International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 11-06-2021, Accepted: 27-06-2021, Published: 12-07-2021
Volume 6, Issue 4, 2021, Page No. 29-35

Effect of different hydroponic subsystems and culture medias on the biochemical composition and growth performance of plant and fish in aquaponics system

B Dhanalakshmi
Assistant Professor, Department of Zoology, Nirmala College for Women, Coimbatore, Tamil Nadu, India

Abstract
In 21st century one of the environmentally sustainable farming method, an integrated agri-aquaculture system and a viable food growing technology which connects consecutive aquaculture with hydroponics in a symbiotic condition will be adopted by farmers to meet the demand of the growing population. The present research was accomplished to evaluate the relative performance of gravel media (M1), coconut husk media (M2) and a composite media of gravels and coconut husk (1:1V) (M3) as media in aquaponic system to grow green gram (*Vigna radiata*) and Nile tilapia (*Oreochromis niloticus*). Each treatment had three replications of similar bedding media. The resultant effects of these treatments revealed better performance of *Vigna radiata* in the treatment T1 performed best followed by T2 and T3, respectively in terms of media plant growth performances was noted to be in the following order M3> M2>M1 with respect to duration of plant growth in different growth periods, plant height, number of leaves per plant, leaf area and number of branch per plant. Gravel substrate grown *Vigna radiate* showed least performance in growth propagation. The selected media and treatment methods, the water and nutrient quality supports for fish and plant growth. At the end of experiment the length and weight gain of experiment fish was 84.95±0.84 cm; 142.5±0.03gm. In the present study the survival rate of fishes were 95% and above in all the selected treatments. So, the present experimental study proves aquaponic as an alternative uses of agricultural by-products due to superior growth observed in this study, it is also highly recommendable due recycling and conversion of waste to product.

Keywords: plant exo-morphology, fish growth, culture medias, hydroponic, aquaponics

Introduction

In developing countries like India due to urbanization and industrialization shrinking total agriculture land, uncontrolled population growth, complex and unpredictable weather create new challenges to the country's agriculture. In addition, to get rid of pollution issues cause by fish waste have raised interest in developing a new form of crop production method, Aquaponics, a valid option to an integrated agricultural system (Islam *et al*, 2018a) [14]. Thus, development of food and animal production system is currently crucial to meet the demands of growing global population in a substantial, ecofriendly and organic way. With this context one of the old concepts of integrated science, the Aquaponics, an innovative agricultural strategy has been recently received a huge attention to produce more and sustainable food. Moreover to reduce environmental problems related to agricultural and fish industry and to maintain food safety the trend of hydroponics and aquaponic are currently adopted by many agricultural societies. This innovative system also offers solution to several sustainability issues, such as pollution, over consumption of water availability and over usage of fertilizers which deplete soil fertility.

Thus, hydroponics systems provide optimized conditions for growth of plant with respect to supply of water and nutrients and the potential of plants to use the nutrient by-products of aquaculture and to keep the recirculating water clean states that this system from environment point of view are recommended as it reduce discharge of nutrient-enriched water and thus prevent eutrophication of neighbouring waters. The above statement was supported by Rakocy *et al*, 2006 [23] who too suggested that this recirculating system helps in leading to a reduction in high ammonia levels in the fish tank, which can otherwise be harmful to fish. According to Lal, 2016 [18] in order to feed the estimated 11 billion people in the world by 2100 and to pay more attention to food safety and human health and studies of Tzortzakis & Economakis, 2008 [35]; Gruda, 2009 [11]; Tyson *et al* 2011 [34], Sharma *et al*, 2018 [29]; Wilson Lenard and James Ward, 2019 too supports and proves that aquaponics concept of vegetables and fish production proves healthy and nutritious products in soil less and resource efficient system proving positive effects on both biomass and quality.

Integrated culture has been practiced from generation to generation in many countries extensively and semi extensively But now using different techniques and growing media and soil less system plants are grown in an organic manner and fishes were grown in unpolluted environment which are helping the society to lead a hygienic, health and safety life. As green gram and tilapia are the best plant and animal which supports aquapoics and hydroponics in the present study Green Gram/ Mung bean (*Vigna radiata* L.) R. Wilczek which is a common and the most important food crop cultivated in South East Asia (Singh and Singh, 1992) was selected as experimental plant. This leguminous plant is the third most important pulse crop of India which is popular, cheap nutritious food consumed by public as they are rich in protein (30%) and Carbohydrate (60%) of its dry weight respectively (Wongsiri *et al*, 2015) [38], fat (1.5%), amino acids, vitamins and minerals etc. (Mubarak, 2005) [21]. In India 3.80 million hectares was used to cultivate *Vigna radiata* and an annual production of 1.1 million tonnes was recorded. In Tamil Nadu, 0.13 million hectares area was used for *Vigna radiata* production which yields an annual production of 458.8 tonnes. Similarly, Tilapia - *Oreochromis niloticus*, the fourth mostly commonly consumed fish was selected as experimental animal as they are very resilient to changes in pH, pollutants, temperature and also it grows quickly, has a good food conversion rate, available throughout the season and consumed by most of the people (Johanson, 2009 [15]; Timmons and Ebling, 2010 [33]).

