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FEASIBILITY OF COCONUT COIR AND WATER HYACINTH ROOTS AS MEDIA IN VERTIPONICS SYSTEM TO GROW MINT

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ABSTRACT

Aquaponics is an innovative and integrated fish-cum-vegetables production system that can produce safer food while reducing environmental hazards. Present experiment was carried out to evaluate the efficiency of coconut coir (T_1) and water hyacinth roots (T_2) as media in a recirculatory (RAS) vertiponics system to grow tilapia (*Oreochromis mossambicus*) and mint (*Mentha arvensis*). The initial length and weight was 15.26(±1.41) cm and 60.06(±17.69) g respectively, and fed commercial pellet feed twice daily, initially at the rate of 5%, which gradually decreased to 3% and finally 2% body weight. Sampling of water, fish and plants were carried out fortnightly. Results showed that the water quality parameters were within the suitable range of fish culture and the amount of nutrients in effluent was lower than in influent as plants extracted the nutrients for their growth and survival. The mean height, number of branches and leaves and weight of plants were significantly higher in T_2 than in T_1. The mint production was also significantly higher in T_2 (12.47 tons/ha/90 days) than in T_1 (8.02 tons/ha/90 days). The fish survival rate was 98.33%, FCR 1.50 and fish production 135.2 tons/ha/90 days. It is concluded that fish production in the experiment was much higher than in conventional semi intensive systems practiced in the country. The system can be used for fish and vegetable production in urban and peri-urban areas, thus enhancing nutrition and food security while minimizing environmental pollution.

Keywords: Aquaculture, RAS, Feasibility, Fish and Mint.

1. INTRODUCTION

Bangladesh is one of the world's leading fish producing countries with a total production of 3.26 million tons in which inland fisheries contributed 82.26% comprising 29.34% from capture fisheries and 52.92% from aquaculture (DoF, 2013). The fisheries sector plays a significant role in alleviating malnutrition, earning foreign revenue and improving the socioeconomic status of the rural poor in the agrarian economy of Bangladesh. Fisheries and aquaculture altogether play a crucial role as a source of animal protein (60%) for millions of people in the country, and support the livelihoods of 10–12% of the population (FAO, 2012). The country ranked 4th position among the world's major aquaculture practicing countries (FAO, 2014). With the increasing population, agricultural land is decreasing day by day in the country, whereas, fish farming is expanding horizontally not addressing the environmental pollution and scarcity of land. In such situation, ecological engineering can be an alternative to solve the problems. It combines the ecology and engineering to solve environmental concerns as well as land scarcity in a cost effective and ecosystem approach (Kangas, 2004). The aquaponics system is a best practical example of ecological engineering, which can maintain sustainability in food production while keeping the environment safe and sound. It is an integrated system that uses nutrients from influent water of fish farming for vegetable, plants and herb production (Homme, 2012). Its principle is that nutrient rich waste water is channeled into growing secondary crop of economic value, while providing cost-effective and environmentally sound alternative water treatment by extracting minerals from it (Rakocy *et al.*, 1997). Depending on nature aquaponics have three different types such as media based which is simple and easy to implement where gravels, pebbles, brick lets and hydro tones are used as media in grow bed to plant the vegetable saplings. It is best suited for the beginners as there are slim chances to failure. Another type is nutrient film technique (NFT) where a thin film of water is flowing through the grow pipes or beds and plants roots remain submerge in the water and extract nutrients from there. Heavy rooted plants can't be grown in this system as it can clog the pipes. Also, some nutrients supplement is necessary in NFT system such as iron. Deep water culture (DWC), works on the idea of floating plants on top of the water allowing the roots to hang freely in the water. This method is one of the more commonly practiced in a commercial environment. Here only a single or two plant types are usually massed produced.

