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Fattening of the Mud Crab *Scylla olivacea* (Herbst, 1896): An Integrated Multi-trophic Aquaculture (IMTA) Approach

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ABSTRACT

Integrated multi-trophic aquaculture (IMTA) uses co-products of one species that are automatically recycled as an input for other species to get a high profit. Considering IMTA, a vertical intensification of mud crab (*Scylla olivacea*) fattening was carried out at the pond's bottom and in the floated cages. Genetically Improved Farmed Tilapia (GIFT) strain of *Oreochromis niloticus* was integrated with crabs in the free pond areas to increase farm output. The experiment was designed with three different treatments, such as crab stocked in earthen ponds (T1), crab stocked in earthen ponds with floated crab cages (T2), and crab stocked in earthen ponds with the integration of floated crab cages and GIFTs (T3). Water quality was monitored regularly to keep the parameters (i.e., temperature, salinity, water pH, dissolved oxygen, alkalinity, and ammonia) within the optimum range for aquatic organisms. The survival rate of crab was significantly higher in T2 and T3 compared with T1. In addition, T2 and T3 were also significantly higher in crab production than T1. Crab productions in the ponds were significantly lower than productions in the floated cages. Besides, the tilapia growth was also found consistent with a moderate survival rate in two consecutive years. Hence, the multi-trophic culture system supports farming mud crab and tilapia combinedly. This study advocates starting IMTA at a large scale at different crab farms. Moreover, some other high-value species may be considered for future research in addition to GIFTs.

INTRODUCTION

Mud crab, a crab of the genus *Scylla*, is widely distributed in the Indo-Pacific region **(Keenan, 1999).** Generally, this shellfish is popular as green crab or mangrove crab in the world **(Ewel, 2008; Gao *et al*., 2014).** In Bangladesh, most of the crabs are captured from brackish water farms, tide-fed shallow lagoons, estuaries and mangrove swamps **(Shelley, 2008)**. Therefore, mud crab aquaculture is considered a traditional practice in South and Southeast Asia **(Rahman *et al*., 2020a)**. The practice is mainly based on the capture of juvenile crabs from natural sources and subsequently fattened within a short period of time to supply as a value-added product **(Mirera, 2011; Sujan *et al*., 2021)** through improving meat content and developing gonad mantle within the body cavity of female crab for making gravid **(Muhd-Farouk *et al*., 2016)**. Female mud crabs with immature gonad inside their body cavity areless demanded in international and domestic markets **(Huq *et al*., 2015)**. Fattened female mud crab has a thriving demand in the countries dominated by Chinese communities and is regarded as one of the demandable seafood items in restaurants of South-East Asia **(Mirera, 2011; Istiak, 2018)**.

Among the mud crab aquaculture practices, fattening is preferred to gain a profit in a short cycle and obtain a handsome return, which has gained popularity in South-East Asian coastal communities **(Cholik & Hanafi, 1992; Liong, 1993)**. Similarly, South-East and South-West coastal people in Bangladesh hane also paid attention to continue crab fattening **(Azam *et al*., 1998)**. Despite having huge possibilities, mud crab culture and fattening are still in the experimental stage in South Asia **(Muhd-Farouk *et al*., 2016)**. Crab fattening is widely practiced in Thailand, Taiwan, Malaysia, Singapore, India, Indonesia, Philippines, Vietnam and Bangladesh. In 2018, the estimated annual production of mud crab was 11,787 tonnes in Bangladesh **(Rahman *et al*., 2020b)**. Conventionally, enclosed earthen pond bottoms are used for crab fattening **(Ganesh *et al*., 2015)**. Thus, the surface and mid-water columns are left unused in the pond. In addition, poor survival rate and low-quality products were noticed in traditional fattening practices due to escaping by burrowing, hiding inside burrows and losing of appendages because of fighting **(Begum *et al*., 2009; Wu *et al*., in press)**. By considering present conditions, crab fattening in floating cages came forward to minimize mortality and to ensure quality products by using surface-water shed. Pens and floating cages made of bamboo, polyethylene nets and galvanized wire nets are usually used in coastal waters, shallow lagoons and ponds are utilized for fattening mud crabs **(Cholik & Hanafi, 1992; Liong, 1993)**. In the Philippines, the only documented studies on fattening crabs were in bamboo and net cages **(Albor *et al*., 1999; Begum *et al*., 2009)**. In Myanmar, the traditional mud crab fattening practice is carried out in ponds, bamboo enclosures and in cages set in rivers and canal system **(Haque *et al*., 2017)**. **Dat (1999)** also reported that mud crab fattening was practiced in cages in Vietnam. Likewise, floating cages were used to fatten mud crab in Malaysia **(Sivasubramaniam, 1992)**. However, **Begum *et al*. (2009)** observed promising findings in crabs fattened in bamboo made cages rather than under earthen ponds in Bangladesh.

