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GROWTH RATE OF GIFT TILAPIA (*OREOCHROMIS NILOTICUS*) CULTURED IN DIFFERENT AQUAPONIC SYSTEMS

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Abstract

Aquaponics is the combined culture of fish and plants in recirculating systems (without soil). Aquaponics uses these two in a symbiotic combination in which plants are fed the waste from fish and in return, the vegetables clean the water that goes back to the fish. In the present study, GIFT Tilapia (109 ± 0.7g) was cultured with three different aquaponics systems to investigate the most appropriate aquaponics system for small scale culture. Three sets of aquaponics systems, Media Bed (MB), Nutrient Film Technique (NFT) and Deep Water Culture (DWC) were created to develop the aquaponics systems for tilapia and lettuce. A total of 40 fingerlings of GIFT tilapia (*Oreochromis niloticus*) collected from Hlawga Hatchery Station, Yangon were introduced to each system. Then, 15 seedlings of lettuce were introduced to aquaponic system. Fish were fed floating pellet for 3% of body weight and cultured from January to May, 2020. The highest weight gains were found in DWC (10.3g) followed by MB (10.2g) and NFT (9.5g). The lowest food conversion ratio (FCR) was in DWC, followed by NFT and MB. For plant quality index, 11 plants of grade A were observed in DWC which were followed by 6 plants each in MB and NFT during the first harvest. In second harvest, plant quality index was observed that number of grade A plants was 8, 5 and 3 plants in DWC, NFT and MB, respectively. According to this study, DWC system shows the most favorable outcome for tilapia and lettuce aquaponic than other systems.

Keywords: Systems, GIFT Tilapia, Lettuce, Aquaponics, FCR

Introduction

Aquaponics combines re-circulatory aquaculture system with hydroponics system in an integrated symbiotic farming concept that ensures efficient nutrient recycling. In this system, the excretory products of the fish are broken down by microorganisms and the resultant by products inputted into the hydroponic system for plant growth (Bosma *et. al*., 2017).

There are three main components of an aquaponics system: fish**,** plant and bacteria. At the design of an aquaponic system, several factors have to be considered when selecting fish, especially because they are going to be living in a tank (Somerville *et al*., 2014).

Serious environmental issues are faced by traditional aquaculture, such as high-water consumption, use of extensive land area, and production of nitrogen and phosphorus compounds (Mariscal-Lagarda *et. al*., 2012). New solutions are essential to see the modern standards of high productivity and minimum environmental impact.

Aquaponics may play an important role in water conservation, globally a major concern for food production (Martins *et. al*., 2010; Rijin, 2013).

This integration aims to convert the normally wasted nutrients excreted by fish into valuable plant biomass. This allows for lower water exchange and spillage which should significantly reduce the environmental impact of fish and hydroponic plant production (Delaide *et. al*., 2017).

In aquaponics, the aquaculture effluent is diverted through plants beds and not released to the environment, while at the same time the nutrients for the plants are supplied from a sustainable, cost-effective and non-chemical source (Somerville *et. al*., 2014).

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In aquaponics system, three types of beds are widely used namely: Nutrients film technique (NFT), ebb-and-flow (EAF) and the deep water culture (DWC) also known as the RAFT beds (Delaide *et. al*., 2017). Most EAF beds are composed of heavy substrate such as clay balls, gravels, send, perlite, etc. These serve as support systems for the plants and as bioremediation medias (Rakocy and Hargreaves, 1993). However, the effect beds in growth rate of fish and plants in aquaponics have not understood yet.

Tilapia are extremely popular in aquaponic systems because they have fast growing and resistant to many pathogens, parasites and handling stress (Somerville *et. al*., 2014). GIFT Tilapia has been introduced in 2016 from Malaysia to Hlagaw fish station, Myanmar with the support of World Fish. If GIFT Tilapia has been used in aquponics system, it is expected to produce good growth rate tilapia within limited water body. Moreover, leafy vegetable production such as lettuce receives a good market price which has fast growth with low nutritional condition and excellent adaptation to the aquaponic system. Therefore, this research has been attended to find out the more effective aquaponics system for GIFT Tilapia and lettuce production.

Materials and Methods

Study site

The present study was conducted at the Laboratory of Aquatic Bioscience, Fisheries and Aquaculture, Department of Zoology, University of Yangon.

Study period

The study period (preparing design, building and making fish and plants tanks) was lasted from June 2019 to November 2019. The culture period for fish and lettuce lasted from December 2019 to May 2020.