Food safety is a vital component of food production and aquaponic farmers must follow available codes of good practice and apply biosecurity protocols for both aquaculture and horticulture components. As in all crop production systems cross-contamination is possible. Fox *et al*, 2012 [10]; Sirsat and Neal, 2013 [31] stated however, the risk in aquaponics farming systems is low when compared with the traditional production of field crops. Aquaponics does not rely on chemicals for fertilizer, or control of pests or weeds which makes food safer against potential residues. At the same time, aquaponics can integrate livelihood strategies to secure food and small incomes for landless and poor households. Domestic production of food, access to markets and the acquisition of skills are invaluable tools for securing the empowerment and emancipation of women in developing countries, and aquaponics can provide the foundation for fair and sustainable socio-economic growth. From the above discussed concept aquaponics is, therefore, a promising, sustainable food production technology, especially in developing/arid countries, where resources are limited, freshwater is scare and population is increasing. So, the present research work was taken up to prove that this Aquaponics, a commercial sustainable system could solve to reduce the waste discharge, minimize the environmental pollution and produce organic products. Thus in this context the present study was undertaken to culture the commercially important fish Tilapia (*Oreochromis niloticus*) and green gram (*Vigna radiata*) combined in aquaponics system.

Materials and Methods

Preparation of experimental setup

The present study was carried out in Aquaculture laboratory, Department of Zoology, Nirmala College for Women, Coimbatore in 2020-2021. The aquaponics set up was installed in the Aquaculture laboratory and the present analysis was carried out for a period of seven weeks. The aquaponic system consist of the glass aquariums with capacity of 20 liter containing airlift pipe (to the biofilter) and submersible water pump which supply water to hydroponic bed.

Among various types of plant and fish culture in aquaponics system the media based aquaponic system was selected to conduct the experiment. Three different media, gravels (gravels size was 1-2 cm) (M1), coconut husk (M2) composite mixture of coconut husk and gravels (M3) as three treatments, each having three replications were used in this experiment for *Vigna radiate* production. An NFT system made of PVC pipelines (3 feet) with hole on the top and float type i.e. raft system made of thermocol (2cm width with six holes) was used for crop irrigation, with a rotating biological contactor filter installed between the fish and crop units in the system. The water was circulated from the fish tank through the biofilter to the cultivation gutter and back to the fish tank. In the control treatment with a hydroponics system, the same set-up as in aquaponic treatment was used but without the fish and without a biofilter. Three replicates of this treatment were also used.

Collection of experimental fish

The selected experimental fish *Oreochromis niloticus* was purchased alive from Ukkadam Lake from the local fish farmers. The live fishes were transferred into covered sterile plastic buckets and transported to lab immediately within few hour

Acclimatization of procured experimental fishes in aquaponic tank

Live experimental fishes *Oreochromis niloticus* (100 fishes) with a weight ranging between 5-10 gm and length of 8-12cm were procured from Ukkadam Lake. Then the fishes were acclimatized to the laboratory condition for 2 weeks in large cement tank (6'x 4' x 3') at 24±3°C. During the study period the fishes were fed with commercial feed twice a day. Before starting the experiment, the entire aquaponics system was well cleaned and kept at dry for one week. An inlet and outlet pipe was set to the fish tank then, the tap water was filled in the full aquaponics system tanks and the water circulation was started in a closed condition of aquaponics system for one week without fish. A 10-12-watt submersible water pump irrigated the vegetable beds with the waste water of tank through the inlet pipe and then the clean water returned to the fish tank through the outlet pipe. After one week, the water quality was adjusted to the level of aquaponics water quality standard for getting appreciable growth of the selected fish and plant yield. Then the experimental fishes of about the same size (5-8gms and 7-10 cm) irrespective of sexes were selected for the experiment and introduced into the experimental setup aquaponic tanks. The plant seed containers filled with different bedding media were placed side by side.

Collection of experimental seed, sowing and maintaining

The seeds of *Vigna radiata* (mung bean) were collected from Tamilnadu Agricultural University of Coimbatore district. The collected *Vigna radiata* seed were soaked overnight later transferred to a petri plate and placed inside a closed dark chamber for 48hrs. The germinated seeds were transferred into the bedding trays. The fish tank water was irrigated by submersible water pump from morning 10 am to evening 5 pm to the *Vigna radiata* beds through inlet pipe.

