 ± 0.43^b	526.63 ± 0.43^a
Dry weight (DW) (gm)	15.9 ± 0.01^c	14.986 ± 0.01^d	15.936 ± 0.01^b	15.980 ± 0.01^a
Leaf area(cm^2)	355.1 ± 0.42^c	345.31 ± 0.42^d	362.18 ± 0.42^b	364.56 ± 0.42^a
Nitrogen (N)	4.22 ± 0.01^b	4.240 ± 0.01^b	4.276 ± 0.01^a	4.286 ± 0.01^a
Phosphor (P)	0.546 ± 0.01^a	0.536 ± 0.01^a	0.560 ± 0.01^a	0.560 ± 0.01^a
Potassium (K)	4.83 ± 0.02^a	4.74 ± 0.02^b	4.75 ± 0.02^b	4.77 ± 0.02^b
Calcium (Ca)	1.603 ± 0.03^b	1.603 ± 0.03^b	1.603 ± 0.03^b	1.616 ± 0.03^a
Magnesium (Mg)	0.606 ± 0.03^a	0.603 ± 0.03^a	0.606 ± 0.03^a	0.613 ± 0.03^a
Chlorophyll (SPAD)	18.56 ± 0.06^b	18.46 ± 0.06^b	18.50 ± 0.06^b	18.80 ± 0.06^a
Circumference (cm^2)	55.36 ± 0.06^b	54.20 ± 0.06^c	56.40 ± 0.06^a	56.53 ± 0.06^a

Hydroponics, Aquaponics =Fish culture + lettuce.
a, b, c, d: means with different superscript in the same row are significantly different ($P \leq 0.05$).

Anne [46] studied the comparison between three different fish (*Oreochromis niloticus*) densities and study the effects on the growth of lettuce (*Lactuca sativa* var. capitata). The results showed that the lowest density (3.5 kg/1,000L) produced significantly smaller lettuces and with nitrogen deficiency symptoms. The middle (6.5 kg/1,000L) and highest density (13 kg/1,000L) formed bigger lettuces, with no significant differences between their weight. Nevertheless, considering the pH unstableness of the highest density and fish death due to competition, it was concluded that the fish density that best met the biological requirements of the system was 6.5 kg/1,000L.

Economic analysis:

Results in Table (4) showed that the total variable costs for T1, T2, T3 and T4 were 280, 435, 460.5 and 486.5 LE/m^3, respectively. The differences in the total variable costs were due to differences in feed costs and production costs. The total fixed costs were almost the same for all treatments; however the total variable and fixed costs had differences among treatments due to the differences in variable costs. As indicated in Table (4) the net returns recorded byT1, T2, T3 and T4 were 95, 168.4, 171.1 and 191.2 LE/m^3, respectively. However, the net returns as percent of the smallest one (T1-100) were 177.26, 180.11 and 201.26 for T2, T3and T4, respectively.

Table (4): Effect of the experimental factors on economic efficiency (LE/m^3).

Item	Hydroponics	Aquaponics		
	T1	T2	T3	T4
First – Costs				
A-Variable costs (LE/m3)				
1-Fish production				
a- Nile tilapia fingerlings	-	45	52.50	60
b- Artificial diet	-	110	128	146.50
2-Lettuce production				
a- Lettuce seed	30	30	30	30
b- Material (pipe, cup and Hogland)	250	250	250	250
Total variable costs (LE/m3)	280	435	460.50	486.50
B-Fixed costs (LE/m3)				
1- Operating costs	15	15	15	15
2- Material & Depreciation	10	10	10	10
Total Fixed costs (LE/m3)	25	25	25	25
Total variable and Fixed costs	305	460	485.50	511.50
% of smallest value	100%	150.82%	159.18%	167.70%
Second- Returns				
Returns from *O.niloticus*	-	228.40	256.60	302.70
Returns from Lettuce yield	400	400	400	400
Total Returns (LE/m3)	400	628.40	656.60	702.70
Net Returns (LE/m3)	95	168.40	171.10	191.20
% of smallest value of net Returns	100%	177.26%	180.11%	201.26%

CONCLUSION

Based on results obtained in this study and on the economical evaluation, it could be concluded that stocking density of 20 fish/aquarium for tilapia, i.e. 200 fish/m^3 with Lettuce plants is suitable for production of both plant and fish in a recirculating aquaponic system because of higher nutrient availability in these aquaponic trough and suitable water quality parameters for growth of lettuce and tilapia fish.

