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Cost effective aquaponics for food security and income of farming households in coastal Bangladesh

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ABSTRACT

This study was designed for integrated culture of fish and vegetables in cost effective aquaponics. Using cheaper, locally available inputs a 3 m^2 (1.52 m × 2.12 m) cages were introduced in pond; within a total cost between US$ 15 and 25. On three sides of the cages, there were sunshade-like structures to support horticulture products and a trellis to support climbing plants. Three treatments were introduced; monoculture of Tilapia (*Oreochromis niloticus*), polyculture of climbing perch (*Anabas testudineus*) and Tilapia (*Oreochromis niloticus)* and monoculture of Climbing perch (*Anabas testudineus*). After 80 days, the average weight of Tilapia was 178.5 g ± 0.92 SE and 174 g ± 1.2 SE in monoculture and polyculture with 19 cm ± 0.11 SE and 17 ± 0.14 SE cm in size respectively from 24 g ± 0.20 SE and 22 g ± 0.22 SE initial weight respectively with 4 cm of initial size. Climbing perch became 70 g ± 1.0 SE weight in monoculture and 57.6 g ± 0.93 SE in polyculture from 0.50 g ± 0.05 SE initial weight. The study found that treatment-1 (benefit cost ratio: 2.2) was more suitable. Considering the low capital cost, good return on investment and reduced vulnerability of this culture system to tidal surges and flood, this technology has the potential to increase resilience of the farming households with ponds towards climate change in the coastal region.

Introduction

The word 'aquaponics' is a combination of 'aquaculture' (fish farming) and hydroponics (cultivation in water). It raises both vegetables and fish in a limited space at a relatively low financial cost by adding diversification in culture technique (Nelson, 2008). This technique is a way of using an aquaculture site for vegetable production and may help to overcome the increasing nutrition demand of Bangladesh in polyculture pond (Mithun et al., 2013; Salam et al., 2013). In developed countries concerns about pollution issues have raised interest in aquaponics as a valid option to get rid of aquaculture wastes through the production of high value vegetables (Rakocy et al., 2006; Diver, 2006). Shrinking total agriculture land, uncontrolled population growth and complex and unpredictable weather create new challenges to the country's agriculture (Edoardo, 2008; Islam et al., 2018a) that highlight the developing new crop production systems like aquaponics (Salam et al., 2014). In coastal areas, herbs and vegetable plants cannot grow well as land remains water-logged in the rainy season, or is dry due to lack of irrigation the rest of the year (Islam et al., 2018b). In the Barisal region, vegetables are cultivated on the household pond dike to avoid water-logging while fish is stocked in the pond. However the ponds of Barisal region are surrounded by large timber trees that hinder sunlight penetration and therefore plant growth. Furthermore, farmers are facing another problem as fish can escape from the pond during inundation due to heavy rain or tidal surge etc. (Haque et al., 2015). In the proposed pond aquaponics system these constraints are reduced because

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plants grow in the middle of the pond out of the shade of trees and there is less chance of fish loss as the fish are in a floating, closed structure.

Integrated culture has been practiced from generation to generation in Bangladesh. Farmers of the Bhangura Upazila of Pabna district are practicing integrated culture of fish, vegetables and duck by enclosing a part of a canal or river by net. Salam et al. (2013) experimented to see the feasibility of raft and rack based vegetable culture in polyculture in Mymensingh region of Bangladesh. Haque et al. (2015) assessed how this technology fits into the socio-economic status of farmers and physical characteristics of the pond by introducing IFCAS (Integrating Floating Cage Aquageoponics System) in the Barisal region. In this study further initiative was taken to modify this integrated culture system to increase productivity and reduce the construction cost of the structure. An attempt was also made to identify suitable fish species, profitable culture type and which density in a culture system fish grow well comparing among the cages of a treatment. Further research is still needed to optimize stocking density for monoculture of tilapia in floating pond aquaponics with more replication though simplicity, easy management and low equipment cost make this system an interesting solution.

Materials and methods

The research was conducted in two communities of 'Char Kawa' union under Sadar Upazila of Barisal district, in the coastal zone of the Bay of Bengal, situated in the south-central part of Bangladesh (Fig. 1). The study period was 80 days, in between 1 October 2014 and 20 December 2014.

Design and structure of the cages

A three square meter (1.52 m × 2.12 m) frame was constructed by bamboo-split. The bottom of the cage frame was formed by a rectangular nylon net with a weight of brick in four corners. On three sides of the cages there was an area for horticulture. Above the cage a horizontal trellis was built to support climbing plants. Of the four sides of the trellis and cage, one side was left open for sunlight penetration and easy collection of fishes and vegetables (Fig. 2).

Three sides of the trellis and cage was extended 12 in. with bamboo frame and net roof (like the sunshade of a building). A mixture of dried pond sludge, cow dung and other manure was placed to plant crops. Several holes were made for access of the roots to pond water. 15–20 Plastic bottles each having 10 L or 15 L floating capacity were attached for flotation.

Setting up of the experiment

Leafy vegetables, less bushy shrubs, climbing vegetables and medicinal plants were planted into low cost containers like unused plastic bottles, plastic baskets, bamboo baskets, plastic plates and even a broken television cover. Different nutritious vegetables having economic importance were selected that included green pepper, bombay pepper, white pepper (locally called *khara morich*), bean, long bean, basil, *pudina* (mint), bitter gourd and tomato.