Bangladesh, a country with a scarcity of per capita productive land, needs to expand vertically rather than horizontally to boost production. Increasing stocking density and enhancement of semi-intensive or intensive management is a well-established method for vertical intensification in fishes and other crustaceans, such as marine shrimp and giant freshwater prawn **(Wang *et al*., 1998)**. This method is not suitable for mud crab aquaculture due to their cannibalistic behavior **(Kawamura *et al*., 2020)**. In this context, combined fattening in pond bottom and floating cages may be the best option for the intensification of mud crab aquaculture by using both the bottom and the surface area of the waterbody. Food waste from floated cages is usually dropped on the bottom of the pond creating lethal gases, but the environment can be kept clear and free from hazards by the bottom crabs in the pond. Besides, uneaten finfish feed is also an option for bottom crabs to meet their dietary needs through recycling the nutrients. Integrated mud crab fattening is a novel approach in Bangladesh. On the other hand, a wide range of younger generation, i.e., children are still suffering from malnutrition in Bangladesh **(Mostafa *et al*., 2020)**. Integration of mud crab fattening with any suitable, symbiotic species which has domestic acceptance and economic importance for enhancing production is an eco-friendly manner. The tilapia is regarded as a suitable species in this delta due to its kitchen behavior, rapid growth, and high domestic demand in both middle-class and poor communities. Integrated mud crab aquaculture is also a new option in Bangladesh. Therefore, the present study aimed to address the concomitant fattening of mud crab in pond bottom and in floating cages along with the integration of hypo-saline fin fish, Genetically Improved Farmed Tilapia (GIFT) to increase total farm output.

MATERIALS AND METHODS

The present study was conducted on the earthen ponds of different farms to demonstrate the methods to the growers for two successive years. Three marginal farmers were selected through informal meetings who were engaged in traditional crab fattening business with their family members and relatives for the last couple of decades as a prime family business. Selected farmers were requested to enlist experimental ponds for crab fattening in their own farms. The location of the experimental ponds was at Shibbati in Paikgacha Upazila of Khulna district. It is situated very close to the Sundarbans mangrove (22°58'24.86" N; 89°30'64.12" E) forest in southwest Bangladesh.

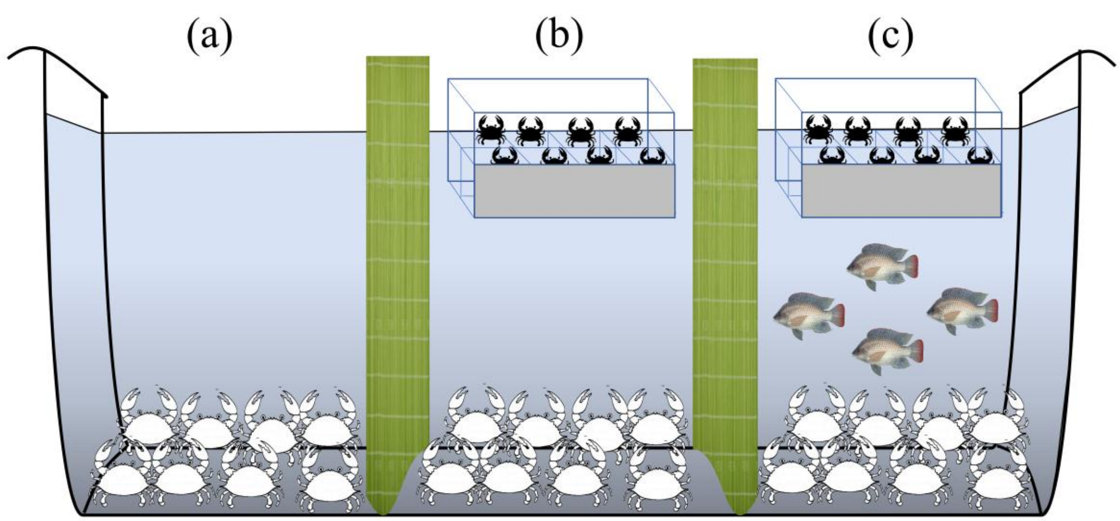

Fig. 1. A pond design with (a) only crabs on the pond’s bottom, (b) crabs on the pond’s bottom and floated cases and (c) crabs on the pond’s bottom and floated cages combined with GIFTs