Mint is an aromatic herb which is used in food preparation to enhance flavor, as an ingredient of traditional medicine and aromatherapy (Normala *et al.*, 2010). Since time immemorial, it has played a vital role in world trade, due to its varied properties and applications (Sahil *et al.*, 2011). It is popular as organic herb in the Indian subcontinent for its health benefit, flavor, oil content and radio protective potential (Baliga and Rao, 2010). Hundred gram of mint contains about 78.65% moisture, 3.75% protein, 0.94% fat, 0.9% minerals and vitamins, 8% fibers and 14.89% carbohydrate along with 70Kcal of energy (The USDA National Nutrient Database, 2011). In addition, it has been used as a folk remedy for treatment of nausea, bronchitis, flatulence, anorexia, ulcerative colitis, and liver complaints due to its anti inflammatory, carminative, antiemetic, diaphoretic, anti spasmodic, analgesic, stimulant, emmenagogue, and anticatarrhal activities (Hadjlaoui *et al.*, 2009). It is mainly grown for its leaves and essential oil. Its leaves are used for herbal medicine preparations (Beemnet *et al.*, 2010), and the essential oil extracted is used in food industries (Verma *et al.*, 2010), because of its main component menthol and menthone (Gul, 1994). Mint oil is valuable natural products that used as raw materials in perfumes, cosmetics, aromatherapy, phytotherapy, spices and nutrition supplement (Prakash and Yunus, 2013).The mint usually grows in dump and water logged area which is unhygienic and prone to contaminated with fecal coliform and gram negative bacteria, whereas, if the mint is grown in aquaponic system in controlled condition, it is believed that the flavor of herbs would be much more higher than those grown in the damp soil (Normala *et al.*, 2010). Therefore, mint production in media based vertiponic system was carried out for integrated nutrient management which would improve the physical, chemical and biological properties of soil less mint production as well as to increase the productivity from a unit of area.

2. MATERIALS AND METHODS

2.1 Experimental site and cycle

The feasibility of coconut coir and water hyacinth roots were tested as media for mint production in vertiponic system. The experiment was carried out during a period of 90 days from 4th June to 4th September 2014 in the backyard Aquaponics laboratory, Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh. Among the different types of Aquaponic system, the media based vertiponic system was selected to conduct the experiment. Two different media, coconut coir (T_1) and water hyacinth roots (T_2), each having three replications were used in this experiment to grow the mint. The experimental design comprises a fish holding tank along with 6 three inch diameter PVC pipes of 3 ft long filled with coconut coir and water hyacinth roots used as the mint growing media. Each pipe contained 11 holes having equal distance from each other. The pipes containing coconut coir and water hyacinth roots were hung in a row using completely randomized design, indicated as T_1R_1, T_1R_2, T_1R_3, T_2R_1, T_2R_2, and T_2R_3. A 750 L capacity plastic water tank was used as the fish holding tank. An inlet and an outlet pipes connected to the vegetable growing tanks. A 25 watt submersible pump was used to recirculate water from the fish tank and pipes holding the growing media. An air pump with four air stones provided oxygen to the fish tank.

2.2 Preparation of fish tank and mint grow pipe

The upper section of a plastic water tank of 750 L was cut off and the lower section washed properly for keeping fish. After setting the tank, the bottom of the tank was filled to a depth of 3-4 inches with washed out brick lets. The inlet and outlet pipes were then plumbed to the vegetable tub and the fish tank. A 20 watt air pump with four air stones was set to diffuse oxygen in the water of the fish tank. An 18 ft long and 3-inch diameter plastic PVC pipe was cut into six equal pieces. Eleven holes of 1.5 inch diameter each were drilled at equal distances in each pipe. Three of the pipes were designated as T_1 and filled with locally collected coconut coir. The other three, designated T_2, were filled with water hyacinth roots. Then the pipes to grow mint were hung outside on a bamboo frame at a sun-exposed spot in the backyard Aquaponics laboratory.

2.3 Planting mint saplings and stocking of fish

Separately grown healthy mint saplings of 7.5-10 cm size each were planted in each pipe. In both treatments the mint sapling was uprooted from the soil and washed well with clean water before being transplanted into the pipes. Followed by mint sapling planting, 60 Tilapia (*Oreochromis mossambicus*) juveniles were collected from the previous experiment and released into the tank water after measuring initial length and weight. The number of fish was determined as 1 fish per 10 liter of water. Commercial floating starter tilapia feed containing 30% protein was used to feed the fish. The feed was applied twice daily, in the morning at 9:00 AM and in the afternoon at 5:00 PM at the rate of 5% of fish body weight during 1st month. The feeding rate was re-adjusted to 3% in the 2nd month and 2% in the 3rd month. Fish tank water was pumped with a 25 watt submersible aquarium filter pump from the fish tank to the mint pipes. The pump was operated only during daytime, switched on at 9.00 AM and switched off at 5.00 PM. The water supply pipe was cleaned regularly to avoid clogging with algae. No weeding was required in the system; however, if any unwanted plants were seen to grow, they were removed immediately.