Three treatments were setup to observe the growth of different culture systems in different densities. Treatment-1 for monoculture of tilapia, treatment-2 for polyculture of climbing perch (*Anabas testudineus*) and tilapia, treatment-3 for monoculture of climbing perch (*Anabas testudineus*). Tilapia (*Oreochromis niloticus*) fingerlings of 22 g ± 0.22 SE and 24 g ± 0.20 SE average weight were stocked in the cages of treatment-1 and treatment-2 respectively. The average weight of each climbing perch fry was 0.5 g ± 0.05 SE. In treatment-1 the stocking density of fries were 100/m^2, 84/m^2, and 67/m^2 in cage-1, cage-2, and cage-3 respectively. Stocking density of tilapia and climbing perch was 84/m^2, 75/m^2, 117/m^2, and 34/m^2, 42/m^2, 25/m^2 in cage-1, cage-2, and cage-3 respectively for treatment-2. Stocking density of climbing perch was 150/m2, 133/m2 and 117/m2 in cage-1, cage-2, and cage-3 respectively for treatment-3 (Table 2). The fry was acclimatized before stocking and after acclimatization then it was counted and released to the cage of aquaponics. For the experiment commercial feed was used. The proximate composition of experimental diet was taken under consideration during selection. The moisture, protein, crude fiber, lipid, ash and nitrogen free extract (NFE) were 12.14, 27.94, 5.23, 7.95, 15.38 and 36.59% in that feed respectively. Farmers were recommended to feed tilapia and climbing perch twice a day in the early morning and afternoon depending on the body weight of the stock. In the first month (October), feeding was done at the rate of 20% and 15% of the body weight of tilapia and climbing perch respectively. From the second month, tilapia and climbing perch were fed up to satiation.

Data collection and analysis

Water quality parameters were examined during the experimental period. Physicochemical parameters of pond water were monitored every ten days interval between 9.30 and 10.30 am. Water temperature was recorded using a Celsius thermometer and transparency (cm) was measured by using Secchi disc of 20 cm diameter. Dissolved oxygen and pH were measured directly using a digital electronic oxygen meter (YSI, Model 58, USA) and an electronic pH meter (Jenway, Model 3020, UK). Total ammonia of water samples was determined with the help of a Hach Kit (Model DR 2010, USA). Nitrate of water samples was determined by using a Hach Kit (DR-2010, USA) and necessary reagent pillow NitroVer-5.

Fish health and disease was monitored during feeding and sampling. Fish were sampled at 20 days intervals and measured to determine length and weight, using a ruler and electronic balance. Fish and vegetable production and consumption data were recorded by farmers. The collected data were analyzed through one way Analysis of Variance (ANOVA) using Microsoft Excel software. The level for significance was set at 0.05%.

Results

Fish production

A significant difference ($p < 0.005$) was found between the growth of tilapia and climbing perch in monoculture and polyculture. The growth of fish (tilapia and climbing perch) was found higher in monoculture than polyculture. This was attributed to many factors such as stock of different age group, management capacity of farmers, water quality, intensity of sunlight penetration into the pond etc. This experiment was conducted in winter season; hence low temperature also affected the actual result of all treatments. Survival rate of the cages of the treatments showed that the survival rate of tilapia was higher than climbing perch.

Growth performance of fish in treatment-1

The growth of tilapia indicated that the growth varied in different density. T-1-C-1 showed the highest growth and survival rate among all the cages of this treatment. Here fish growth decreased as the density increased except T-1-C-2. The initial weight of fry was 24 g and length was 4 cm during the releasing period. The final weight and length of fish were 201 g ± 0.92 SE and 20.5 c ± 0.10 SE for T-1-C-1, 155.5 g ± 0.89 SE and 18.5 c ± 0.10 SE for T-1-C-2,