Experimental design

The experiment was designed with three different treatments and each of which was replicated thrice. The first treatment (T1) was implemented with 16 crabs.m^{-2} in the pond. The second treatment (T2) was carried out by rearing crabs both in pond (with the density of 16 m^{-2}) and cage (with the density of 16 crabs.m^{-2}). Crabs were stocked in earthen ponds (16 crabs.m^{-2}) with the integration of floated crab cages (16 crabs.m^{-2}) and four GIFTs per square meter in the third treatment (T3) (Fig. 1).

Pond preparation

To make all ponds suitable for IMTA, three adjacent earthen ponds were dried and re-excavated. Every single pond, with an area of 81 m^2 (two decimals), was prepared for starting the experiments. Moreover, each pond was divided into three compartments (COMPT) (27 m^2 $COMPT^{-1}$) with bamboo fences. Pond edges were fenced by using bamboo splits and nylon nets. At a rate of 250 kg.ha^{-1}, agricultural lime was broadcast at the pond's bottom. After seven days, the ponds were filled up (about one meter) with tidal water from the adjacent river. Fertilization was completed with dried cattle manure at a rate of 750 kg.ha^{-1}, Triple Super Phosphate (TSP) at a rate of 25 kg.ha^{-1}, and granular urea at a rate of 20 kg.ha^{-1}). Thereafter, ponds were observed for almost seven days to ensure the production of natural feeds.

Preparing and setting of cages

Cages were prepared prior to the start of the research. A total of 24 cages (one m^2 space for a single cage; containing 16 chambers; every single chamber with the volume of 30 cm × 25 cm × 25 cm) were made for a single earthen pond. Cages were set up at the surface of the pond by considering the respective treatments. Eight floated cages covered the surface area of each pond’s compartment. All cages were covered by bamboo made covers to avoid crabs’ escaping.

Stocking of non-gravid crabs and GIFT

After 7 days of fertilization, female crab (100 g) with immature gonad was stocked at the rate of a single crab $COMPT^{-1}$ for every cage and 16 crabs.m^{-2} for the open water body of the pond. All male fingerlings of Genetically Improved Farmed Tilapia (GIFT) with an average weight of 2.5 g were stocked at the rate of four tilapias m^{-2} in the ponds according to the experimental design. The crabs in cages and ponds were fed once a day with low valued chopped small trash fish (Tilapia) at the rate of 8-15% of the total biomass. GIFT was fed on each alternate day by combining rice bran and fish meal (75:25) at the rate of 10-15% of body weight. A periodic check up on the progress of crab fattening was made during the culture period. About 40% of water was exchanged with tidal water every 5-7 days throughout the trial period.

Sampling and monitoring

During the experiment, crabs were checked regularly from each compartment and randomly from the open pond area by placing the crabs against electric light or strong sun light. *In situ,* the monitoring of temperature, salinity, dissolved oxygen concentration and pH value were carried out daily at early morning (at 07:30 am) by following the methods of **AOAC (1990)** and **APHA (1992)**.

Harvesting

Just after noticing the newly fattened crabs, gravid individuals were collected through a scoop net. In contrast, crabs from open pond area were collected by a crab harvesting trap, lined with bait (Thopa) and collected directly by hand. After the fattening period, the crabs were harvested from the compartment through a scoop net. However, all of the crabs from the pond were caught by thopa (line with baits) or picked up directly by hand. Then the crabs were categorized as F1 (weight of individual crab >180 g with all the appendages unbroken); F2 (weight of individual crab between 150 g and 179 g with least damage of appendages) and F3 (weight of individual crab between 100 g and 149 g with broken appendages). The pincers/chelae pods of the crab were tied with straw or string to facilitate easy handling. On the other hand, after pumping out the water from the ponds, all GIFTs were harvested from the bottom of the pond.