2.4 Sampling of fish and harvesting mint

The mint sampling was done fortnightly but 1st harvest was carried out after one month of growing period. Following the harvest, their length and number of branches, leaf number and weight were recorded. Ten fishes were sampled randomly caught from the tank by using a scoop net. Length and weight of the fish were measured and the data were recorded in the computer. The fish and mint were finally harvested after 90 days of experiment. Fish length and weight at harvest were measured and their % length gain and % weight gain, specific growth rate (SGR), feed conversion ratio (FCR), survival rate and fish production were calculated.

2.5 Sampling of fish tank water parameters

Physio-chemical parameters such as dissolved oxygen (DO), temperature and pH of fish tank water were measured fortnightly. Sera water testing kits and Hanna® instruments (pH/Ec/TDS/DO) were used to test the physio-chemical parameters of water. Total nitrogen (Total-N), electric conductivity (EC), carbonate (CO_3), hydrogen carbonate (HCO_3), potassium (K), sulfur (S), sodium (Na) and phosphorus (P) were measured two times 1st at the beginning and 2nd at the end of the experiment at the Humboldt Soil Testing Laboratory, Soil Science Department, BAU.

2.6 Data processing and analysis

The collected data were recorded in the computer and checked for any error. Preliminary data were transferred into Microsoft Excel master sheet and prepared to show the findings of the experiment in tabular and graphical formats. One way ANOVA was performed on the collected data using Xlstat at 95% significance level. Tukey's HSD (Honestly Significant Difference), Duncan's multiple range tests and Fisher's LSD (Least Significant difference) tests were done to test for significant differences within the three triplicates and across the two treatments media means.

3. RESULTS

3.1 Water quality parameters

The average pH, temperature and dissolved oxygen of the water in the fish tank, recorded throughout the culture period, were 7.83(±0.14), 28.67(±1.18) $^{\circ}$C and 3.86(±0.04) ppm respectively. Except for DO, Fisher's LSD test showed no significant differences in the values of different water quality parameters at different dates (Table 1). The nutrient values in the effluent water were lower than in the influent water, but the difference was not significant in Fisher's LSD test (Table 2). The highest amount of EC was recorded in influent water in August of the experiment. Nutrients had significantly reduced in the effluent water at the end of the study because plants had extracted nutrients for their growth at that time. The amount of carbonate was higher at the beginning but was significantly reduced at the end in August. However, carbonate had increased again in the effluent water at the end of the experiment, possibly because of its reduced extraction by the mint plants at that time. The total-N, potassium, sulfur and sodium concentrations gradually increased from the beginning of the experiment but reduced again in the effluent water towards the end of the study, suggesting that these nutrients were consumed by the plants at a higher rate. However, the phosphorus content in the effluent water decreased during both months because the plants extracted phosphorus for their growth. The concentration of hydrogen carbonate however increased throughout the experiment and a significantly higher amount was recorded at the end of the study. It remained therefore unclear whether plants had used hydrogen carbonate or not (Table 2).

Table 1: Physio-chemical parameters in the fish tank water observed in different dates

Date	Parameters		
	pH	**Temperature (°C)**	**DO (ppm)**
4.6.2014	7.70 (±0.12)^{bc}	29.30 (±1.12)^{ab}	4.80 (±0.02)^{a}
19.6.2014	7.80 (±0.13)^{bc}	29.50 (±1.22)^{ab}	3.80 (±0.03)^{f}
4.7.2014	7.70 (±0.15)^{bc}	27.60 (±1.15)^{b}	4.70 (±0.05)^{b}
19.7.2014	7.60 (±0.11)^{c}	28.60 (±1.17)^{ab}	3.60 (±0.01)^{g}
4.8.2014	8.40 (±0.14)^{a}	27.90 (±1.18)^{ab}	4.10 (±0.04)^{d}
19.8.2014	7.70 (±0.16)^{bc}	28.10 (±1.19)^{ab}	3.90 (±0.06)^{e}
4.9.2014	7.90 (±0.17)^{b}	29.70 (±1.21)^{a}	4.30 (±0.07)^{c}
Mean	7.83 (±0.14)^{bc}	28.67 (±1.18)^{ab}	3.86 (±0.04)^{f}

The values in the same column having similar letter (s) do not differ significantly whereas values bearing the dissimilar letter (s) differ significantly as per Duncan's multiple range tests. Values in the parenthesis indicate the standard error.