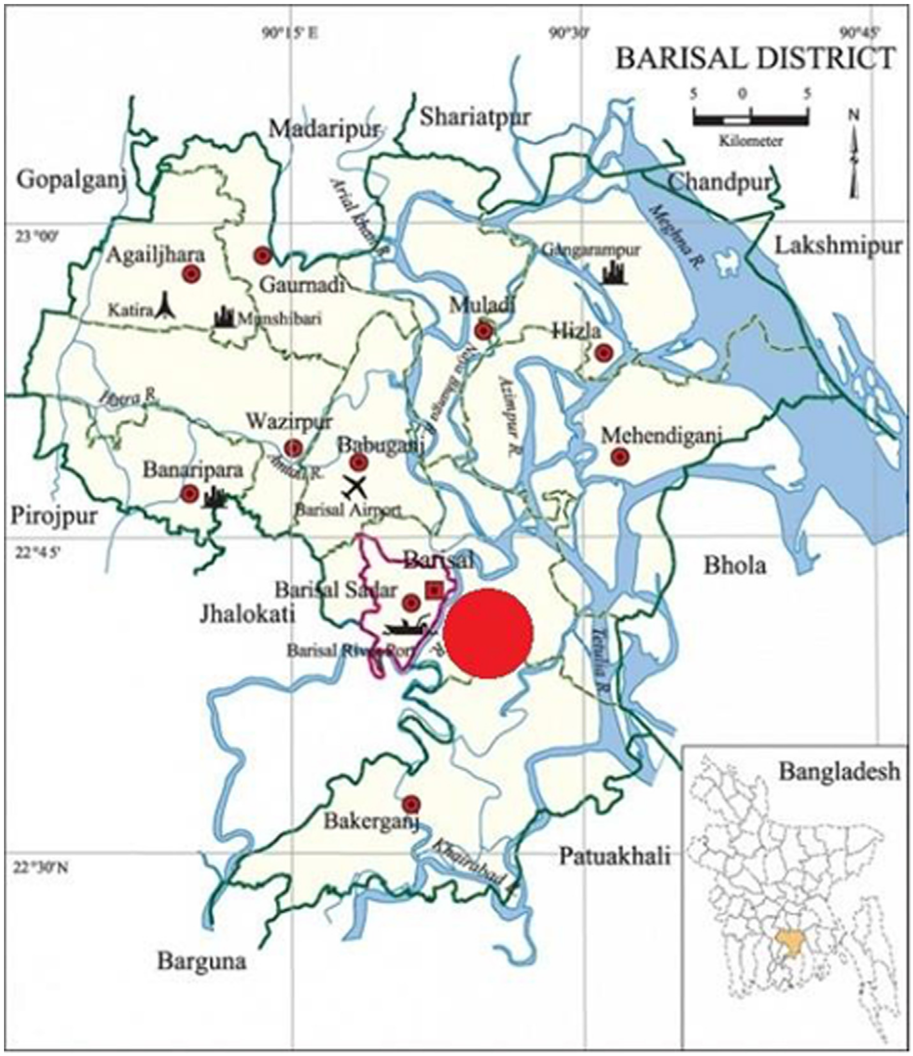

Fig. 1. Map of the study area.

178.5 g ± 0.96 SE and 17 c ± 0.15 SE for T-1-C-3 respectively (Fig. 3). The maximum final weight was observed in C-1 having stocking density 100 fish/m^2. The lowest final weight was observed in C-2 having stocking density 84 fish/m^2. The weight gain of fish was 177 g ± 0.92 SE, 121.5 g ± 0.89 SE and 154.5 g ± 0.96 SE for T-1-C-1, T-1-C-2 and T-1-C-3, respectively. Total production was 40.2 kg, 38.88 kg, 53.6 kg in C-1, C-2 and C-3 respectively. The FCR was observed to be 1.2, 1.28 and 1.23 in C-1, C-2 and C-3 respectively. The survival of monosex tilapia was observed as 97.67%, 94.25% and 93.40% in C-1, C-2 and C-3 respectively.

Growth performance of fish in treatment-2

Tilapia gave better growth in C-1 while climbing perch gave better result in C-2. The initial weight was 22 g and 0.5g for tilapia and climbing perch respectively. Final weight for tilapia was 187 g ± 0.96 SE, 163 g ± 0.98 SE, 172 g ± 1.66 SE and for climbing perch was 50 g ± 0.89 SE, 57 g ± 0.89 SE, 66 g ± 1.01 SE, whereas, weight gain was 165 g ± 0.96 SE, 141 g ± 0.89 SE, 150 g ± 1.66 SE for tilapia and 49.5 g ± 0.89 SE, 56.5 g ± 0.89 SE, 65.5 g ± 1.01 SE for climbing perch with the total production of 45 kg, 33.75 kg, 34.4 kg for tilapia and 10.2 kg, 21.3 kg, 22.77 kg for climbing perch in C-1, C-2, C-3 respectively. Final length for tilapia and climbing perch was 19.13 cm ± 0.12 SE and 6.5 cm ± 0.11SE, 15.21 cm ± 0.10 SE and 7 cm ± 0.13 SE, 16 cm ± 0.20 SE and 8 cm ± 0.10 SE in C-1, C-2, C-3 respectively (Fig. 4). The FCR of the treatment was observed 2.2. The survival rate was 94% for tilapia and 80% for climbing perch.

Growth performance of fish in treatment-3

The growth of climbing perch in monoculture is higher than polyculture. The initial weight of fry was 0.5 g and size was 0.4 cm during the releasing period. The final weight of fish was 70 g ± 1 SE and size was 8 cm ± 0.11 SE. Weight gain of individual fish was 69.5 g ± 1 SE. Total production of climbing perch was 31.5 kg. FCR of climbing perch was 2.5 and the survival rate was 84.5%. Empirical evidence of the effects of stocking density on growth and survival of climbing perch was found in this study. In the present study, the average individual fish weight was 57.5 g in treatment-2 (polyculture) and 70 g in treatment-3 (monoculture) after an 80 days culture period.

Water quality parameter

The physicochemical parameters of water in all the treatments were monitored during the experimental period where the parameters were, temperature, transparency, pH, dissolved oxygen, nitrite and ammonia. The value of the parameters did not differ significantly ($p > 0.05$) in different treatments (Table 1). During the whole experiment, water temperature was considerably low due to entering the winter season.