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REFERENCES

1. FAO (2018). The State of World Fisheries and Aquaculture 2018- Meeting the sustainable development goals. Rome. Licences: CC BY-NC-SA 3.0 IGO.
2. Rakocy, J. E. (2012). Aquaponics-integrating fish and plant culture. Aquaculture Production Systems, 1, 343–386.
3. Knaus, U. and Palm, H.W. (2017). Effects of fish biology on ebb and flow aquaponical cultured herbs in northern Germany (Mecklenburg Western Pomerania). Aquaculture, 466: 51-63.
4. Al-Hafedh, Y.S.; Alam, A. and Beltagi, M.S. (2008). Food production and water conservation in a recirculating aquaponic system in Saudi Arabia at different ratios of fish feed to plants. J. World Aquacult. Soc., 39(4): 510-520.
5. Graber, A. and Junge, R. (2009). Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. Desalination, 246(1–3): 147–156.
6. Bernstein, S. (2011). Aquaponic gardening: a step-by-step guide to raising vegetables and fish together. New Society Publishers.
7. Bailey, D.S. and Ferrarezi, R.S. (2017). Valuation of vegetable crops produced in the UVI Commercial Aquaponic System. Aquaculture Reports, 7: 77–82.
8. Bala, B. and Satter, M. (1989). System dynamics simulation and optimization of aquacultural systems. Aquacultural Engineering, 8(6): 381–391.
9. Rakocy, J.E.; Masser. M.P. and Losordo. T.M. (2006). Recirculating aquaculture tank production systems: Aquaponics- integrating fish and plant culture. Southern Regional Aquaculture Center; SRAC Publication No. 454.
10. Okimoto, D.K. (2004). Aquaponics export conducts workshops in American Samoa.
11. Timmons, M.B. and Ebeling, J.M. (2007). Recirculating Aquaculture. 2nd ed. Northeastern Regional Aquaculture Center. Ithaca, NY: Cayuga Aqua Ventures.
12. Lennard, W.A. (2006). Aquaponic integration of murray cod (*Maccullochella peelii peelii*) aquaculture and lettuce (*Lactuca sativa*) hydroponics. PhD., RMIT University, Victoria, Australia.
13. Jones, J.B.Jr. (2016). Hydroponics: a practical guide for the soilless grower. CRC press.
14. Resh, H.M. (2016). Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower. CRC Press.
15. Resh, H.M. (1989). Hydroponic food production: a definitive guidebook of soilless food growing methods (No. 04; SB126. 5, R4 1989).
16. Takeda, F. (1997). Strawberry production in soilless culture systems. In International Symposium on Growing Media and Hydroponics 481(289-296).