Table 2: Nutrients in the influent and effluent water in the aquaponic system

Parameters	July		August	
	Influent	**Effluent**	**Influent**	**Effluent**
EC (µc/cm)	394 (±47.17)^{b}	338 (±31.21)^{b}	598 (±37.17)^{a}	391 (±58.17)^{b}
CO_3 (ppm)	72 (±6.12)^{a}	36 (±1.12)^{b}	12 (±2.12)^{c}	42 (±9.12)^{b}
HCO_3 (ppm)	189.1 (±17.13)^{b}	195.2 (±1.2)^{b}	219.6 (±28.13)^{ab}	256.2 (±51.13)^{a}
Total N (ppm)	4.2 (±1.15)^{b}	3.2 (±0.15)^{b}	11.2 (±1.15)^{a}	5.6 (±1.15)^{b}
P (ppm)	0.832 (±0.11)^{c}	0.398 (±0.03)^{d}	1.686 (±0.11)^{a}	1.191 (±0.11)^{b}
K (ppm)	15.13 (±1.14)^{a}	15.53 (±1.18)^{a}	14.5 (±2.14)^{a}	4.632 (±0.74)^{b}
S (ppm)	3.509 (±0.16)^{b}	3.709 (±1.19)^{b}	8.96 (±1.16)^{a}	1.67 (±0.19)^{c}
Na (ppm)	43.99 (±7.17)^{a}	43.99 (±1.21)^{a}	39.531 (±2.11)^{b}	37.95 (±1.17)^{b}

The values in the same column having similar letter (s) do not differ significantly whereas values bearing the dissimilar letter (s) differ significantly as per Duncan's multiple range tests. Values in the parenthesis indicate the standard error.

3.2 Fish growth and production

The initial mean length and weight of fish were 15.26(±1.41) cm and 60.06(±17.69) g respectively, and increased to 20.77(±1.55) cm and 174.6(±45.87) g at the final harvest. For each cm length increase of fish, the weight increased on in an average 19.91g. Tukey's (HSD) test showed significant differences in mean length and weight of fish between few sampling dates but not all the dates (Table 3). The Coefficient of determination, (R^2 value) was 0.982, signifying that 98% of the variation of the dependent variable (weight) can be explained by the independent variable (length). The positive correlation (r=0.99) between the length and the weight of tilapia is very high (Fig. 1). The mean food conversion ratio in the experiment was 1.50, survival was 98.33%, % length gain 36.11(±9.93), % weight gain 190.71 (±159.29) and total production of tilapia were 135.20 tons/ha/90 days (Table 4).

Table 3: Length (cm) and Weight (g) of fish in different dates

Date	Length (cm)	Weight (g)
04.06.2014	15.26 (±1.41)^{c}	60.06 (±17.69)^{d}
19.06.2014	16.09 (±0.96)^{c}	77.39 (±15.95)^{d}
04.07.2014	16.72 (±1.66)^{c}	83.55 (±28.96)^{d}
19.07.2014	17.21 (±1.59)^{bc}	90.71 (±24.77)^{cd}
04.08.2014	19.04 (±1.59)^{ab}	129.90 (±34.21)^{bc}
19.08.2014	19.50 (±1.66)^{a}	134.50 (±37.55)^{ab}
04.09.2014	20.77 (±1.55)^{a}	174.60 (±45.87)^{a}

The values in the same column having similar letter (s) do not differ significantly otherwise differ significantly ($p<0.05$) as per Duncan's multiple range tests. Values in the parenthesis indicate the standard error.