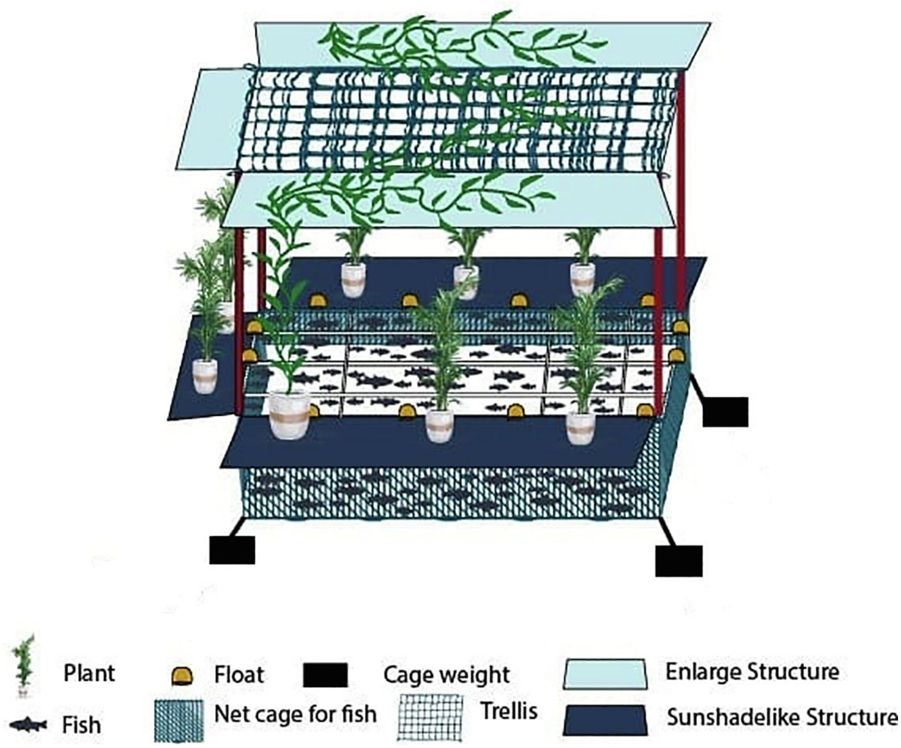

Fig. 2. Design of pond aquaponics with different components.

Management technique

To minimize the effect of winter and increase the production different initiatives were taken such as- stocking of larger size fingerlings, regular movement of the cages i.e. the cages of aquaponics were moved to the area in the pond where direct sunlight was available by pulling it with a rope and a pulley. Due to shift of cage, movement of fish occurred that increased the appetite and metabolism of fish. This initiative also allowed easy passage of wastage from the cage that improved the water condition as water surface agitation was important for maintaining a high oxygen level, removal of toxic waste and good gas exchange.

Growth performance of vegetables

Though fast growing vegetables were produced in aquaponics but better result was found in less bushy shrubs plants e.g. green pepper 5.7 ± 0.2 to 5.5 ± 0.4 kg and bombay pepper 2 ± 0.5 to2 ± 0.2 kg.

Production of leafy vegetables e.g. basil was 5 ± 0.5 to 5 ± 0.2 kg where 1.66 kg was grown per m^2. Average production of climbing plants such as long bean, bean/bitter guard was 7 ± 0.8–7 ± 0.1 kg and 5.5 ± 0.7–5.5 ± 0.5 kg respectively. Average production of very high priced medicinal plant *pudina* (mint) was 1.5 ± 03–1.5 ± 0.1 kg (Table 2). During the culture period green pepper, white pepper was harvested three times, whereas, bean, tomato, long bean, basil, bombay pepper, bitter guard was harvested two times and *pudina* (mint) was harvested one time.

Cost benefit analysis

The structural cost of aquaponics varied from US$ 15 to 25 (1200-2000 BDT) depending on the cost of available local materials. The overall net benefit from the intervention in treatment-1 was higher than treatment-2 and treatment-3.

Cost benefit analysis of different treatments

In treatment-1 aquaponics construction cost, maintenance and input cost and total cost per cycle, were US$ 25 (2000 BDT), US$ 48. (3842 BDT), US$ 52.16 (4175 BDT) respectively. Income from fish, income from vegetables and total income were US$ 77.4 (6189.40 BDT), US$ 36.32 (2889 BDT), US$ 113.72 (9078.40 BDT). Total average profit for treatment 1 was US$ 61.56 (4903.40 BDT). The benefit-cost ratio was 2.20.

Aquaponics construction cost, maintenance and input cost, total cost, was US$ 15.62 (1200 BDT), US$ 62.28 (4982.38 BDT), US$ 67.28 (5382.38 BDT), respectively in treatment-2. Income from Tilapia, income from climbing perch, income from vegetables and total income was US$ 66.15 (5292 BDT), US$ 19.8 (1584 BDT), US $ 38.94 (3114 BDT), and US$ 124.88 (9990 BDT). Total profit was US$ 57.60 (4607.62 BDT). Whereas the benefit-cost ratio was 1.90. The cost benefit analysis was calculated by considering 250 tilapia and 100 climbing perch of cage-1 of treatment-2 as this density of tilapia and climbing perch was found ideal for polyculture in pond aquaponics.