Data analysis

Procured data on crab, GIFT and water quality variables were compiled, categorized, computed and tabulated by using a computer program; Microsoft Office Professional Plus 2016. This program was also used to run one tailed T-test to distinguish between the survival rate of crab in ponds and cages. In contrast, few statistical tests were implemented with respect to this study's objectives by using another computer program named, Statistical Product and Service Solutions (SPSS) ver. 25. One-way ANOVA and Duncan's Multiple Range Test **(Duncan, 1955)** were employed to observe the differences in survival rates and growth parameters among the treatments. The analyzed data are presented mostly in tabular forms to describe them elaborately for extracting the information accurately.

RESULTS

1. Water physico-chemical characteristics

The recorded physico-chemical parameters viz. temperature, salinity, pH, dissolved oxygen, alkalinity and total ammonia of water during the culture period are presented in Table (1). All the hydrological parameters of the experimental ponds were within the acceptable ranges for brackish water aquaculture of the crab and the tilapia in both years. Temperature is one of the key physical modifiers affecting the growth, energy flow and biological impacts of marine organisms. There were very little temperature fluctuations in the experimental ponds. The temperature of the experimental ponds ranged between 26º C and 33º C. Salinity is considered as one of the most fundamental factors for mud crab culture. The salinity level in different experimental ponds varied between 9 ppt and 17 ppt. The recorded pH values of this study ranged from 7.5 to 9.0. Dissolved O_2, alkalinity and the ammonia levels of the experimental ponds ranged from 5-7.7, 90-48 and 0-1.2 ppm, respectively.

Table 1. Ranges in different water quality variables during the study period

Variables	Treatments						Optimum level †Shelley and Lovatelli (2011)
	T1		T2		T3		
	Y 1	Y 2	Y 1	Y 2	Y 1	Y 2	
Temperature (^{0}C)	31.0↑ 26.5↓	32.0↑ 26.5↓	30.5↑ 26.0↓	33.0↑ 26.0↓	31.0↑ 26.0↓	32.5↑ 26.5↓	25–35
Salinity (ppt)	15.0↑ 10.0↓	17.0↑ 9.0↓	15↑ 10↓	17↑ 9↓	15↑ 10↓	17.0↑ 09.0↓	10–25
Water pH	8.60↑ 7.60↓	8.7↑ 7.5↓	8.6↑ 7.5↓	8.5↑ 7.6↓	8.8↑ 7.6↓	8.9↑ 7.6↓	7.5-9.0
Dissolved oxygen (ppm)	6.80↑ 5.00↓	7.1↑ 5.3↓	7.7↑ 5.2↓	7.5↑ 5.4↓	7.2↑ 5.1↓	7.3↑ 5.2↓	>5
Alkalinity (ppm)	138.0↑ 95.0↓	140.0↑ 90.0↓	144↑ 92↓	132↑ 94↓	148↑ 98↓	146↑ 90↓	>80
Total ammonia (ppm)	1.10↑ 0.20↓	0.9↑ 0.1↓	0.8↑ 0.0↓	0.7↑ 0.0↓	1.2↑ 0.1↓	1.1↑ 0.1↓	<3

Note: Y 1 = Year 1; Y 2 = Year 2; ↑ = Maximum value; ↓ = Minimum value; †Source

Table 2. Total and category-wise survival of fattened crabs for the successive two years of experiment under different treatments

Parameters	Survival rate (%)	F1 (% of survivors)	F2 (% of survivors)	F3 (% of survivors)
†T1	21.78±1.74[a]	52.33±2.08	32.00±1.00	15.67±2.89
†T2	51.08±1.69[b]	64.67±4.16	21.33±5.77	14.00±2.00
†T3	50.56±1.87[b]	64.00±4.36	26.00±6.08	10.00±2.00
†Crab in Pond	20.98±1.14[a]	53.00±3.95	27.50±6.12	19.50±3.27
†Crab in Cage	81.07±2.01[b]	75.50±5.16	18.17±6.21	6.33±1.87
‡T1	21.33±1.00[a]	53.23±2.10	31.15±0.98	15.62±1.68
‡T2	51.67±0.58[b]	64.18±3.14	21.67±4.37	14.15±1.98
‡T3	51.17±0.76[b]	63.50±4.30	25.75±3.02	10.75±2.10
‡Crab in Pond	21.17±1.43[a]	51.87±2.45	28.25±4.23	19.88±2.37
‡Crab in Cage	81.75±2.72[b]	73.20±3.66	20.37±5.21	6.43±2.71