17. Douglas, J.S. (1985). Advanced guide to hydroponics. Pelham Books, London.
18. Jensen, M.H. (1989). Hydroponic culture for the tropics: opportunities and alternatives. Proc. 10th Annual conference on Hydroponics. Hydroponic Society of America.
19. Craver, J.K. and Williams, K.A. (2014). Hort Technology, 24(5): 610–617.
20. Smeets, K.; Ruytinx, J.; Van, B.F.; Semane, B.; Lin, D.; Vangronsveld, J. and Cuypers, A. (2008). Plant Physiology and Biochemistry, 46(2): 212–218.
21. Ruiz, M. and Taleisnik, E. (2013). Crop and Pasture Science, 64(6): 631–639.
22. Dunwoody, R.K. (2013). Aquaponics and hydroponics: the effects of nutrient source and hydroponic subsystem design on sweet basil production. MSc. Thesis, Fac. Agric., University of Central Missouri.
23. El-Sayed, A.F.M. and Teshima, S.I. (1991). Tilapia nutrition in aquaculture. Reviews in Aquatic Sciences, 5:247-265.
24. FAO, Food and Agriculture Organization of the United Nation (1997). Aquaculture production statistics 1986-1995. FAO, Fish. Circ. 815 Rev. 9. Rome, Italy.179 pp.
25. Rubatzky, V.E and Yamaguchi, M. (2012). World vegetables: principles, production, and nutritive values. Springer Science & Business Media.
26. NRC (2011). Nutrition requirement of fish, Committee on Animal Nutrition, Board on Agriculture. National Academy Press, Washington, DC, 114 pp.
27. China State EPA. (2002). Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB 18918-2002, ICS13.060.30 Z60).
28. Tigchelaar, E.C. (1986). Tomato breeding. In: Basset M.J. (ed.) Breeding Vegetables crops. Westport, USA, AVI Publishing Co., Inc., 135–170.
29. Thompson, J.F. and Morrison, G.R. (1951). Determination of organic nitrogen: Control of variables in the use of Nessler‘s reagent, ’Analytical Chemistry, 23(8):1153-1157.
30. APHA, (1998). Standard methods for the examination of water and wastewater. Prepared and published jointly by American Public Health Association, American Water Works Association, and Water Pollution Control Federation., Washington, DC.
31. Sveier, H.; Raae, A.J. and Lied, E. (2000). Growth and protein turnover in Atlantic salmon (*Salmo salar* L.); the effect of dietary protein level and protein particle size. Aquacult, 185(1): 101-120.
32. Koller, H. R. (1972). Leaf area and leaf weight relationship in the Soybean Canopy. Crop Sci., 12: 180-183.
33. Badran A.E. (2015). Comparative analysis of some garlic varieties under drought stress conditions. J. Agric. Sci., 7(10): 271-280.
34. Pearson, D. (1976). The Chemical Analysis of Foods. Longman Group Ltd., Harlow, U.K.
35. Cottenie, A.; M. Verloo; G. Velgh; L. Kiekens and R. Camcrlynck (1982). Chemical analysis of plant and soils. Lab. of Analytical and Agro. State Univ. Ghent –Belgium.
36. Asaduzzaman, M.; Shah, M.K.; Begum, A. Wahab; M.A. and Yang, Yi. (2006). Integrated cage-cum-pond culture systems with high valued Climbing Perch (*Anabas testudineus*) in cages and low-valued carps in open ponds. Bangladesh J. Fish. Res., 10(1): 25-34.

37. SAS (2006). Statistical Analysis System, SAS user's guide: statistics version 9.1.3 Ed., SAS Institute Inc. Cary, NC., USA.
38. Kamal, S.M. (2006). Aquaponic production of Nile tilapia (*Oreochromis niloticus*) and bell pepper (*Capsicum annuuml*) in recirculating water system.Egypt. J. Aquat. Biol. & Fish., 10(3): 85-97.
39. Boyed, C.E. (1998).Water quality for pond aquaculture. Research and development series No. 43. pp. 37. International Centre for aquaculture and aquatic Environments. Alabama Agricultural Experiment Station. Auburn University.
40. Rakocy, J.E.; Shultz, R.C; Bailey, D.S. and Thoman, E.S. (2004). Aquaponic production of Tilapia and Basil: Comparing a Batch and Staggered cropping system, Acta Horticult. 648: 63-69.
41. Gui,Y.; Wang, Y.; Chen, W. Z. and Li, F. (1989). Use of fluctuating temperature to promote growth of *Tilapia nilotica*. J. Fisher. China, 13(4): 326 – 331.
42. Rocha, A.F.; M.L.F. Biazzetti; M.R. Stech and R.P. Silva (2017). Lettuce production in aquaponic and biofloc systems with silver catfish *Rhamdia quelen*. Bol. Inst. Pesca, Sao Paulo, 44:64-73.
43. Selek, M.; M. Endo; M. Yigit and T. Takeuchi (2017). The Integration of Fish and Plant Production: Nile Tilapia (*Oreochromis niloticus*) and Basil (*Ocimum basilicum*) Culture in Recirculating and Aquaponic Systems. J. Aquac. Eng. Fisheries Res. 3(1): 28-43.
44. Sami, S.A. (2010). Effluent Water Characterization of Intensive Tilapia Culture Units and its Application in an Integrated Lettuce Aquaponics Production Facility. MSc. Thesis, Fac. Science, Auburn Univ.
45. El-Helaly, M.A. (2019). Effect of Fish Diets Supplemented with Vitamin /Mineral Premix on Growth and Yield of Lettuce under Aquaponic System. American-Eurasian J. Agric. & Environ. Sci., 19 (1): 48-53.
46. Anne, L.A. (2018). Study of the effects of an aquaponics system with different fish densities in lettuce. MSc. Thesis, Fac. Agric., Junio, Ekaina.