Experimental setup and operation of aquaponic systems

Three different aquaponics systems including Media Bed Unit (MB), Nutrient Film Technique (NFT) and Deep Water Culture (DWC) were developed (Fig.1). Three systems included the same size of fish tanks, hydroponic tanks and bio-filters. Fiber tanks were used to rare fish. The size of fiber tank was (0.85m×0.61m×0.43m) with a capacity of 225L. The size of hydroponic tanks to cultivate the lettuce is (0.43m×0.6m×0.6m) with the capacity of 250L.

For the design of Media bed Unit (MB) system, the beds hydroponic tanks were prepared by filling the gravel (Diameter = 2 cm) into the height of 24 cm. A total of 15 seedling plants with pots were introduced inside the gravel. Water in the hydroponic tank was filled into 30 cm to submerge the gravel under water. Water pump was placed inside bucket and set up in the tank to protect flowing of the gravel to the pump. Water from the fish tanks was introduced to the hydroponic tank by gravity while water from the hydroponic tank return back to fish tank by the function of electronic water pump.

For NFT system, series of 15 plastic bottles were connected and allocated on the tank with the aid of bamboo support. A small pore was created by knife on the bottle to allow the exceed water to the tank. In each bottle, two whole (D= 5 cm) were prepared with 15 cm distance to introduce the seedling plants. Therefore, there are total of 15 plants pot in the system.

In Deep Water Culture (DWC) as Styrofoam was used floating grow bed on the surface of the plant tank which was filled in the water. The area of floating beds was (0.6×0.4) m^2. The total of 15 plantation pots was allocated in floating bed by drilling the Styrofoam with 5 cm apart each other.

Water pump (75 Watt) were used in all systems. The running water system was set up between plant tank and fish tank with the aid of pump through bio filter.

The biofilter tank is one of the most important components in an aquaponics system as it reduces the toxicity of the nitrogenous waste for fish. In the present study, shells from bivalve were used as substrate in the biofilter to growth the nitrifying bacteria in large surface area. Large plastic bucket (0.39 m in diameter ×0.43 m in height) was filled with shell of bivalves until two-thirds of the bucket. Tapwater was used for all expermental tanks. Each experiment design was set up for triplicate.

Fish stocking

A total of 400 fingerlings GIFT farm Tilapia (*Oreochromis niloticus.*) (2.5 ± 0.7g) were collected from Hlawga Hatchery Station, Yangon. A total of 40 fingerlings GIFT tilapia were put in each tank (0.85 x 0.61 x 0.43 m^2). Floating pellet (3 mm) containing crude protein (33%), crude fat (6%), NFE (47.9%), ash (5.2%), fiber (2.9%), gross energy (18.9%) and digestible energy (15%) were feed with 3% of body weight per day by dividing into two times. Fish were weighed every 30 days to record the growth rate.

Preparation of vegetables

Seeds were put in seedling trays with coconut coir and soil. Seeds were germinating within four days. After two weeks, seedling of lettuce were transplanted in pot (Plate 2). Seedlings of lettuce were cultivated in gravel in MB, in the whole of Coca cola bottles in NFT and in the whole of styrofoam in DWC. The density of plant was 15 plants m $-^2$. Plants were put to the pot together with substrate (coconut coir) which help the plants to stand vertical (Plate 1).

Fish growth parameters analysis

Fish growth performance such as weight gain, specific growth rate and feed conversion ratio were evaluated in accordance with Cerozi and Fitzsimmons (2017).

$$\text{Weight gain (WG, g)} = \frac{Wf - Wi}{\text{number of fish per replicate}}$$

$$\text{Specific growth rate (SGR, \%)} = 100 \times \frac{\ln Wf - \ln Wi}{\text{days of feeding period}}$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{feed intake (g)}}{\text{weight gain (g)}}$$

Plant quality index (PQI)

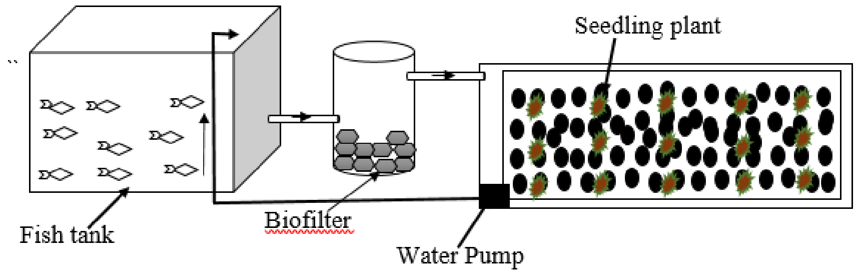
Additionally, a plant quality index (PQI) was evaluated by grades attributed to visual aspect of the leaves. Visual parameters included abnormalities in the leaf surface such as yellowish color and/or imperfections (wrinkles and burns). The grades were from A to D as follows: (Pinho *et. al*., 2017).