In treatment-3 aquaponics construction cost, maintenance cost, total cost was US$ 18.75 (1500 BDT), US$ 60.3 (4825BDT), US$ 65 (5200 BDT) respectively. Income from fish, income from vegetables, total income was US$ 85.93 (6875 BDT), US$ 37.41 (2993.5 BDT), US$ 123.35 (9868.5 BDT). Total profit was US$ 58.35 (4668.5 BDT). Whereas the benefit-cost ratio was 1.90 (Table 3).

Discussion

The interest in aquaponics is growing as an important part of the solution of increasing food shortages and needs for healthy food (Savidov et al., 2005). In Bangladesh land area is decreasing with the increasing population. So, we need to integrate the culture system. Pond aquaponics is such a new integrated aquaculture–agriculture technology for poor farmers particularly for climate

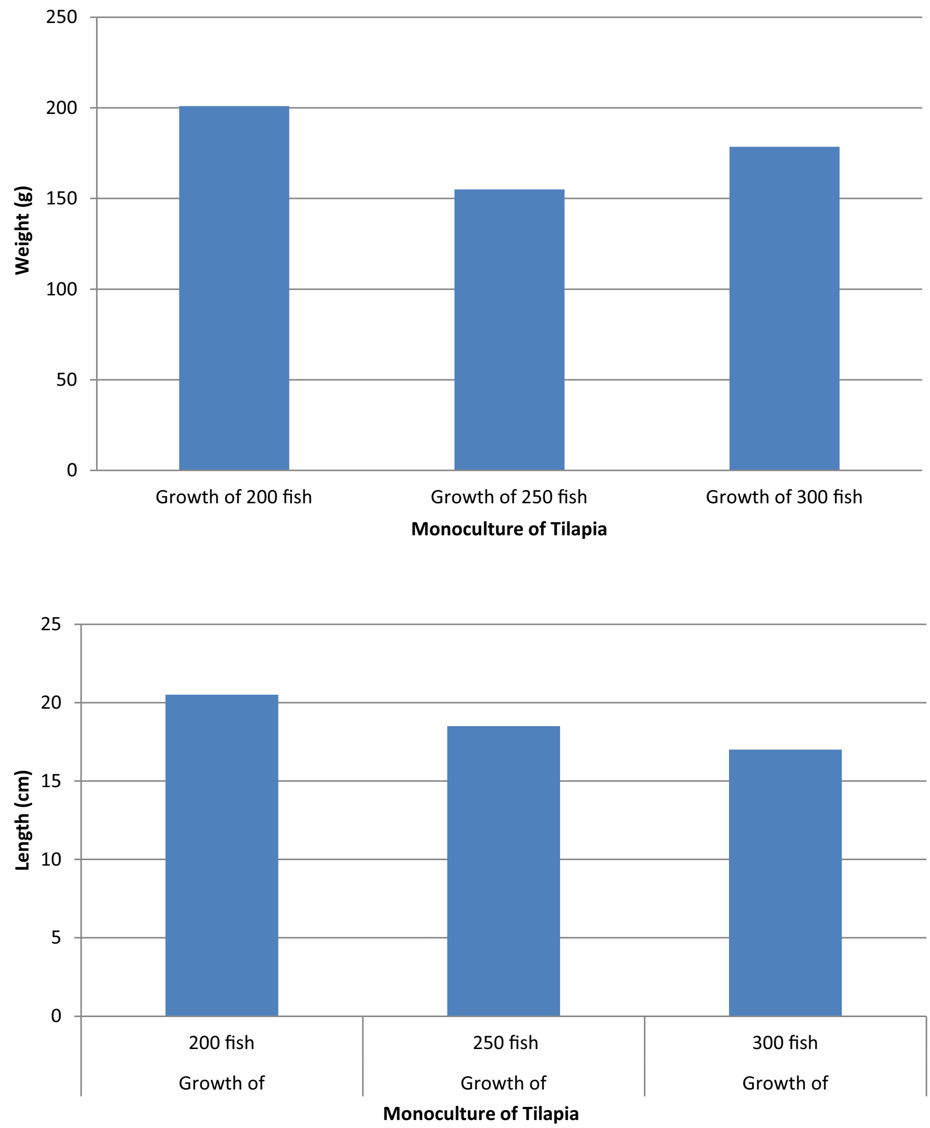

Fig. 3. Weight (g) and length (cm) of tilapia after final sampling in monoculture. Upper panel shows the mean weight of tilapia (at different stocking density). Lower panel shows the length of tilapia (at different stocking density).

resilient community. The study identified that cost effective pond aquaponics had great potentiality to ensure food security by meeting day to day requirements of fish and vegetables with combating against malnutrition and adaptation to climate change. Similar opinion was found in the case of raft and rack aquaponics in the other part of Bangladesh (Salam et al., 2013).

Cost effective pond aquaponics was also compatible with the livelihoods of conservative rural households. Socio-cultural norms restrict the women to go outside the homestead area to work. Pond aquaponics could solve the problem maintaining their social and religious norms as women can take part in feeding fish, harvesting and collection of vegetables from their homestead area. It also acts as an alternative income source for the rural households. Though having lot of benefit, initial high investment of floating aquaponics system makes restrict the extension of the technology in larger scale. The study was conducted to reduce investment, identify suitable species with profitable culture type (monoculture or polyculture) and density to spread floating aquaponics technology up to the marginal farmers.