Note: $p<0.05$; †Year 1; ‡Year 2

2. Survival rate and production performance of mud crab

The overall survival rate of mud crab with the percentage of survivors in each category (F1, F2 and F3) during fattening is presented in Table (2) for both experimental years. The overall survival rate of fattened mud crab in the first year of experiment was 21.78±1.74 %, 51.08±1.69 % and 50.56±1.87 % in T1, T2 and T3, respectively. The survival rate in T2 and T3 was significantly higher ($p<0.05$) than that in T1. The overall survival rate of fattened mud crab in the second year experiment was 21.33±1.00 %, 51.67±0.58 % and 51.17±0.76 % in T1, T2 and T3, respectively. In the first year, the survival rate in T2 and T3 was also significantly higher ($p<0.05$) than that in T1 in the second year experiment. The survival rate in the pond system was 20.98±1.14 % and 21.17±1.43 % in the first and second years, respectively. On the other side, the survival rate in the cage system was 81.07±2.01 % and 81.75±2.72 % in first and second years, respectively which clearly showed that the survival rate in the cage system was significantly higher ($p<0.05$) than that in the pond system. Interestingly, the mean percentage of survivors in F1 category was always higher than that in F2 followed by the F3 category for both consecutive years. The category wise survival pattern was as follows: F1>F2>F3, respectively.

Table 3. Production of fattened crab in ponds and cages

Treatments	Fattening duration (days)	Production in pond ($kg.m^{-2}$)	Production in cage ($kg.m^{-2}$)	Total production ($kg.m^{-2}$)
†T1	12-14	0.60±0.01	-	$0.60±0.01^{a}$
†T2		$0.53±0.01^{a}$	$2.28±0.05^{b}$	$2.81±0.06^{c}$
†T3		$0.54±0.02^{a}$	$2.12±0.04^{b}$	$2.66±0.06^{b}$
‡T1	12-14	0.59±0.01	-	$0.59±0.01^{a}$
‡T2		$0.60±0.02^{a}$	$2.27±0.02^{b}$	$2.87±0.04^{b}$
‡T3		$0.59±0.01^{a}$	$2.29±0.03^{b}$	$2.88±0.04^{b}$

Note: $p<0.05$; †Year 1; ‡Year 2; - Not available

Fattening duration and production performance of mud crab under different treatments in the present study are presented in Table (3). The harvested amount of 12-14 days fattened mud crab in the first year experiment was 0.60±0.01, 2.81±0.06 and 2.66±0.06 $kg.m^{-2}$ in T1, T2 and T3, respectively. The mud crab production in T2 and T3 was significantly higher ($p<0.05$) than in T1. The production of fattened mud crab in the second year experiment was 0.59±0.01, 2.87±0.04 and 2.88±0.04 $kg.m^{-2}$ in T1, T2 and T3, respectively. In the first year, the mud crab production in T2 and T3 was also significantly higher ($p<0.05$) than that in T1 in the second year experiment. The production of the fattened mud crab in cage was significantly higher ($p<0.05$) than production in pond culture for both experimental years.

3. Growth performance of GIFT cultured concurrently with crabs

Besides concurrent fattening of mud crabs in earthen pond and cages, the tilapia (GIFT) was stocked with a density of four $GIFTs.m^{-2}$ in T3. The mean initial and final weight, survival rate and production were documented in Table (4). The average initial weight of GIFT was 2.50±0.21 g and 2.50±0.18 g in the successive experimental years. The final weight (mean±SD) of GIFT was recorded as 245.5±24.25 g and 226.7±18.25 g in the successive experimental years. The survival rate of GIFT in consecutive years was recorded as 41.67±2.78 % and 43.21±2.33 %, respectively. The production of GIFT was estimated as 0.41±0.02 and 0.39±0.01 $kg.m^{-2}$ in year 1 and year 2, respectively.