Experimental Water and Plant parameter analysis

During the seven week of study period physical, chemical and nutrient parameters were analyzed at an interval of two weeks in accordance with standard methods for examination water and wastewater (APHA, 2012). The chemical and reagents used for analysis were all of analytical R grade and was used without further purification. All the solutions were prepared in double distilled water. Similarly, at an interval of two weeks ten fishes were sampled randomly and measured carefully for length, weight using standard measuring scale and electronic balance respectively. At the end of 15 day in plant samples also the following exomorpholocial parameters like plant height, branch number, leaf number, leaf length and width (area) were measured with a measuring scale

Data Analysis

Fish and plant growth parameters differences in each treatment were analyzed by ANOVA with statistical SPSS software tool 16.0 Version to exhibit significant differences among the treatments at significant level of 0.05% and 0.01%.

Result and Discussion

The concept of combined production of healthy, nutritious vegetables and high-protein fish using a water-based nutrient delivery approach, the aquaponic system was recently taken up by the agricultural group to meet the global demand of growing population, to maintain health safety and face food shortage problem (Ding *et al*, 2015 [8]; Bailey and Ferrarezi, 2017 [3]). As the population is getting increased day by day the land area usage too is increasing so, to help and sustain the agriculture by the farmer resilient community for future closed hydroponic systems integrated with aquaculture can be adopted.

Growth performance of experimental plant - *Vigna radiata* (Mung bean)

In the present study, the growth performances of selected experimental plant *Vigna radiata* in selected three media treatments (T1- Gravel; T2- Coconut husk; T3- Gravel + Coconut husk) were observed and recorded (Fig.1-4) at a particular intervals i.e. (21st day; 35th day and 49th day) respectively. Randomly 10 seedlings were selected from each medium replication for morphological evaluation. After collection the seedlings were washed free of medium and measured for height, number of branches, number of leaves and leaf area. Usually *Vigna radiate* characteristically germinate within 4 to 5 days but in the present study the rate of germination increased as the amount of moisture introduced during the germination period due to hydroponic circulating system. The result of germination was faster within 4 days which proved that hydroponic system along with aquapoincs is much better than conventional plant growing system.

On 21st day of harvesting the average of plant height 19.9±1.27cm; leaf area i.e. length and breadth 5.8±0.55cm; Number of leaves 25±2.04 and branches 10±1.77 was recorded in mixed media i.e. gravel and coconut husk (M3) while in coconut husk media (M2) the recorded average of plant height 15.4±1.19cm; leaf area 3.7±0.12cm; Number of leaves 23.4±2.01 and branches 6±0.9 (Fig.1). The minimum plant height 11.7±0.16cm; leaf area2.3±0.20cm; number of leaves and branches recorded were 21.4±1.15; 3±0.05 was recorded in M1 grown *Vigna radiata* respectively. During the present analysis on the 49th day the significantly highest mean height of the plants ($P \leq 0.05$) was 27.5±2.38 cm found in M3 followed by M2 of 21.8±2.20cm and M1 of 19.7±1.90 cm, respectively while on the 35th the plant height recorded was 23.7±2.12 cm; 19.5±1.19 cm and 14.3± 1.06 cm inM3, M2 and M1. Significant differences among the treatments were observed in the mean heights of plants in all sampling dates i.e. 21st day sampling ($P\leq 0.01$) and 49th day sampling ($P \leq 0.05$).

Among the sampling medias the number of leaves recorded was in the following trend i.e. M3>M2> M1 and among the sampling period it was noted as 49th > 35th >21st Day. The number of leaves recorded in media M3 was 25±2.04, 28.6±1.71 and 32.9±1.43 on 21st, 35th and 49th day after treatment. Similarly the number of leaves recorded in M2 media was on 21st day 23.4±2.01, on 35th day 25.4±1.63and 49th day30.7±1.50. Among the selected medias, M1media grown *Vigna radiata* recorded minimum number of leave on sampling period 21st (21.4±1.15), 35th(22.6±1.45) and 49th (27.8±1.37) day (Fig.2).The selected media showed significant effects on mean number of leaves of each plant in every sampling stage i.e. On 21st day ($P \leq 0.01$) and on 49th day sampling ($P \leq 0.05$).

In the present study, the mixed media M3 exposed plant recorded larger leaf area and number of branches than other media M2 and M1 respectively. The highest average of leaf area recorded in M3 was 7.8±1.69cm and least 3.9±0.33cm in M1 on 49th day of sampling. The maximum leaf area was observed in 5.8±0.55cm and minimum 2.3±0.20cm was noted on 21st day in M3 and M1 media grown *Vigna radiate*. Significant distinctions in mean leaf area of plants were reported among the three media grown plant sampling ($P \leq 0.05$) (Fig.3). Similarly, the number of branches recorded was also noted to be maximum in M3 10±1.27 (21st day of sampling); 13±1.33 (35th day of sampling) and 15±1.39 (49th day of sampling). Plant sample collected from M2 recorded good number of branches (6±0.09; 9±0.12; 12±1.5) when compared to M1 measured plant samples (3±0.5; 5±0.6;7±1.0) sampled on 21st, 35th and 49th day respectively (Fig.4). This might be due to higher-availability of nutrients essential for increasing leaf size and branch numbers in the mixed media.