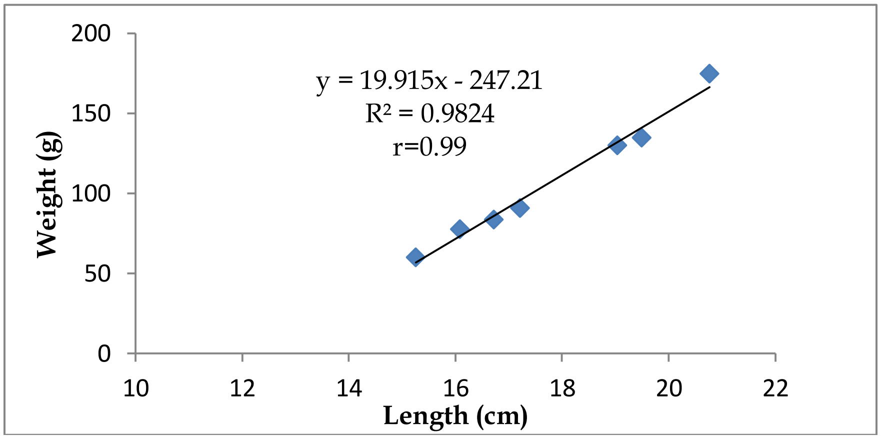

Figure 1: Length–weight relationship of tilapia

Table 4: Growth performances tilapia observed during the study period

Growth Performances	**Value**
Mean initial length (cm)	15.26 (±1.41)
Mean final length (cm)	20.77 (±1.55)
Mean length gain (cm)	5.51 (±0.14)
% length gain	36.11 (±9.93)
Mean initial weight (g)	60.06 (±17.69)
Mean final weight (g)	174.6 (±45.87)
Mean weight gain (g)	114.54 (±28.18)
% weight gain	190.71 (±159.29)
Specific growth rate (% per day)	0.83
Feed conversion Ratio (FCR)	1.50
Survival rate (%)	98.33
Fish Production (tons/ha/90 days)	135.2

3.3 Plant growth and yield

The mint height and leaf number were measured at 15-days interval and harvesting was started after one month of growth. The mean height, number of leaves and weight of the plants at the end of the experiment were 19.62(±2.23) cm, 25.19(±3.72) and 4.54 (±0.67) g respectively in T_2. Moreover mean height, number of leaves and weight of the plants in T_1 were 8.95(±0.55) cm, 18.41(±4.15) and 1.16(±0.21) g respectively (Table 5). Tukey's (HSD) test showed no significant differences between the plant height in T_1 and T_2 on different sampling dates except on 18.6.2014, 3.7.2014 and 18.7.2014 ($p<0.05$). On the other hand, leaf numbers were significantly different between T_1 and T_2 on the sampling dates of 18.6.2014, 3.7.2014 and 3.8.2014. Similarly, weight gain was found significantly different between T_1 and T_2 on the sampling dates of 3.7.2014 and 3.8.2014. The mint production was significantly higher in T_2 (12.47 tons/ha/90 days) than in T_1 (8.02 tons/ha/90 days) (Table 5). Plant growth and yield observed in different sampling dates are shown in Fig. 2.

Table 5: Plant growth and yield observed in two different media during study period

Media	Date	Plant height (cm)	No. of leaves (no.)	Weight (g)
Coconut coir (T_1)	18.6.2014	9.90 (±1.92)^{b}	10.03 (±2.70)^{b}	No data
	3.7.2014	17.34 (±4.34)^{ab}	19.64 (±5.44)^{ab}	2.54b (±0.47)^{c}
	18.7.2014	8.95 (±0.55)^{b}	16.64 (±3.05)^{ab}	1.16 (±0.21)^{c}
	3.8.2014	14.35 (±0.81)^{ab}	18.41 (±4.15)^{ab}	1.89 (±0.40)^{c}
	18.8.2014	15.85 (±5.54)^{ab}	22.18 (±6.81)^{ab}	1.75 (±0.45)^{c}
	4.9.2014	10.99 (±1.68)^{ab}	17.67 (±7.80)^{ab}	1.70 (±1.0)^{c}
Water hyacinth roots (T_2)	18.6.2014	12.78 (±2.10)^{ab}	10.11 (±1.26)^{b}	No data
	3.7.2014	19.62 (±2.23)^{a}	24.56 (±1.0)^{a}	4.54 (±0.67)^{a}
	18.7.2014	11.00 (±2.39)^{ab}	15.98 (±2.67)^{ab}	2.01 (±0.50)^{c}
	3.8.2014	15.56 (±0.94)^{ab}	25.19 (±3.72)^{a}	3.85 (±0.84)^{ab}
	18.8.2014	16.61 (±6.16)^{ab}	20.30 (±2.22)^{ab}	1.59 (±0.18)^{c}
	4.9.2014	13.09 (±0.16)^{ab}	19.00 (±5.04)^{b}	2.0 (±0.884)^{c}
Mint production in T_1 (tons/ha/90 days)				8.02 (±2.47)^{b}
Mint production in T_2 (tons/ha/90 days)				12.47(±3.04)^{a}

The values in the same column having similar letter (s) do not differ significantly otherwise differ significantly ($p<0.05$) as per Duncan's multiple range tests. Values in the parenthesis indicate the standard error.