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Study of the effects of different monosex Nile tilapia (*Oreochromis niloticus*) fingerlings densities on Lettuce (*Lactuca sativa*) and water quality in a low-tech recirculation aquaponic system

دراسة تأثير كثافة إصبعيات البلطي النيلي (*Oreochromis niloticus*) أحادي الجنس على الخس (*Lactuca sativa*) ونوعية المياه تحت نظام الأكوابونيك

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المستخلص

زادت مبادرات الاغذية المستدامة، والوعى للاهتمام بسرعة الاستتزراع المائى اسمكى والنباتى على نطاق واسع فى الوكالات المحلية حيث يسمح تكامل تكنولوجيا الاستزراع المائى السمكى والنباتى انتاج كل من الخضروات والاسماك فى المناطق التى تعانى من نقص المياه او التى تعانى من نقص التربة.

تهدف هذه التجربة إلى مقارنة ثلاثة كثافات مختلفة من اصبعيات أسماك البلطى النيلى (*O. loticus*) ودراسة الآثارالمترتبة على نمو الخس Lettuce (*Lactuca sativa*) وجودة المياه في تكنولوجيا نظام الأكوابونيك وإعادة تدوير المياه الضحلة على نطاق صغير. أجريت هذه الدراسة في نظام تكنولوجيا إعادة تدوير مياه الأستزراع المائي مع نظام الزراعة النباتية المائية في مزرعة إنتاج الأسماك التجريبية، كلية الزراعة، جامعة الأزهر، القاهرة، مصر . تم تصميم أحواض الأكواريوم التجريبية في 12 حوض طولية الشكل على أحجام متساوية تبلغ 105 لتر ^{3} حجم كلى للحوض (100 لتر ^{3} حجم ماء) لكل منهما . تم إعداد 4 معاملات من الأكوابونيك والهيدروبونيك بثلاثة مكررات في هذه الدراسة لمدة 56 يومًا في 18 يناير 2018 وتم حصادها في 14 مارس 2018 . وقد كانت T1 ممثلة الكنترول (نبات الخس باستخدام فقط محلول (Hoagland) ، T2و T3 و T4 ممثلة لتجارب تربية كثافات تخزين البلطي 15 سمكة/ أكواريوم (150 سمكة/ م^3) , 17 سمكة / أكواريوم (175 سمكة/ م^3) و 20 سمكة / أكواريوم (200 سمكة/ م^3) مع نباتات الخس،على التوالي . تم تغذية السمك مرتين يوميًا حتى الأشباع باستخدام حبيبات طافية متاحة تجاريًا بنسبة 30٪ من البروتين. تمر مياه الصرف من أحوض السمك إلى قاع الخضار بواسطة مضخة مياه غاطسة 40 واط. خلال الفترة التجريبية تم رصد معايير نوعية المياه المختلفة بانتظام . تم قياس نمو وإنتاجية الخس باستخدام الوزن الطازج والوزن الجاف (g)ومساحة الورقة (cm2) والكلوروفيل (SPAD). وكان نطاق درجة حرارة الماء من 27 إلى 29 درجة مئوية (متوسط 28 درجة مئوية) ، تركيزالأكسجين الذائب 6.8 إلى 7.4 ملجم / لتر (متوسط 7.1 ملجم / لتر) ،ودرجة الحموضة (pH) من 7.10 إلى 7.4(متوسط 7.25) ، والأمونيا (NH_3) 0.10 إلى 12 .0 ملجم / لتر (متوسط0.11 ملجم / لتر) ،النتريت (NO_2)(من 0.03 إلى 0.05 ملجم / لتر (متوسط 0.04 ملجم / لتر) والنترات (NO_3) من 14.0 إلى 18.0 (متوسط 16.0 ملجم/لتر). في نهاية التجربة، تشير الدراسة إلى أن كثافة التخزين التى تبلغ 200 سمكة / م 3 مع نباتات الخس، مناسبة لإنتاج كل من النباتات والأسماك في نظام الأكوابونيك إعادة تدوير المياه بسبب ارتفاع توافر المواد الغذائية في هذه الأحواض المائية مع معايير نوعية المياه المناسبة.