During the present study the plant samples measured in M1 recorded least leaf area and branch numbers when compared to M2 grown plant which may be due to the presence of nutrients required for leaves and branches were higher in coconut husk (M2) rather than the gravel media (M1) and thereby higher leaf area and number of branches was found in the coconut husk media. The present result might be due to supply of higher amount of essential nutrients to the plant roots through the faster nitrification process by the mixed media> Coconut husk media> Gravel media.

Thus, all the exo-morphological parameters recorded during the present experimental analysis were noted to be best in M3 followed by M2 and M1. That means, the mixed media displayed better performance than the individual media in case of plant growth. Studies of Savidov *et al*, 2005 [27]; McCauley *et al* [19], 2005, Rakocy *et al*, 2006 [23] reports too stated that the results of growth parameters obtained in the that mixed media performance was best than the individual medias due to higher aeration within the media, supply of more nutrients to plant, faster nitrification and symbiotic action between medias. In the present study the gravel media could not provide best growth result in the plant *Vigna radiata* which may due to fast drainage capacity and less retention time for the uptake of nutrients by plant particularly required for the growth parameters. But the *Vigna radiata* plant grown in coconut husk media was good when compared to gravel media as it could receive the required nutrient due to more retention capacity of M2. The present study results corroborated with the report of Das, 2011.

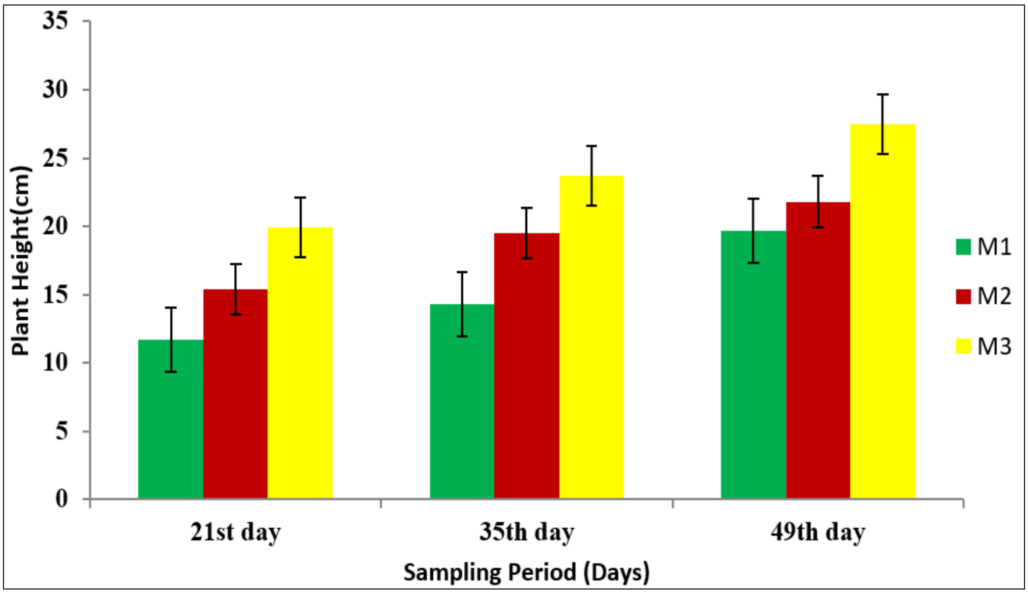

Fig 1: Effect of different medias on the plant height parameter of *Vigna radiata* cultured in aquaoponic treaments