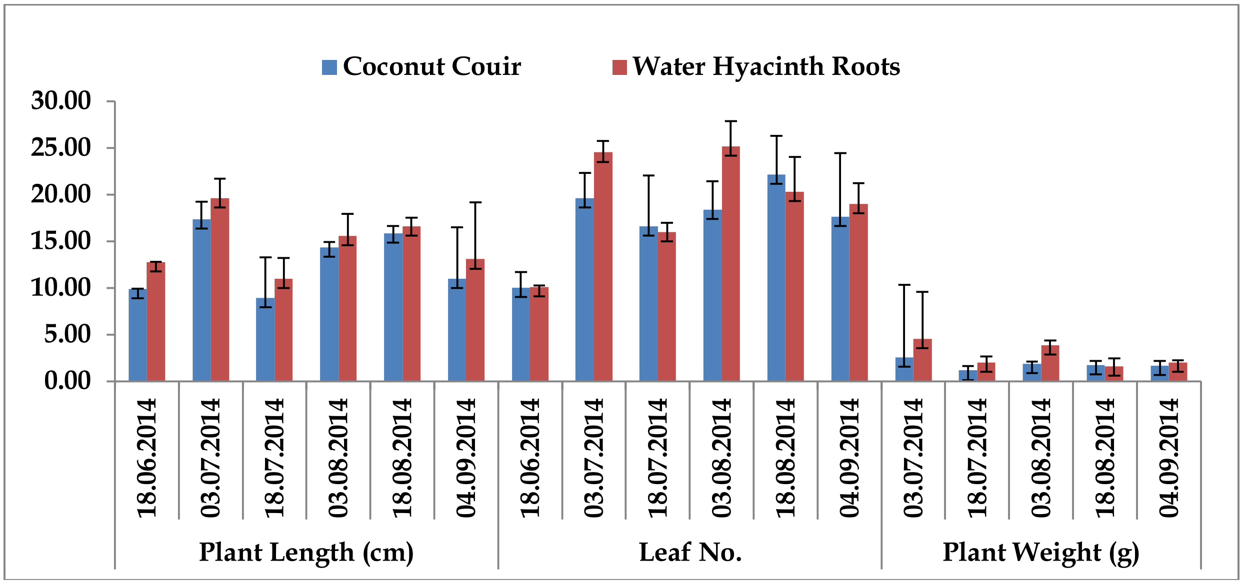

Figure 2: Plant growth and yield observed in different dates in treatments T_1 and T_2

4. DISCUSSIONS

4.1 Water quality parameters

The experiment was carried out to grow mint in two media, the coconut coir (T_1) and water hyacinth roots (T_2) in triplicates to see which media perform better in the RAS vertiponic system. A critical challenge in aquaponic system is maintaining a water pH that is suitable for both fish and plants. The ideal water pH for hydroponic plants is 5.5–6.5, while for the fish the ideal pH is between 7.0 and 9.0 (Tyson et al., 2007). The range of pH value in the water in the present experiment was 7.60(±0.11) to 8.40(±0.14) during the culture period. The mean pH value of 7.83(±0.14) was suitable for fish but not optimal for plants. Ekubo and Abowei (2011) mentioned that the average pH of a closed water body is 7.4; the range of 7.0 to 8.5 is optimum and favorable to fish growth. Plants in an aquaponic system grow best at pH 6.0 to 6.5 and the nitrifying bacteria perform better at pH 6.8 to 9.0 (Nelson, 2008). So, the range of pH value found in the present study was also good for nitrification as the nitrifiers rely on a biochemical reaction (oxidation) as a way of transporting electrons, drawn from the ammonia or nitrite compounds. Just we can imagine oxygen as a garbage collector. Under the low oxygen levels, the bacteria use nitrite or nitrate as an acceptor, or garbage collector, reversing the process from nitrifying to denitrifying (removal of nitrates).