A = Excellent, up to 5% of the leaves surface with imperfections
B = Good, 33% imperfections
C = Average, 66% imperfections
D = Poor, 100% imperfections

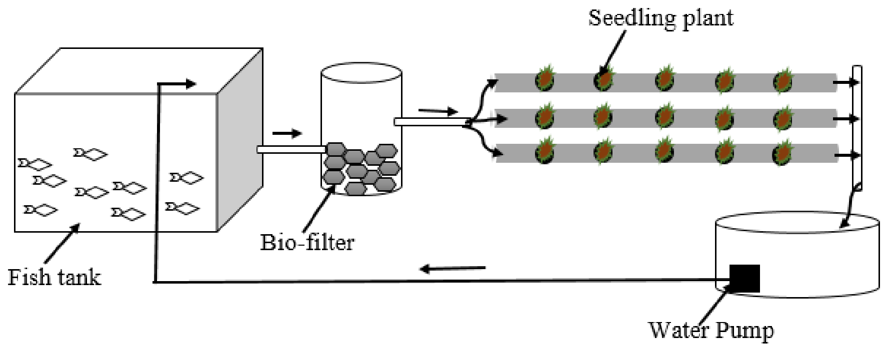
Plants grades assessed using a “blind” approach where three valuators did not know which systems has been used.

Water quality

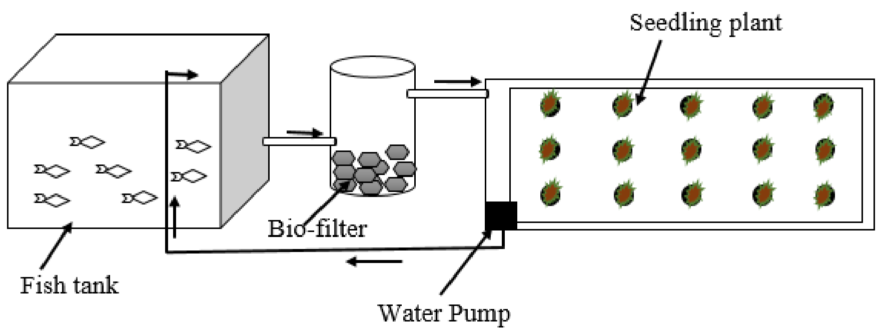
The water quality parameters; pH, dissolved oxygen and temperature were monitored by probes (ID-1100, USA and ID-150, Iijima Electronics Corporation) every day in all tanks. Nitrate and ammonia equipment calibrated from the experimental tanks were measured twice a week using colorimetric test kits.



(A) Media Bed Unit (MB)



(B) Nutrient Film Technique (NFT)



(C) Deep Water Culture (DWC)

Figure 1 Schematic diagram of three aquaponic systems used in the experiment

(A) Media Bed Unit (MB) system

(B) Nutrient Film Technique (NFT) system

(C) Deep Water Culture (DWC) system

Plate 1 Three different units in aquaponics system

Plate 2 Germination of Lettuce before introducing to aquaponics systems

Results

Growth of GIFT Tilapia

Growth of fish was studied within the period of five month cultured in different aquaponics systems. In the beginning of experiment, mean weight of tilapia was 2.5g in all systems. Fish weight gradually increased during study period. At the end of experiment, the highest mean weight was found in DWC (21.8 g), followed by MB (20.6 g) and NFT (19.8 g) respectively (Fig.2).

The highest final weight gains were recorded in DWC (10.3g) while the lowest weight gain in MB (10.2g) followed by NFT (9.5g) in the end of experiment (Fig.3). Final specific growth rate of fish was (2.3) similar specific growth rate in all systems (Fig.4).

Food conversion ratio (FCR) in April, were 1.4, 1.1 and 1 in Media Bed Unit (MB), Nutrient Film Technique (NFT) and Deep Water Culture (DWC) respectively. The highest FCR was found in MB while the lowest FCR was recorded in NFT followed by DWC system. Although the highest FCR was found in MB, in the end of experiment in May, the same FCR was recorded for all systems (Table 1).