Stocking density is an important factor that determines the economic viability of the production system. Though a positive effect of stocking density on growth is identified in some species, it is well accepted that the stocking density play a vital role for growth and survival of many aquatic animal. Stocking density is linked to the surface area per fish or volume of water. The increase in stocking density also increases stress. There are no previous studies to identify the suitable density of tilapia or any other fish and its effect on its growth and survival in floating aquaponics system. The present study was conducted considering this the densities of fish where there were no significant differences in initial weight of fish in different treatment of Tilapia. The study identified that fish attained best growth at lower stocking densities. The findings of the study agreed with findings of Begum, 2009; Roy, 2009; Rahim, 2010. Suresh and Lin (1992) also reported decreasing growth and survival of tilapia *Oreochromis niloticus* (Linnaeus 1758) with increasing stocking density. Similar effects of stocking density observed in a wide variety of fish species on survival and growth (Imsland et al., 2003; Rahman, 2006; Rahman and Verdegem, 2010). The present study identified that density of 100 fish/m^2 was more suitable for monoculture of tilapia in floating aquaponics system. Further research is still needed with more replication to finalize stocking density for monoculture of tilapia in

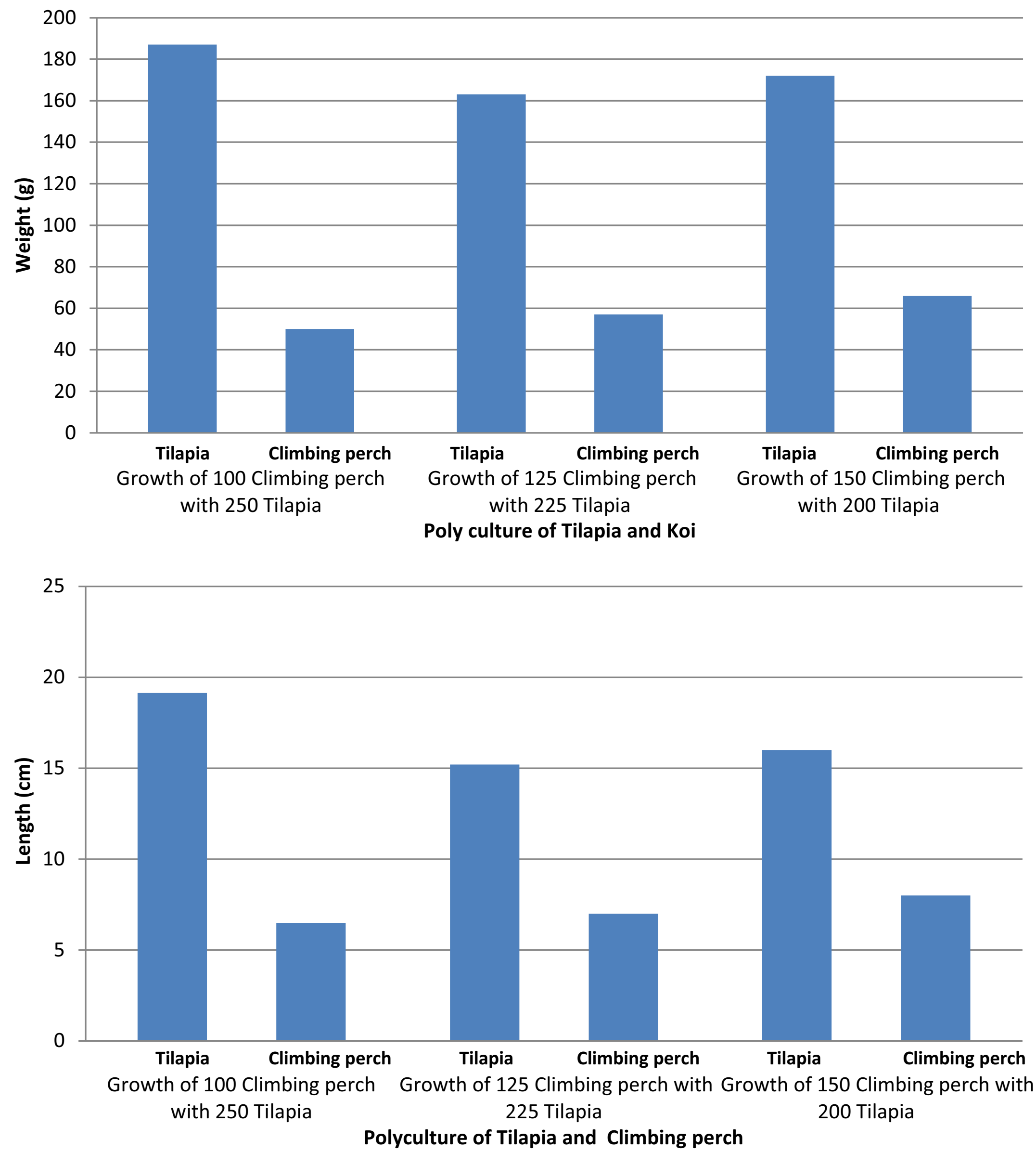

Fig. 4. Weight (g) and length(cm) of tilapia and climbing perch after final sampling in polyculture. Upper panel shows the mean weight of tilapia and climbing perch (at different stocking density). Lower panel shows the length of tilapia and climbing perch (at different stocking density).

