



Sustainable Semi-Intensive Aquaculture of Climbing Perch (*Anabas testudineus*) in Mymensingh Region, Bangladesh: A Comparative Study

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Authors' contributions

This work was carried out in collaboration between both authors. Author UHM designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author MNH managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

This study examines the growth and yield of Vietnamese *koi* with Thai *koi* for developing a suitable culture management technique of *koi* for sustainable production and unveiling the most cost effective culture of *koi* species. The study was conducted for a rearing period of 100 days in four farms at Gauripur upazila in Mymensingh district in Bangladesh. The treatment 1 (T₁), treatment 2 (T₂) are considered for Vietnamese *koi* and treatment 3 (T₃), treatment 4 (T₄) are considered for Thai *koi* with stocking density 1,72,900 per hectare for T₁ and T₃ and 2,47,000 for T₂ and T₄ at four different farms of study area. The ponds were stocked with an initial length of 0.75±0.01 cm and weight of 0.20 g in all the treatments. The culture period has the optimum level of physicochemical parameters. The study reveals that the maximum weight gain was in treatment T₁ of Vietnamese *koi* and lowest in treatment T₄ of Thai *koi*. Similarly, physical length, weight and survival of *Anabas testudineus* also followed the same trends as weight gain. Individually treatment T₁ shows significantly higher specific growth rate than the other treatments. Besides, food conversion ratio was significantly higher in treatment T₁ followed by treatment T₂, T₃ and T₄. However, the mean

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fish production were 17092, 15000, 10746 and 10469 kg/ha in treatment T₁, T₂, T₃ and T₄ respectively. Consistently, highest growth, survival and higher net economic benefit from *A. testudineus* were found in treatment T₁ among the four treatments. Vietnamese *koi* population of treatment T₁ has appeared to be most suitable for good quality aquaculture practice for 100 days rearing semi-intensive system among the four treatments. Therefore, monoculture practice of Vietnamese *koi* is a perfect scheme of choice for a commercially viable and sustainable *koi* culture to meet up the protein deficit and as well as to accelerate the sustainable development of Bangladesh.

Keywords: *Anabas testudineus*; aquaculture; management; sustainable; Bangladesh.

1. INTRODUCTION

Fisheries play a vital role in nutrition, livelihood earning and export earnings in Bangladesh. Fishes contribute to 60% of animal protein intake, about 4.39% of gross domestic product and 2.46% of export earnings; approximately 1.4 million people are directly engaged in fishing, 11 million in part-time fishing and another 3 million in aquaculture activities [1-4]. However, the International Union for Conservation of Nature (IUCN), Bangladesh [5] assessed 253 freshwater fish species and revealed 64 as threatened species in Bangladesh, of which 9 were critically endangered, 30 were endangered, 25 were vulnerable, near threatened 27, least concern 122 and 40 data deficient freshwater species [5,6]. The culture of various fish species can help to prevent extinction of these fresh water fish species. *Anabas testudineus* (Bloch) is one of the common exotic fish species in Bangladesh. It is one of the most important fresh water perch fishes of Bangladesh which is locally known as *Koi* in different places of Bangladesh. In late 1980s, the catches of the fish have drastically declined from open waters due to climatic and ecological changes in inland water bodies and thus has been recognized as an endangered species [7,4]. Resulting the uneven and unplanned irrigation and land use pattern, excessive exploitation, unlawful practice of capture fisheries, water body encroachment and various ecological changes in its natural habitat; this native species is threatened now [8,9]. Considering the importance of this species from nutritional, economics and biodiversity points of view, it is necessary to develop an appropriate culture technique of *A. testudineus* [8]. This aquaculture method will be helpful to meet up the dietary demand and this tasty fish will be available for the people of Bangladesh [10]. Thus, the comprehensive information on culture technique is necessary for large scale production of *koi* fish. However, the Thai *koi* (*Anabas*

testudineus) had been introduced in 2002 in Thailand for their high adaptability, fast growing, nutritious value and market price [11]. Potentiality of Thai *koi* culture has increased in various part of Bangladesh especially in Mymensingh region due to its fast growth nature. Thai *koi* culture is carried out in both monoculture and polyculture systems among that polyculture are more suitable in the context of Bangladesh [12]. With the variation of feeding supplement that effect on the growth and production of Thai *koi*. Studies find that the growth of Thai *koi* fry varied significantly ($P>0.05$) with different feeds [13]. Similarly, stocking density plays a crucial role in the production and growth of Thai *koi* [14]. Conversely, due to inbreeding problem, growth rate of Thai *koi* is declining day by day in many areas. In contrast, another very fast growing fish known as Vietnamese *koi* has been introduced in Bangladesh in 2010 for its higher production and growth than the other variety of *koi*. It was observed that Vietnamese *koi* attained maximum size of 400g within 100 days culture period. According to local fish farmer Vietnamese *koi* grows as much as 250-300g within 100days culture period and the body color is almost similar to native *koi*.