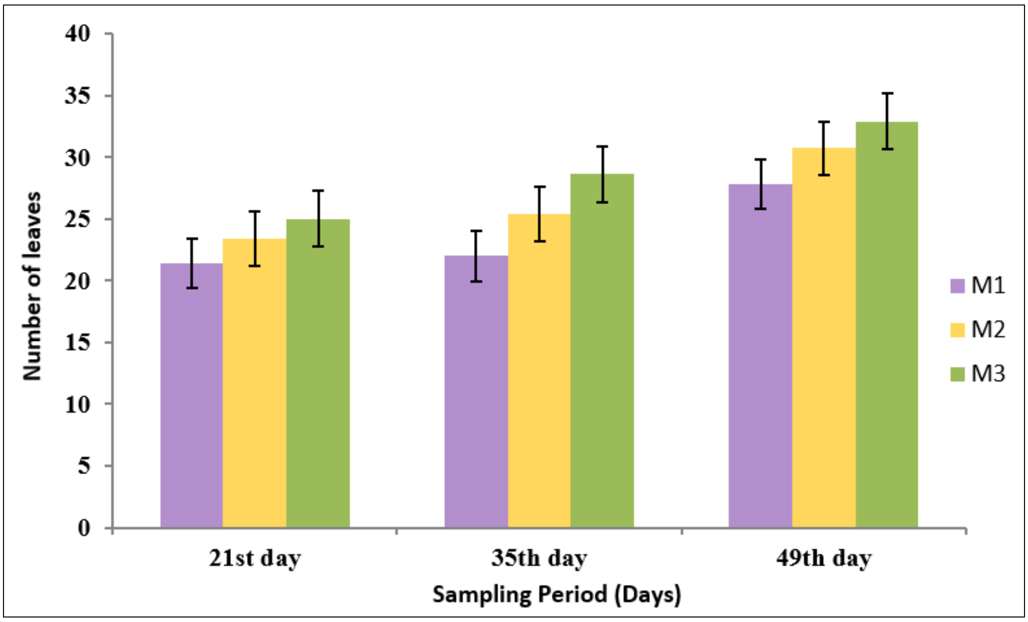

Fig 2: Effect of different medias on the number of leaves of *Vigna radiata* cultured in aquaoponic treaments

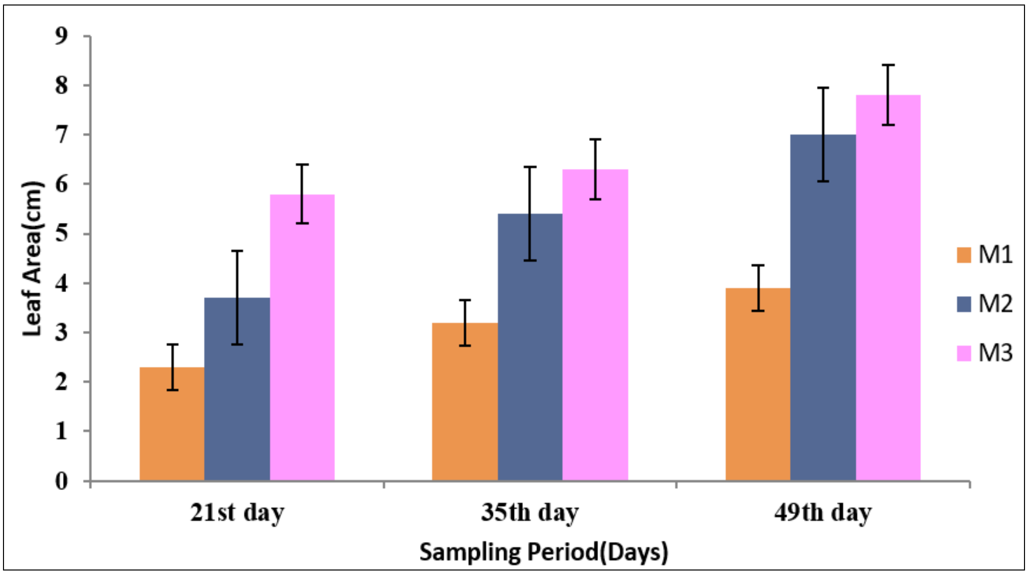

Fig 3: Effect of different medias on the leaf area of *Vigna radiata* cultured in aquaoponic treaments

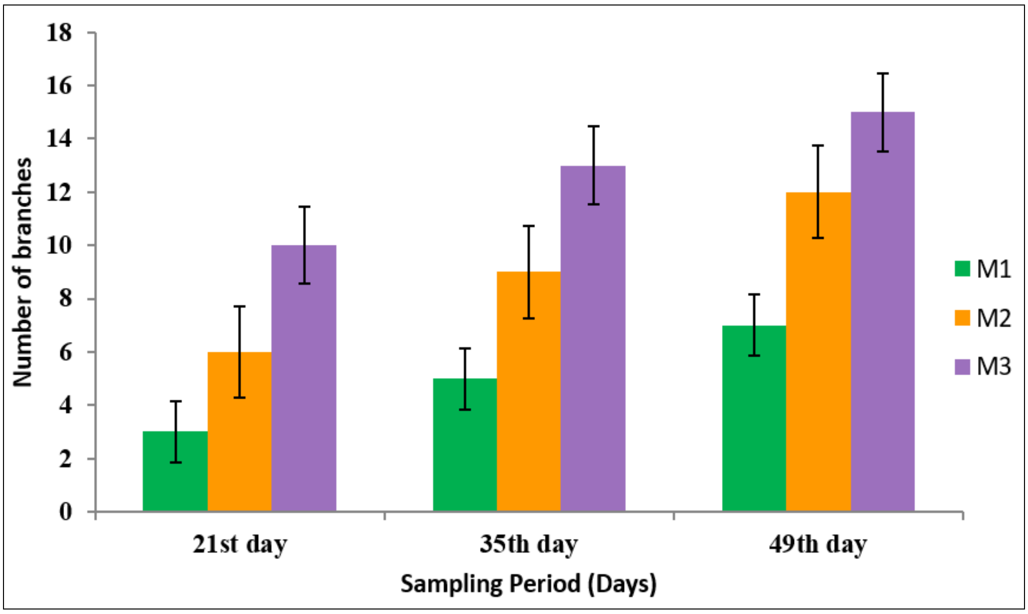

Fig 4: Effect of different medias on the number of branches of *Vigna radiata* cultured in aquaoponic treaments