Table 1
Water quality parameters of the treatments.

Water quality parameter	Treatment (Average of 3 cages of each treatment ± SD)		
	Treatment-1	Treatment-2	Treatment-3
Temperature (°C)	24 ± 2.3	24 ± 2.6	24 ± 2.4
Transparency (cm)	21 ± 1.5	21 ± 2.2	21 ± 2
Dissolved Oxygen (mg L^{-1})	5 ± 0.2	5 ± 0.4	5 ± 0.5
pH	7.5 ± 0.4	7.5 ± 0.5	7.6 ± 0.2
Nitrite (mg L^{-1})	0.10 ± 0.02	0.10 ± 0.04	0.10 ± 0.05
Ammonia (mg L^{-1})	18 ± 2.1	18 ± 2.2	18 ± 2.2

pond aquaponics. Until then, stocking 100 individuals of tilapia per decimal will give a good production to the farmers in the South Asian regions. There is also no previous evidence comparing the effects of climbing perch density on its growth and survival in pond aquaponics system. This study identified that higher yield and FCR was observed at higher fish density while higher growth and survival rate was observed at lower fish density and the relation between fish growth and fish yield was not linear. The findings of the study agreed with the finding in different parts of Bangladesh (Rahman, 2000). The result of the present study (70 g after 80 days trial) was better than the result of Mondal et al. (2010) who observed average individual harvesting weight of climbing perch of 27 g in tilapia ponds after a 120 days culture period. The plausible cause could be that the average individual growth difference between treatments was very small compared to the difference of stocking density between treatments. The similar non-linear relation between fish growth and fish yield was also found in tilapia cultured in fiberglass tanks (Al-Harbi and Siddiqui, 2000).

Water quality parameters exert an immense influence on the maintenance of a healthy aquatic environment (Sunny et al., 2017). 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 (Islam et al, 2018a). The experiment was conducted just before the winter season. The lower temperature

Table 2
Vegetables production in aquaponics.

Vegetables	Weight (kg)			Price (BDT)/kg			Total price (BDT)		
	(Average of 3 cages of each treatment ± SD)								
	T-1	T-2	T-3	T-1	T-2	T-3	T-1	T-2	T-3
Green pepper	5.7 ± 0.2	5.5 ± 0.5	5.5 ± 0.4	120 ± 5.2	120 ± 5.5	120 ± 5.8	684 ± 24	660 ± 28	670 ± 25
Bombay pepper	2 ± 0.2	2 ± 0.5	2 ± 0.3	250 ± 10.1	250 ± 10.5	250 ± 10.5	500 ± 20	500 ± 25	500 ± 15
White pepper	1.5 ± 0.4	1.5 ± 0.2	1.5 ± 0.5	90 ± 8.5	90 ± 5.8	90 ± 7.1	135 ± 1.5	135 ± 0.5	135 ± 2
Basil	5 ± 0.2	5 ± 0.5	5 ± 0.5	40 ± 5.0	40 ± 4.8	40 ± 4.5	200 ± 2.1	200 ± 1.6	200 ± 1.5
Pudina (mint)	1.5 ± 0.1	1.5 ± 03	1.5 ± 0.2	400 ± 10.5	400 ± 10.2	400 ± 10.6	600 ± 12	600 ± 15	600 ± 10
Long bean	7 ± 0.5	7 ± 0.8	7 ± 1.1	50 ± 5.1	50 ± 5.8	50 ± 6.2	350 ± 4.5	350 ± 3.5	350 ± 3.2
Bean/bitter guard	5.5 ± 0.2	5.5 ± 0.5	5.5 ± 0.7	40 ± 5.5	40 ± 6.5	40 ± 5.0	220 ± 1.1	220 ± 1.1	220 ± 1.1
Tomato	4 ± 0.5	4 ± 0.7	4 ± 0.7	50 ± 4.1	50 ± 5.0	50 ± 4.5	200 ± 3.5	200 ± 3	200 ± 2.5

T-1 = Treatment-1, T-2 = Treatment-2, T-3 = Treatment-3.

Table 3
Average Cost benefit analysis of treatment-1, 2 and 3 (Average of 3 cages of each treatment).