The mortality of GIFT tilapia was found 98% in the beginning of experiment. The highest mortality was found in May at the temperature of 32 ºC. The survival rate during the experimental period was 98%, 96%, 93% and 87% in MB, NFT and DWC respectively (Fig. 5).

Lettuce production

During experimental period, the condition of plants was measured in all aquaponics systems. Plants were cultivated and harvested for two production cycles of lettuce during the study period. Plant quality index was assessed as A, B, C and D according to the quality of plant. For plant quality index, 11 plants of grade A were observed stocking density of 15 plants m^{-2} in DWC which were followed by 6 plants each in MB and NFT in the first cycle of harvest. In the first cycle, 1 plant was grade D in MB and NFT. However, none of the lettuce was grade D in DWC. In second cycle of harvest, plant quality index was observed that number of grade A plants was 8, 5 and 3 plants in DWC, NFT and MB respectively (Fig. 6).

Water quality

The water quality was recorded from January to May 31, 2020. In all experiments, average dissolved oxygen ranged 4.9 to 6.0 mg/L while water temperature varied 23.3 to 31 ºC. In all aquaponic systems, pH level ranged from 7.3 to 7.7. The ammonia levels ranged 0 to 0.3 mg/L while Nitrate levels varied 0 to 0.2 in all aquaponics systems (Table 2).

Table 1 Food conversion ratio during experimental period

FCR	February	March	April	May
MB	1.5	2	1.4	1
NFT	1.5	2.1	1.1	1
DWC	1.3	2.1	1	1

Table 2 Water Parameters during experimental period

Parameters	January			February			March			April			May		
	MB	NFT	DWC	MB	NFT	DWC	MB	NFT	DWC	MB	NFT	DWC	MB	NFT	DWC
Dissolved Oxygen	5.7	5.8	5.7	6	6	6	5.8	5.8	5.8	6	6	6	5.1	5.1	5.2
Temperature	24.6	24.6	24.6	25.9	26	26	27	27	27	29	29	29	31	31	31
pH	7.6	7.7	7.6	7.5	7.5	7.6	7.4	7.5	7.4	7.4	7.4	7.4	7.5	7.5	7.6
Ammonia	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0.2
Nitrate	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2