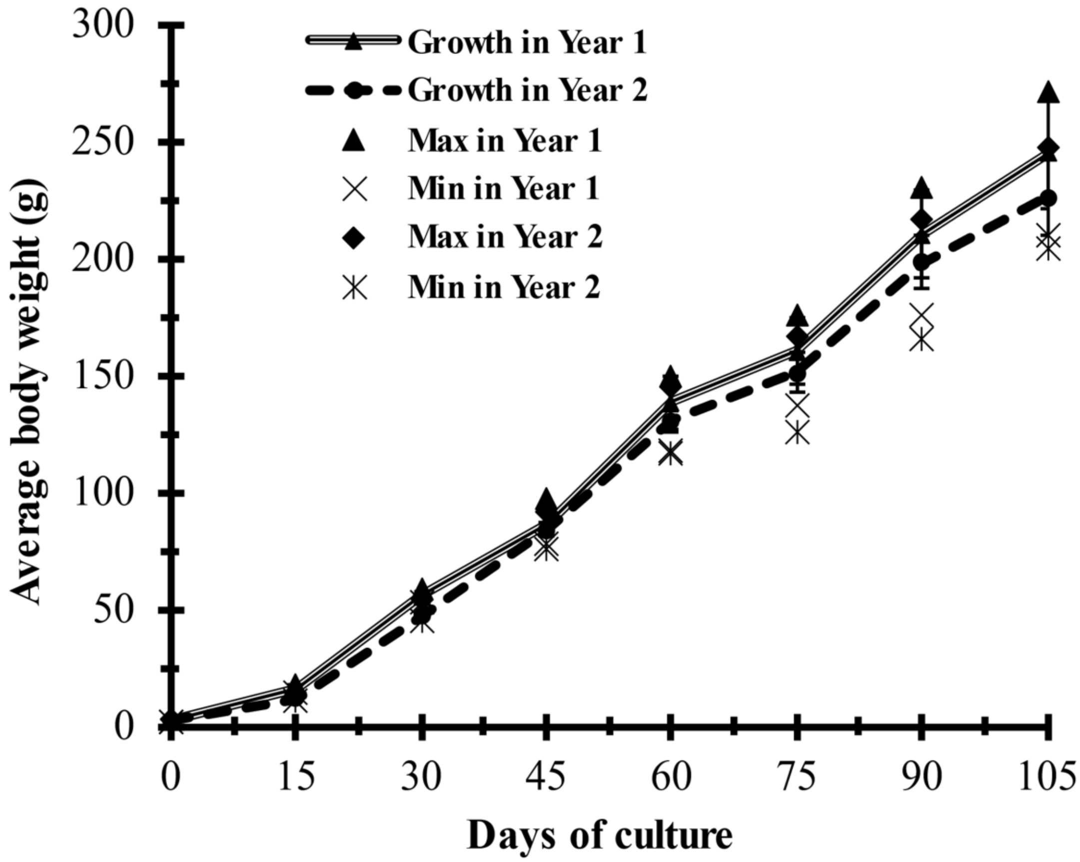

Fig. 2. Growth Performance of GIFT in integrated multi-trophic aquaculture

Growth data of GIFT are displayed regarding the culture period of 105 days in Fig. (2). Similarly, the average increased body weight of GIFT was recorded fortnightly and presented accordingly. The average raised weight was quite slow in the first 15 days after stocking. Thereafter, the growth seemed speedy until 60 days of growing. Again, the growth was a bit slow for the next 15 days. After 75 days, a sharp growth was observed and was faster than any other growth intervals. On the first 15th, 30th, 45th, 60th, 75th, 90th, and 105th days of culture, the observed body weights (mean±SD) were 2.5±0.05 g, 16.5±1.25 g, 55.5±2.55 g, 86.9±5.75 g, 138.6±11.25 g, 160.4±14.44 g, 210.8±18.99 g and 245.5±24.50 g. Likewise, 2.5±0.04 g, 12.15±1.05 g, 47.2±2.95 g, 84.47±4.75 g, 130.9±8.25 g, 151.6±11.44 g, 198.8±16.99 g and 226.7±18.25 g weights were recorded in the second year of the experiment by considering same time interval. The highest weight recorded was 17.90 g on day 15 of the first year of trials. On day 15, the calculated lowest gained weight was 14.40 g in the same year. Similarly, the same period was required to reach a biggest weight value of 14.80 g in the second year. Then, the smallest weight value was computed giving a value of 10.65 g in the same year. The maximum and minimum weights recorded on the 45th day were 97.32 g and 78.20 g in the first year. In the second year, the gained weights were between 76.30 g and 91.52 g on day 45. Furthermore, the highest weights in the first and second years were recorded as 176.40

and 166.50 g, respectively. However, the lowest weights in the first and second years of experiments were recorded as 137.20 g and 126.25 g, accordingly. The extreme and the least weights on the 105th day were calculated recording a value of 271.20 g and 210.25 g in the 1st year of experiment. In the second year, gained weights on the 105th day were between 247.30 g and 204.55 g.