Growth performance of experimental animal- *Oreochromis nilitocus*

In the present study the prime physicochemical parameters like temperature, transparency, pH, dissolved oxygen, nitrite and ammonia of water in all the treatments (T1- Media based system; T2- Floating raft system and T3- Nutrient Film Technique) were monitored during the experimental period and the growth performances of Nile tilapia- *Oreochromis nilitocus* regarding length (cm), weight (gm), length and weight gain, growth rate, survival and feed conversion ratio were presented in Table 1-2.

Table 1: Water quality parameters of the treatments

Parameters	Units	T1	T2	T3
Temperature	ºC	23±1.3	23±1.7	23±2.0
Transparency	Cm	20±1.5	20±2.1	20±2.4
Dissolved oxygen	mg/l	5.1±0.2	5.1±0.4	5.0±0.5
pH		7.4±0.2	7.4±0.4	7.5±0.2
Nitrite	mgL^{-1}	0.9±0.01	0.9±0.03	0.94±0.05
Ammonia	mgL^{-1}	16±2.1	16±2.3	16±2.2

* Each value is the Mean ±SD of three replicates (N=3)
* T1- Media based system; T2- Floating raft system and T3- Nutrient Film Technique

According to Barker *et al*, 2009 [4]; Sunny *et al*, 2017 [32] assessment of water quality is very essential and vital requirement for aquaculture production to maintain and produce high quality profitable fish. Islam et al, 2018a [14] stated that morphometric and physiology of fish like Growth, feed efficacy and feed consumption of fish are normally governed by a few physicochemical parameters, which included temperature, transparency, pH, oxygen, nitrite and ammonia of water. If any impairment in water quality it will alter growth, reproduction and even cause mortality.

From Table 1 it is clear that all the physicochemical parameters necessary for fishes in the fish rearing tanks were within the recommended range for aquaculture as stated by Ajani *et al*, 2011 [1]. The value of the all water quality parameters did not differ significantly ($p > 0.05$) in different treatments. Results of water analysis revealed that maintaining perfection of water quality parameters in aquaponic system specifically significant increase in pH value with dissolved oxygen and significant decrease in toxic ammonia, nitrite and temperature. According to Endut *et al*, 2009 [9]; Homme, 2012 [12] report aquaponics help farmers community to conserve water resources with control of water quality, the production schedule and the fish product which supports the present study (Shamsuddin *et al*, 2012) [28].

The growth parameters of the Nile tilapia *Oreochromis nilitocus* at the end of the experiment varied significantly ($P \leq 0.05$). All the growth parameters were recorded maximum in T1 followed by T2 and least in T3. The present study results was in accordance to Salam *et al* (2013) [25]; Salam *et al* (2014) [26]; Rana *et al* (2015) [24]; Bethe *et al* (2017) [5]; Kamrun Naher Azad *et al*, 2018 [16] cultured Tilipa whose recorded mean values of the morphological parameters like length gain and moderate specific growth rate of the present experimental fish was more or less analogous (Table 2).

Table 2: Growth performance of *Oreochromis nilitocus* in aquaponics treatment during the study.

Growth Parameters	Units	T1	T2	T3
Initial Length	cm	10.66±1.58	9.12±1.30	8.00±0.75
Final Length	cm	19.65±2.11	15.42±2.03	11.12±1.83
Initial Weight	gm	18.06±2.92	13.56±2.10	11.35±1.74
Final weight	gm	38.91±4.30	32.42±3.11	27.53±1.80
Mean length gain	cm	8.99±1.34	6.3±0.73	3.12±1.08
Mean weight gain	gm	20.85±1.38	18.86±1.01	16.18±0.06
Length gain	%	84.95±0.84	69.07±0.56	39.0±1.05
Weight gain	%	115.4±0.47	139.1±0.48	142.5±0.03
Feed conversion ratio		2.10±1.18	1.98±1.02	1.79±0.85
Specific growth rate	%	0.85±2.19	0.73±1.83	0.68±0.98
Survival rate	%	97.3±2.39	96.0±2.10	94.8±1.93

* Each value is the Mean ±SD of three replicates (N=3)
* T1- Media based system; T2- Floating raft system and T3- Nutrient Film Technique

In the present study the difference and fluctuation in fish growth among treatments could be due to reduction or disruption in feed intake by fish and behavioural responses to environmental change like stress and may be due to stocking density also. Khandaker *et al* (2013) [17] and Oladimeji *et al* (2018) [22] results are support the findings of the present study which states that recirculating fish waste with water through hydroponics increases the root growth and plant growth regulators activity. Moneruzzaman *et al*, 2010a [20] reported that fish waste contains important plant nutrient and growth regulators which enhance the growth of the plants.