Tilapia is, in general, highly tolerant of low dissolved oxygen concentrations, even down to 0.1 mg/L (Magid and Babiker, 1975), but optimum growth is obtained at concentrations greater than 3 mg/L (Ross, 2000). In the present study, the range of DO content in fish tank water was 3.60(±0.01) to 4.80(±0.02) ppm, with mean DO of 3.86(±0.04) ppm. The DO concentration in the present study decreased after 2 weeks from the start of the experiment. This may be due to the microbial activities and plant root respiration (Pierce and Rice, 1998). The nitrifying bacteria growing on the root systems could have taken up the oxygen (Sutton *et al*., 2006), thus decreasing DO levels in the re-circulated water returning to the fish tank. Towards the end of the experiment, DO concentrations increased again, which could be due to reduced microbial activity in the system (Holtman *et al*., 2005). The survival of tilapia depends upon how long it is exposed to low dissolved oxygen.

Tilapia has a wide range of temperature tolerance between 20-35°C for growth, where the optimum is reported to be 26 to 28°C. The ideal water temperature for Nile tilapia (*Oreochromis niloticus*) ranges are 28-35°C (Chervinski, 1982). The low and high lethal temperature thresholds for Nile tilapia are 11 and 42 °C respectively (Balarin and Hatton, 1979). During the experiment the water temperature in the fish tank ranged from 27.60(±1.15) to 27.90(±1.18) °C, with an average temperature of 28.67(±1.18) °C. So, the temperature found in this experiment was within the suitable range of tilapia growth. On the other hand, nitrification takes place between 7 and

35°C with an optimum temperature of 15 to 25°C (Wortman and Wheaton, 1991). So, the temperature obtained in current experiment falls within the range of nitrification.

4.2 Influent and effluent water quality parameters lab test

In aquaponics, the waste produced by fish serves as manure for the plants and cleaner water returns to the fish tank again. The highest value of phosphorus was 1.69(±0.11) ppm as measured in the influent while it was reduced to 1.19(±0.11) ppm in the effluent in August. However, 52% P removal was found in July that was 29.5% in August. It can be noted that initially P concentration in the influent water was lower in July than in August and removal was higher but later when concentration has increased plants took it according to their requirement that reduced the extraction level Ghaly *et al.* (2005) reported 91.8 to 93.6% P reduction in aquaponic system where he grown barley as vegetable. Boyd (1998) reported the tolerable P level in aquaponic systems was 0.20-1.15 ppm. The phosphorous level in the present study was within the range of the above findings.

The potassium and sulfur concentrations in the effluent water were higher than in the influent at the start of the experiment. However, at the end of the experiment, when the plants had reached maturity, these concentrations in the effluent significantly reduced relative to their influent concentrations. Sodium content remained static in inlet and outlet water at the start of the experiment, but gradually decreased in 2nd month, suggesting that the plants may require a little amount of sodium for their growth. Lower nutrient concentrations are generally acceptable for aquaponics as nutrients are derived from excess feed provided to the fish in the tank, and small amounts of nutrients are added from the fish feces and mineralization of organic matter (Rakocy *et al.*, 2004).

Higher rates of CO_3 reduction (72.00±6.12 to 36.00±1.12 ppm) were noticed in the system in July, while the value increased significantly in the effluent in August. On the other hand, the HCO_3 level gradually increased over the culture period as plants didn't take up the carbonate at significant level. A similar result was obtained by Salam *et al*. (2014).

The lowest total-N removal from the influent was 23% in the present study (4.20±1.15 to 3.20±0.15 ppm) observed in July, whereas the highest removal from the system was 50% in August. Ghaly and Snow (2008) reported 76% of total-N removal with Arctic charr (*Salvelinus alpinus*) based aquaponics system, which was higher than the present findings.

The EC is the measurement of electrical current movement through the water. The current can only move through water when there is some salt dissolved in water, but cannot move through pure water. A greater amount of salt dissolved in the water, higher EC and higher nutrient concentrations in water result in superior growth of plants (Bill, 2004).The EC value decreased in the effluent throughout the culture period. The highest EC value was 598.00(±37.17) μc/cm in inlet water, which reduced to 338.00 (±31.21) μc/cm in the outlet. The current results are evidence of nutrient removal from the fish tank water that was utilized by the mints for their growth.