*MB = Media bed unit
*NFT = Nutrient film technique
*DWC = Deep water culture

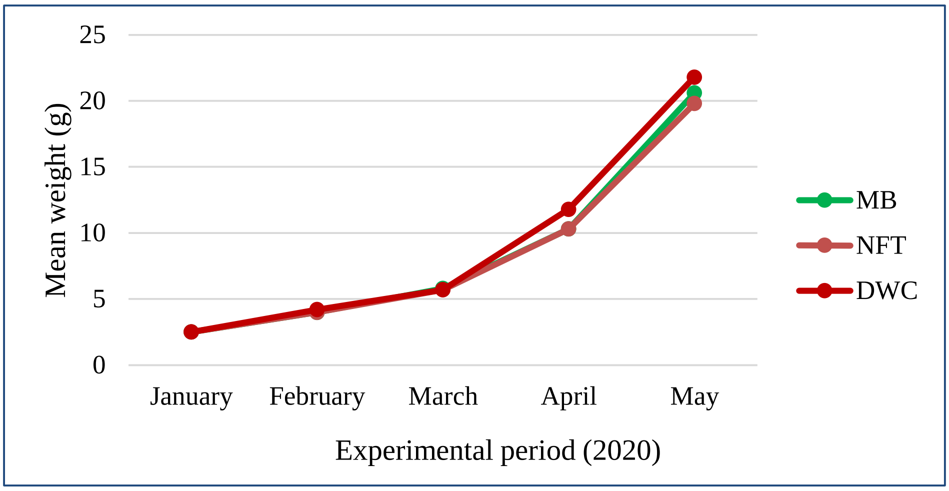


Figure 2 Total weight of GIFT tilapia in three aquaponics systems

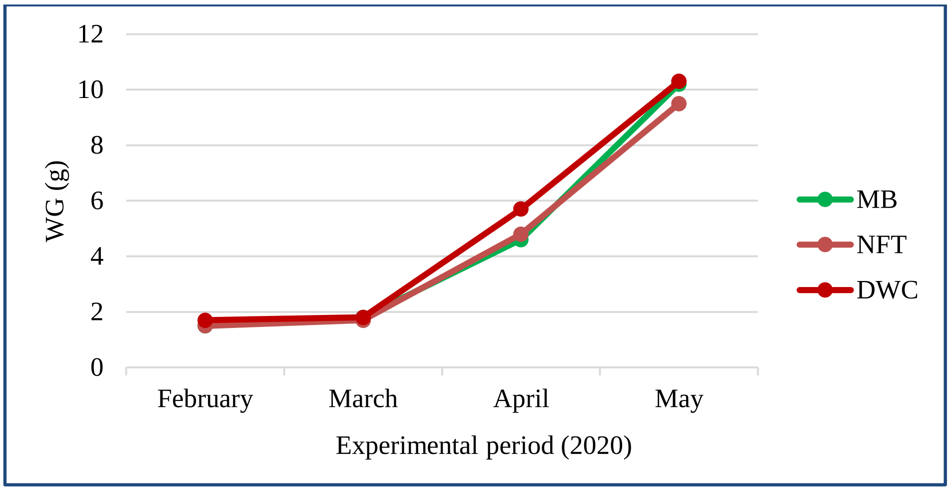


Figure 3 Weight gain of GIFT Tilapia during the experimental period

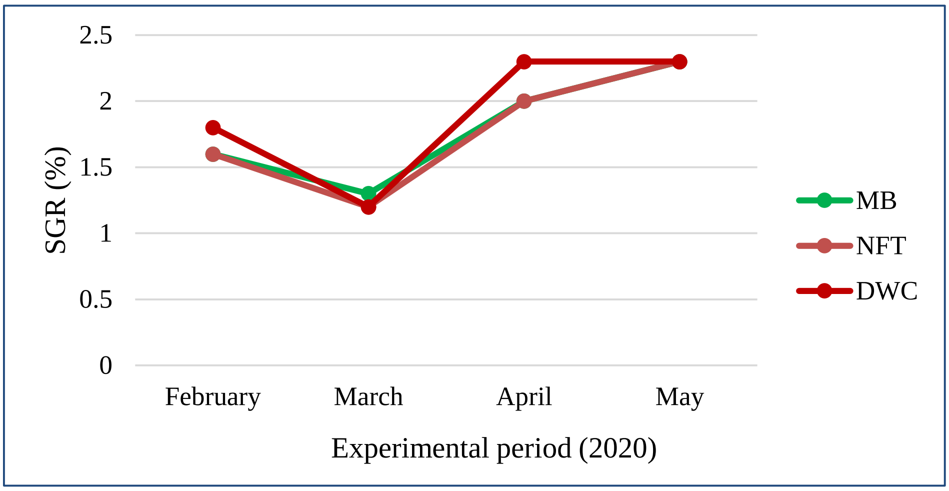


Figure 4 Specific growth rate of GIFT Tilapia in all systems

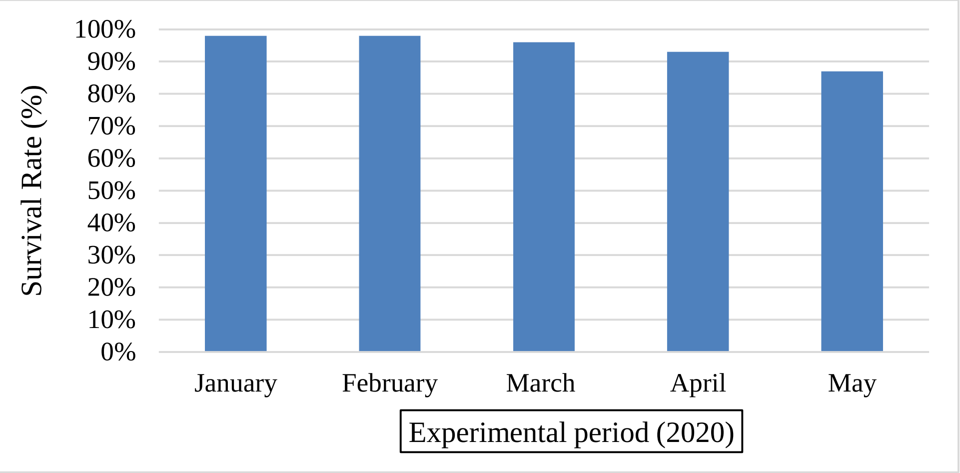


Figure 5 Survival rate of GIFT Tilapia during the experiment

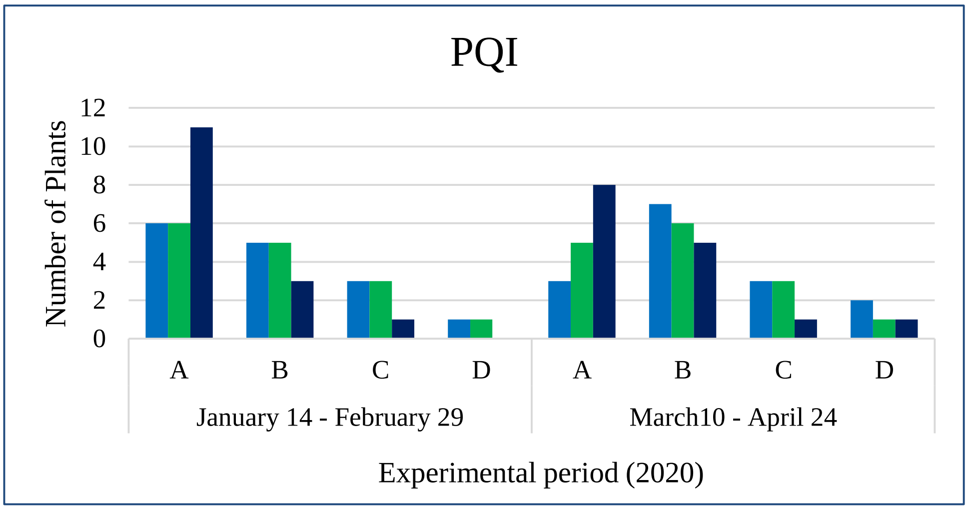


Figure 6 Plant Quality Index of lettuce in all aquaponics systems

Discussion

The growth rate of GIFT tilapia and plant in three different aquaponics systems were studied in the present study. The best growth rate of fish and plant were found in deep water culture (DWC), The weight gains of three aquaponics systems not much differ very yet, however, the highest weight gain was recorded in DWC (10.3g). In April and May, DWC was found in the highest weight gain and SGR. Tilapia grows fast if they are given the right conditions and may achieve approximately 1 kg in 8-9 months (Martins *et. al*., 2009).

The same FCR was found (1.5) in MB and NFT while it was (1.3) DWC in February. However, the same FCR (1) reached in May in all systems. The FCR of present research is better than Rakocy *et. al*., (2006) in which FCR was 1.7 to 1.8. It is assumed that GIFT tilapia is a strain that has been genetically improved for aquaculture purpose.

The best plant quality index was recorded in DWC because it seems that in MB and NFT cannot supply required nutrient for plant and as a result, 30% of plants are PQI grade B. Grade B means 33% of plant is imperfection as the plant is wrinkles and burn (Pinho *et. al*., 2017). The root in DWC system seems freely absorb nutrient from water while roots in MB were restricted in the gravel. On the other hands, roots in NFT was limited in the plastic bottle. Therefore, longer roots in DWC system can absorb nutrient from the water to the leaves of lettuce. Plants in the MB and NFT are nutrition deficiency and as a consequence, grade B plant was more collected (Fig. 5).