The growth of fish species mostly depends on the population density, which means population density of the species and its growth rate tend to be inversely related [15]. However, Das et al. [16] recorded 555 kg/ha/yr production of Indian major carps in polyculture system when stocked at the rate of 7000 fish/ha and fed commercial feed in ponds. Thakur and Das [17] reported that in India they produced 1800 kg/ha in 170days and 702 kg/ha during the period of 11 months, where stocking density were 60,000/ha and 1, 25,000/ha respectively. Ali et al. [18] found that chemical fertilizers act principally on the auto trophic and grazing food chain by directly stimulating phytoplankton production within the ponds. Akhteruzzaman [19] studied on the

monoculture of *A. testudineus* under semi-intensive culture system, Fingerlings of 8-9 g average weight were stocked at a density of 16000/ha. They were fed once per day with a mixture of rice bran, mustard oil cake and fishmeal at a ratio of 3:1:1. After 5 months rearing the average yield was 450 kg/ha and average survival rate was 78%. In 1997, Scientist Charoentesprsit conducted an experiment on climbing perch *A. testudineus* and were stocked at 3 stocking densities, 100, 200 and 300 fish/m² and fed on diet containing 20, 25 and 30% protein for 12 weeks. Halim et al. [14] studied the effect of feeding levels and feeding frequencies on the growth and feed utilization of small (2.11 ± 0.10 g initial weight) and large (10.30 ± 0.15 g initial weight) size fingerling of climbing perch (*A. testudineus*) in tank condition.

Likewise, Mahmood et al. [20] conducted an experiment to assess the suitability of different larval feed for fry of climbing perch *A. testudineus*. The author tested 4 different feeds namely *Artemianauplii*, tubificid and zooplankton for a period of 28 days. Haque et al. [21] conducted research on monoculture to Thai *koi* (*A. testudineus*) to find out the suitable stocking density and its effects on growth production and profit. After 108 days of culture the final average weight of fish was found 69.60 ± 16.88 , 68.46 ± 17.80 and 61.75 ± 16.15 g in T₁ T₂ and T₃ respectively which were significantly different among the treatments ($p < 0.05$). Kohinoor et al. [22] studied the monoculture of climbing perch (*A. testudineus*) under different stocking densities in farm management condition. The author found that, after four months culture, mean weight gain varied from 71 g to 96 g. Adhikary et al. [23] conducted an experiment on culture of Thai *koi* (*A. testudineus*) in earthen ponds with different feeding regimes to assess the effect of poultry droppings on growth performance in monoculture in absence of fertilization. Hasan et al. [13] conducted study to elucidate the effect of three supplement feeds on growth and production of Thai *koi* and observed that growth of fry varied significantly ($p > 0.05$) with different feeds.

Besides, Azim et al. [24] observed that the mean values of temperature 26°C, transparency 32.2 cm and pH 7.1 from a set of ponds. Wahab et al. [24] recorded a low content of dissolve oxygen ranging between 2.0-7.2 mg/l during the experiment in pond. Ahmed et al. [25] studied on histopathology of an air breathing teleost (*A. testudineus*) in the laboratory of the Bangladesh

Agricultural University and recorded that temperature ranging from 15.5°- 31.0°C, DO from 3.00-5.45 mg/l, pH from 7.00- 7.55 and hardness from 38.00 - 68.50 mg/l. Ahmed et al. [26] studied on a disease occurrence and histopathology of catfish and histopathology of snakehead in the laboratory and recorded that temperature ranged from 16.0°C to 31.5°C and dissolved oxygen from 2.8 to 5.5 mg/l. Narejo et al. [27] studied on the water quality parameters and their monthly fluctuations recorded throughout the study period were found within the suitable ranges for the stripped fish culture. Apart from this, Chakraborty and Haque, 2014; Ahmed, et al., 2015; Chakraborty, 2016; Kohinoor, et al., 2017; Shofiquzzoha, et al., 2018; Vongvichith, et al., 2020 also examine the growth and production performance of climbing perch (*Anabas testudineus*) at farm level in different places in Bangladesh. The review of existing literatures reveals that limited studies have been conducted by giving exhaustive insight on the current issue. Therefore, to fill this research gap the present study intends to explore the economically viable methodology for mass production of *A. testudineus* through a management strategy that could possibly be undertaken in other places of Bangladesh. This study intends to examine the growth and yield of Vietnamese *koi* with Thai *koi* and to develop the suitable the culture management technique of *koi* for sustainable production as well as to unveil the most cost effective culture of *koi* species.