As it is essential to supply food and ensure safety as an innovative agricultural technology this integrated culture called Aquaponics appears to be beneficial. The media based system and floating raft system proved to be more ecofriendly and it can be used any terrains, throughout the year and cost wise also it is economical when compared to nutrient film technology. Suitable plant and fish management has developed the interest of many farmers and entrepreneurs to instill this integrated system because of low investment but good income, low risk but good returns and less maintenance. Even at each home along with home garden this integrated Aquaponics with hydroponics can be installed and be used for home consumption. Thus, Aquaponics along with hydroponics serve as a good standard production of green vegetables and it also proved from the conducted experimental study that this system have great potentiality to ensure food security by meeting day to day requirements of fish and vegetables and helps in combating against malnutrition and adaptation to climate change.

Acknowledgement

I the author of this thankful to the management of Nirmala College for Women, Coimbatore in whose facility and seed money fund the research work was carried out. I would like to thank the Management and Department of Zoology for Providing the aquaculture lab and infrastrucutre. I owe my sincere thanks to Department of Marine Science, Marine Planktonology & Aquaculture Laboratory, Bharathidasan University, Tiruchirappalli for assisting in technical support of the aquapoinc systems.

References

1. Ajani EK, Akinwole AO, Ayodele IA. Fundamentals of Fish Farming in Nigeria. Wale Crown Publishers, Ibadan, 2011, 158.
2. Anonymous. Agricultural Statistics of Pakistan. Agriculture and Livestock, Economic Wing, Islamabad, Pakistan, 1997, 46-47.
3. Bailey DS, Ferrarezi RS. Valuation of vegetable crops produced in the UVI Commercial Aquaponic System. Aquacult Rep,2017:7:77-82.
4. Barker D, Allan GL, Rowland SJ, Kennedy JD, Pickles JM. A Guide to Acceptable Procedures and Practices for Aquaculture and Fisheries Research. Third Edition. Primary Industries (Fisheries) ACEC. Nelson Bay, Australia, 2009.
5. Bethe LA, Salam MA, Fatema UK, Rana KMS. Effects of molasses and compost tea as foliar spray on water spinach (*Ipomoea aquatica*) in aquaponics system. Indian Journal f Fisheries and Aquatic Studies,2017:5(3):203-207.
6. Bradley K Fox, Clyde S Tamaru, James Hollyer, Luisa F Castro, Jorge M Fonseca, Michele Jay-Russell *et al*. A preliminary study of microbial water quality related to food safety in recirculating aquaponic fish and vegetable production systems. Food safety and Technology, 2012.
7. Das PK. Effect of variety spacing and planting date on the growth and yield of Okra, MS Thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh, 2011.
8. Ding XT, Zhang ZH, Jiang YP, Chen CH. Application prospect of aquaponics technology in urban families. Acta Agriculturae Shanghai,2015:31:150-153.
9. Endut, A, Jusoh A, Ali N, Wan Nik WNS, Hassan A. Effect of flow rate on water quality parameters and plant growth of water spinach (*Ipomoea aquatica*) in an aquaponic recirculating system. Desalination and Water Treatment.,2009:5:19-28. doi: 10.5004/dwt.2009.559
10. Fox BK, Tamaru CS, Hollyer J, Castro LF, Fonseca JM, Jay-Russell M *et al*. A preliminary study of microbial water quality related to food safety in recirculating aquaponic fish and vegetable production systems. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. Food Safety and Technology. FST,2012:51:1-11.
11. Gruda N. Do soilless culture systems have an influence on product quality of vegetables? J. Appl. Bot. Food Qual,2012:82:141-147.
12. Homme JM. Aquaponic–Grønn vekst, 2012, 281.
13. Islam MM, Islam N, Mostafiz M, Sunny AR, Keus HJ, Karim M. Balancing between livelihood and biodiversity conservation: amodel study on gear selectivity for harvesting small indigenous fishes in southern Bangladesh, Zool. Ecol, 2018b. https://doi.org/10.1080/21658005.2018.1429895.
14. Islam MM, Sunny AR, Hossain MM, Friess DA. Drivers of mangrove ecosystem service change in the Sundarbans of Bangladesh. Singapore J. Trop. Geogr, 2018a, 39(2). https://doi.org/10.1111/sjtg.12241.
15. Johanson, Erik K. “Aquaponics and Hydroponics on Budget.” Tech Directions,2009:69(2):21-23.ERIC. Web 24. Jan 2013.
16. Kamrun Naher Azad, MA Salam, Md Zakir Hossain. Performance evaluation of different bedding media in aquaponic system for growth and production of okra and tilapia. International Journal of Engineering Research & Science,2018:4(9):14-25.
17. Khandaker MM, Boyce AN, Normaniza O, Faruq G, Motior Rahman M, Sofian-Azirun M. Fruit development, pigmentation and biochemical properties of wax apple as affected by localized application of GA3. Brazilian Archieves of Biology and Technology,2013:56(1):11-20.
18. Lal R. Feeding 11 billion on 0.5 billion hectare of area under cereal crops. Food and Energy Security,2016:5:239-251.
19. McCauley A, Jones C, Jacobsen J. *Basic Soil Properties.* Montana State University Extension Service, 2005, 1-12.
20. Moneruzzaman KM, Hossain ABMS, Normaniza O, Saifudin M, Sani W, Amru N. Effects of removal of young leaves and cytokinin on inflorescence development and bract enlargement in Bougainvillea glabra var. "Elizabeth Angus". Australian Journal of Crop Science,2010a:4(7):467-473.
21. Mubarak AE. Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus)* as affected by some home traditional processes. Food Chem,2005:89:489-495.
22. Oladimeji AS, Olufeagba SO, Ayuba VO, Sololmon SG, Okomoda VT. Effects of different growth media on