The lettuce and basil did not grow efficiently in clay balls contrary to Lennard and Leonard (2006) who compared their growth rate in NFT, DWC and EAF (MB). This may be explained in caused by reduced water flow around the roots and hence reduced nutrients availability (Trang *et. al*., 2010). Plant growth in the present study followed the relationship DWC > Gravel bed (MB)> NFT.

On the aspect of water quality, the average of water temperature ranged 23.3 ·C- 31·C. This was suitable for tilapia but was often warmer than the optimum temperature needs of lettuce (Resh, 2012). Dissolved oxygen were above 5 in all tanks because all tanks were aerated during the study period. The average of pH in all aquaponics systems were (7.3 to 7.7). Rakocy *et. al.*, (2004) suggested that pH should be above 7 in aquaponics to promote nitrification in aquaponic system. Ammonia levels and Nitrate levels in aquaponic system is low because biofilter convert fish waste ammonia into plant food nitrate (Rakocy, 2004). Results indicated that DWC is the most appropriate all aquaponics systems. It can be constructed available facilities, a simple recirculating aquaponics system for combined production of fish and vegetables with a minimum use of water and space.

Conclusion

Three sets of aquaponics systems (MB, NFT and DWC) were created to reveal the appropriate system for Tilapia and lettuce aquaponic system. The highest final weight gain was found in DWC followed by MB and NFT. Lettuce were cultivated and harvested for two production cycles during the study period and the best plant index is also found in DWC. According to the result, DWC system showed the more favorable outcome for good growth rate of tilapia and lettuce than the other aquaponics systems.

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