DISCUSSION

In IMTA, the co-products (organic and inorganic wastes) of one cultured species are recycled to act as nutritional inputs for others, and species from different trophic levels are raised in close proximity to one another **(Knowler *et al*., 2020)**. The integrated multi- trophic aquaculture is a symbol of integrated mariculture in subtidal coastal zone as an improved aquaculture system **(Zhang *et al*., 2018)**. This study examined mariculture of two species in different water layers to get a purified and optimum ecosystem with adequate farm output **(Fig. 1).**

Now-a-days, vertical intensification of agriculture is a novel approach to meet the dietary demand of the hunger world **(Singh *et al*., 2020; Babu *et al*., 2021)**. Similarly, the vertical intensification in aquaculture has become popular to get high output from a single crop. The present study exclusively demonstrated the advantages of the use of the whole water column in a pond. Water quality parameters can play a very important role in terms of aquaculture practices **(Brown *et al*., 2020)**. Suitable and congenial water quality variables ensure higher growth rate, survivability and production by keeping a friendly culture environment **(Deswati *et al*., in press)**. The temperature of water in this study varied within the range of 26~32ºC. The range of salinity levels in the study fluctuated between 9 ppt and 17 ppt. Hereafter, the water pH value and the dissolved oxygen (DO) were recorded within a range of 7.5~8.9 and 5.0~7.7 ppm, respectively. Furthermore, alkalinity (90~25 ppm) and total ammonia (0~1.2 ppm) were observed during the experiments. All water quality parameters were found within the optimum ranges for doing aquaculture (Table 1). Optimum water parameters provide all necessary nutrients to grow phytoplankton, zooplankton and other arthropods to feed the cultured fish and shell-fish. Undoubtedly, proper nutrition in the waterbody ensures high growth and low mortality. Therefore, ideal water quality is very important for fish culture **(Ojwala *et al*., 2018)**.

The survival rate of aquatic organisms mainly depends on the culture environment, stocking density and the nature of the cultured organism. The mud crab is mainly found wild, aggressive and cannibalistic in nature and has a tendency to escape through burrowing **(Rahman *et al*., 2020b)**. However, under the integrated multi-trophic management system, the survival rate in cages was 81 % and 21 % in the pond. **Begum *et al.* (2009)** reported a similar survival rate (86 %) of mud crab in cages. As a result, the mean survival rate of crab fattening in the case was significantly ($p<0.05$) higher than fattening in open ponds. Similarly, the crab survival rate was significantly ($p<0.05$)

higher in T2 and T3 than that in T1 in the experiment (Table 2). Therefore, the multi-trophic culture system allows combined farming of crab and tilapia.

Production of aquaculture depends on the survival rate and growth of the fish and shell fish. In the second year, the average crab production (2.29±0.03 kg.m^{-2}) in the case of cages was higher than the mean crab production (0.59±0.01 kg.m^{-2}) in earthen ponds. In the first year, a similar result was also observed. Production of IMTA was successfully implemented with significantly higher production (2.88±0.04 kg.m^{-2}) though T3 (Table 3). The GIFT (*Oreochromis niloticus*) was seen as a potential species which can be grown in culture systems ranging from backyards to intensively managed tanks and ponds. It became a species of interest among common people as the tilapia survives well in adverse environmental conditions **(Bhujel, 2014)**. In Southeast Asia, the tilapia polyculture with other native fishes is also widely integrated with agriculture and animal farming **(Wang & Lu, 2016)**. Therefore, this species was incorporated into this experiment to get better output. As would be expected, the average production of GIFT (*O. niloticus*) was between 0.39 and 0.41 kg.m^{-2} during the culture period in this study. Besides, the survival rate fluctuated between 42 % and 43 %. The highest and the lowest recorded weight on the 105th day was 271.20 g and 210.25 g in the first year and 247.30 g and 204.55 g in the second year, respectively (Fig. 2). In addition, the tilapia was able to add extra production to increase the outcome in T3 (Table 3).

To sum up, the multi-trophic culture system supports cultured crab and tilapia combinedly. The tilapia's growth was also fair in the multi-trophic system as an additional outcome. Some dead and live tilapias turned into a nutritious diet of young crabs as *Scylla olivacea* is carnivorous. This study advocates starting integrated multi-trophic aquaculture on a large scale at different crab farms. In contrast, some more expensive species may attempt to replace the tilapia in order to increase profits.

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