water quality and plant yield in a catfish-pumpkin aquaponics system. Journal of King Saud University-Science,2018:1(10):1-7.
23. Rakocy JE, Masser MP, Losordo TM. Recirculating aquaculture tank production systems: aquaponics – Integrating fish and plant culture. Southern Reg. Aquacult. Center,2006:454:1-16.
24. Rana KMS, Salam MA, Hashem S, Islam MA. Development of black soldier fly larvae production technique as an alternate fish feed. International Journal of Research in Fisheries and Aquaculture,2015:5(1):41-47.
25. Salam MA, Asadujjaman M, Rahman MS. Aquaponics for improving high density fish pond water quality through raft and rack vegetable production. World Journal of Fish and Marine Sciences, 2013:5(3):251-256.
26. Salam MA, Jahan N, Hashem S, Rana KMS. Feasibility of tomato production in aquaponic system using different substrates. Progressive Agriculture, 2014:25:54-62.
27. Savidov N, Hutchings E, Rakocy JE. Fish and plant production in a recirculating aquaponic system: a new approach to sustainable agriculture in Canada. Acta Horticult,2005:1(742):209-221.
28. Shamsuddin M, M Belal Hossain, M Mofizur Rahman, M Asadujjaman M, Yusuf Ali. Performance of Monosex Fry Production of Two Nile Tilapia Strains: GIFT and NEW GIPU, World Journal of Fish and Marine Sciences,2012:4(1):68-72.
29. Sharma N, Acharya S, Kumar K, Singh N, Chaurasia OP. Hydroponics as an advanced technique for vegetable production: An overview. Journal of Soil and Water Conservation,2018:17(4):364-371.
30. Singh U, Singh B. Tropical grain legumes as important human foods. Econ.Bot,2018:46:310-321.
31. Sirsat SA, Neal JA. Microbial profile of soil-free versus in-soil grown lettuce and intervention methodologies to combat pathogen surrogates and spoilage microorganisms on lettuce. Foods,2018:2:488-498.
32. Sunny AR, Naznin S, Rahman MJ, Nahiduzzaman M, Wahab MA. Assessment of the river water quality parameters and pollution: an insight from Dhaka city. International Symposium on Sustainable Urban Environment (Issue, 2017). Tezpur University, Assam, 2017.
33. Timmons MB, JM Ebeling, FW Wheaton, ST Sumerfelt, BJ Vinci. Recirculating aquaculture systems, 2nd Edition. Northeastern Aquaculture Center Publ. No. 01-002. Cayuga Aqua Ventures, 2002.
34. Tyson, RV, Treadwell DD, Simonne EH. Opportunities and challenges to sustainability in aquaponic systems. Hort Technol,2011:21:6-13.
35. Tzortzakis NG, Economakis CD. Impacts of the substrate medium on tomato yield and fruit quality in soil less cultivation. Journal of Horticultural Science,2008:35(2):83-89.
36. Vijayan MM, Leatherland JF. Effect of stocking density on the growth and stress-response in brook charr, Salvelinus fontinalis, Aquaculture,1988:75:159-170.
37. Wilson Lennard, James Ward. A Comparison of plant growth rates between an NFT Hydroponic System and an NFT Aquaponic System. Horticulturae, 2019:5(27):1-16. Doi:10.3390/horticulturae5020027.
38. Wongsiri S, Ohshima T, Duangmal K. Chemical Composition, Amino Acid Profile and Antioxidant Activities of Germinated Mung Beans (*Vigna radiata*) J. Food Process. Preserv,2015:39:1956–64.
39. Felix E, Avwemoya FE, Abah A. Some methods of monosex tilapia production: A review. skin (Megbowo, 2013; Beardmore et al.,, 2001). 2019;6:38.