Serial no	Elements	Amount (Kg/no)			Unit price (US$)	Total price (US$)		
		T-1	T-2	T-3		T-1	T-2	T-3
Cage structure								
1	Bamboo	5	2	3	1.875	9.37	3.75	5.625
	Plastic bottle (10 L)	20	15	15	0.125	2.5	1.88	1.88
2	Cage net	8 m	8 m	8 m	0.525	4.2	4.2	4.2
	Hapa							
	Wages of tailor					3.12	3.12	3.12
	Trellis net, rope, nails					5	1.25	3.12
	Plastic bottle (Plant tub)	16	16	16	0.05	0.8	0.8	0.8
	Structural cost					25	15	18.75
	(Depreciation cost) cost for every 4 months (Durability 2 years)					4.16	5	4.68
Maintenance cost	250	250		0.0625	15.6	15.625		
3	Tilapia fry							
	Climbing perch fry		100	450	0.025		2.5	11.25
	Floating feed							
	Tilapia	54 kg	55.25		0.6	32.4	33.15	
	Climbing perch		18.09	78.5	0.625		11.3	49.06
	Total input cost					48	62.28	60.3
	Total cost (structure + maintenance)					52.16	67.28	65
Fish production								
4	Tilapia production	44.21	39.2		1.75	77.4	66.15	
	Climbing perch production		7.2	31.25	2.75		19.8	85.93
Vegetable production								
	Green pepper	5.7	5.7	6.1	1.5	8.6	8.55	9.15
	Bombay pepper	2	2	2	3.13	6.3	6.25	6.25
	White pepper	1.5	1.8	1.68	1.13	1.7	2.07	1.9
	Basil	5	7	5	0.5	2.5	3.5	2.5
	Pudina	1.5	1.5	1.5	5	7.5	7.5	7.5
	Long bean	7	8	7.8	0.63	4.4	5	4.88
	Bean/ bitter guard	5.5	6	5.5	0.5	2.8	3	2.75
	Tomato	4	5	4	0.63	2.52	3.125	2.5
		Total			36.32	38.94	37.41	
	Total income			113.72	124.88	123.35		
	Total Benefit (Total income-Total cost)			61.56	57.6	58.35		
	Benefit-cost ratio (total income/Total cost)			2.2	1.9	1.9		

1.00 US$ = 80.00 BDT in December 2015.

may have had a negative effect on overall fish production. In this study water temperature was not within the suitable range as the optimal temperature for the growth of most tilapia species is 25–28 °C (Swingle, 1967; Haque et al., 2015). Reproduction of tilapia stops at 22 °C and feeding below 20 °C (Wohlfarth and Hulata, 1983). Small fishes are more susceptible to low temperature than larger fish (Atwood et al., 2003). So, comparatively large sized fishes were stocked as the fish body weight has a significant effect on cold tolerance (Charo-Karisa et al., 2005). Regular movement of the cage can help to increase growth as the fish will be in warmer water that is heated up by sunlight and because the movement is expected to activate the fish which would increase the metabolism (Hofer and Watts, 2002; Belokopytin, 2004). Concentration of nitrate and ammonia was comparatively high that could be attributed to decomposition of organic matter particularly plant's leave of pond dike. The findings of the study agreed with the other study of coastal Bangladesh (Haque et al., 2015). Status of temperature, transparency, pH and oxygen did not vary significantly within the study period that suggested that installation floating aquaponics system in the pond did not deteriorate the water quality of pond as the roots of vegetable plants absorb nutrient generated from the feces of fish in the water (Sirsat and Neal, 2013).

Different types of vegetables such as green leafy vegetables, less bushy herbs, climbing vegetables, ornamental flowers, and medicinal plants are produced in this aquaponic system (Ghaly et al., 2004; Ugwumba et al., 2010). Among the different types of plants green leafy vegetables like basil and less bushy shrubs like pepper gave better result within short time as these had low to medium nutritional requirements (Adler et al., 2000). Less bushy plants like tomato and climbing plants included long bean, bean, and bitter gourd showed better growth in bamboo baskets than plastic bottles due to its large place along with the more mixture of soil and cow dung that increased the nutrition availability for plants (Adler et al., 2000; Sirsat and Neal, 2013).

Inundation, overflow of water is an important reason of lower aquaculture production in coastal areas compared to other regions of Bangladesh (Islam et al., 2016; Sunny, 2017; Sunny et al, 2018). Floating aquaponics could solve this problem as in cage aquaponics the fish cannot escape when the water overflows the pond dikes, assuming that the cage is not damaged by debris or washes out of the pond with the overflowing water. This phenomenon could bring a change in the aquaculture of this coastal region (Salam et al., 2013). Again, herbs and vegetable plants cannot grow well in the southern coastal areas due to shading and excess or lack of water. Aquaponics can solve part of these problems and will be more popular than traditional culture system due to less use of land and chemicals (Veludo et al., 2012).

Conclusion

Integrating culture system has been appeared an innovative technology in Bangladesh and is essential to increase food production to ensure continuous supply of food. Pond aquaponics can contribute more to solve part of these problems and will be more popular than traditional only pond fish culture system due to optimal use of the pond. It is proved that floating aquaponics system is environmental friendly fish and vegetable production system and it could be used in flood prone and coastal saline affected soil region to produce fish and vegetable round the year.

Identification of suitable species, density and management technique of present study has contributed to draw the attention of the marginal farmers more. Farmers have expressed their satisfaction with the growth of the plants and specially fish even in winter. Main reasons for the popularity of this low cost aquaponics are the good economics, low risk, low initial capital investment and a return on investment of 100% after 80 days. Besides, harvest of a small amount of fish or vegetables for home consumption or sale is very easy, and only limited daily follow up is needed for feeding and maintenance work. More research is needed to extend the use of this floating system and implement it commercially. This technology is not only applicable in ponds but also may be applied in beels (static lake), river, *haor* (depression of shallow water), *baor* (oxbow lake) and other water bodies if security of the aquaponics system can be maintained.

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