4.3 Fish growth and yield

Tilapia is the most common fish used in aquaponics system worldwide. It is well adapted to changes in pH, temperature and in pollutants (Johanson, 2009). In addition, tilapia can grow quickly; the feed conversion ratio is higher than conventional culture species and it accepts all sorts of foodstuffs for their growth (Childress, 2003). The length and weight of Tilapia in this experiment increased from 15.26(±1.41) to 20.77(±1.55) cm and 60.06(±17.69) to 174.6(±45.87) g respectively at the time of final harvest where the length and weight gain were respectively 5.51(±0.14) cm and 114.54(±28.18) g. Midmore (2011) reported a mean weight gain of tilapia of 85.39(±12.04) g after 180 days of rearing in a roof-top and self-sufficient on fresh food production in Australia. The present finding is much higher than Midmore's findings. The reason behind the higher growth of fish can be the better management practice; higher rate of nutrient absorption, good quality feed used and clean water, and a more favorable temperature than the above study. The FCR of the present study (1.50) matched with the finding (1.5-2.0) of Watanabe *et al*. (2002) and is bit higher than Kanial (2006), who reported FCR of about 1.81 in a recirculating system using Nile tilapia at the density of 100 fish/m^3 in the central laboratory of aquaculture research in Egypt for 180 days and obtained.

In the present study, tilapia was reared at a density of 80/m^3 in a 750 liter plastic water tank for 90 days in the RAS system, with a survival rate of 98.33%, similar to the survival rate of 97% reported by Kanial (2006). Chhorn *et al.* (2008) reported survival rates of tilapia ranging from 88.6 to 99.3%, where he used various levels of lipid from different sources. The present findings are also within this range. The total tilapia production was 135.2 tons/ha/90 days, which is much higher than the conventional semi-intensive tilapia mono culture system and similar to intensive fish farming practiced globally. Licamele (2009) conducted an aquaponics experiment combining tilapia and lettuce culture in RAS. He stocked 2 kg fish/m^3 and fed formulated feed at 2% of fish biomass daily, reporting a production of 16.71 kg fish/m^3/90 days, i.e. much lower than the present fish production.

4.4 Plant growth and yield

Aquaponics is an integrated system where fish is growing in RAS and vegetable in the soilless hydroponic system without the use of fertilizers and pesticides. The system is efficient to reduce chemicals and water use in an integrated aquaponics system and managed to maximize profit from the system utilizing free nutrients, less water and competent monitoring, elimination of separate bio-filters, and yielding two crops from the same input and space, time and labour (Rakocy, 1999) and Rakocy *et al*. (2004) reported similar results from the aquaponic system. Water hyacinth is an aquatic plant suitable to be used as aquaponics media for filtration of organic matter, suspended materials, heavy metals, excess nutrients from the aquaponics system at high efficiency. While water hyacinth root was used as a media for mint production, gradually its volume shrank due to its decomposition with continuous water supply and rainfall, which created additional problems such as insect growth and went down slightly from its original position with the mint plants. Coconut coir is however widely used in various plant growing substrates such as potting mix, hanging basket and flower planting. The coconut coir used in the present study as T_1 in comparison to mint production with water hyacinth media (T_2) is less expensive and locally available. It has anti-microbial properties. Although coconut coir is an organic plant material, it breaks down and decomposes very slowly; it do not provides any nutrients to the plants growing in it, making it a perfect medium for hydroponics. Coconut coir is also pH neutral, holds moisture well, while allowing good aeration for the roots.

The total mint production was 8.02 and 12.47 tons/ha/90 days in T_1 and T_2 respectively. Salam *et al*. (2013) reported mint production from rafts in pond and racks at the pond dyke at 763 and 1969 kg/ha/90 days respectively. They also mentioned mint production was highly profitable in comparison to other crops, with a benefit-cost ratio of about 6.33 for rafts and 14.97 for racks (Salam *et al.*, 2013). In another mint growing study, Roy *et al.* (2013) found a benefit-cost ratio of 7.82. Normala *et al.* (2010) also mentioned that mint growth was higher in aquaponics system than in suspended culture. The findings from the present study are higher than those found in the previous studies. If farmers cultivate fish with mint in a vertiponics system, they can reduce pressure on land and improve livelihoods through higher income from the system. The system is environmentally friendly and does not create any harm to the nature, so-called green technology (Normala *et al.*, 2010). The technology can be piloted with other crops in different agro-ecological zones in the country to test its efficiency.

5. CONCLUSION

Aquaponics run with the principles of recycle nutrients and water that seem to be a promising solution for sustainable aquaculture and hydroponic practices. The present study used two different media in the vertiponics system which performs well; however, water hyacinth performed significantly better than the coconut coir media. The system made more efficient use of nutrients compared to conventional systems, and therefore could potentially help to enhance food and nutrient security in the country if adopted at large scale. In this amazing food growing technology the fish acts as the powerhouse of vegetable production.

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