2. MATERIALS AND METHODS

2.1 Study Area

The study area Gauripur located at 24°45'30"N and 90°34'30"E with an area of 274.07 square-kilometre, which is a sub-district in the district of Mymensingh, the northern part of Bangladesh. The four farms have been selected for the present experimental purpose, and can serve as the representative sample of northern aquaculture management practices. The experiment was conducted in four farms e.g. locally known as *Fish King Farm*, *Bondhon Hatchery*, *Masud Fish Farm* and *Peal Hatchery* in the study area. The study was carried out for 100 days from May to August 2019 at the mentioned area (Fig. 1). The ponds were having similar rectangular size, depth, basin conformation, contour and bottom type. During the study the water depth was maintained at a level of 1.0 to 1.5 m.

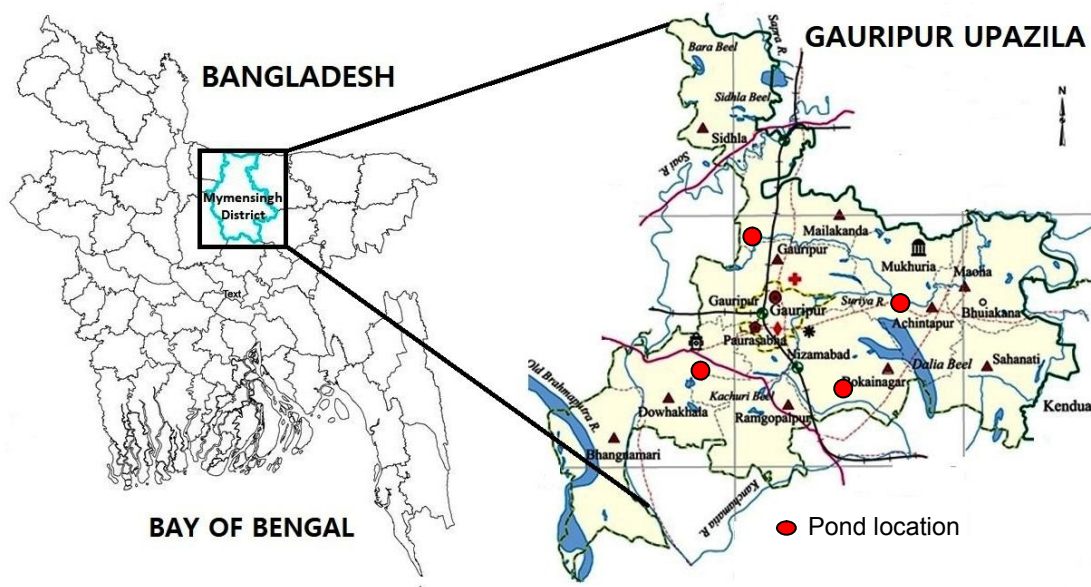


Fig. 1. Location map of the study area

2.2 Experimental Design

In order to conduct the experiments two treatments were considered for Vietnamese *koi* and another two for Thai *koi* among the four experimental treatments for the culture period of 100 days. In each treatment two replications were considered to find out the result (Table 1). The pond area was 0.08 hectare and stocking weight was 0.2 gm in all treatments.

2.3 Pond Preparation

With a view to explore the proper result the aquatic weeds, undesirable fishes, insects and other aquatic organisms were removed manually and the grasses on the pond dykes were also pruned manually into very small size. The ponds were dewatered, exposed to full sunlight and had

a well-designed system of inlet and outlet. After drying, quicklime (CaCO_3 , 250 kg/ha) was spread over the pond bottom. Then, all the ponds were filled with ground water. Five days subsequent to liming, the ponds were fertilized with organic manure. Quicklime (50 kg/ha) was maintained fortnightly to control water quality of different treatments.

2.4 Stocking

An initial length of 0.75 ± 0.01 cm was stocked in all the treatments. Stocking densities were designed at the rate of 1,72,900/ha for Vietnamese *koi* and Thai *koi* in treatment T_1 and T_3 . While, stocking densities were designed at the rate of 2,47,000/ha for Vietnamese *koi* and Thai *koi* in treatment T_2 and T_4 .

Table 1. Experimental treatment layout of Vietnamese *koi* and Thai *koi*

Treatments	Replications	Pond size (hec)	Stocking density/hec	Stocking weight (gm)
T_1 (Vietnamese <i>koi</i>)	R_1	0.08	172900	0.2
	R_2	0.08	172900	0.2
T_2 (Vietnamese <i>koi</i>)	R_1	0.08	247000	0.2
	R_2	0.08	247000	0.2
T_3 (Thai <i>koi</i>)	R_1	0.08	172900	0.2
	R_2	0.08	172900	0.2
T_4 (Thai <i>koi</i>)	R_1	0.08	247000	0.2
	R_2	0.08	247000	0.2

2.5 Feed Selection and Feeding Strategy

Supplementary readymade floating *Mega feed* and sinking *Saudi Bangla* feed was supplied at the rate of 6-80% of their total biomass twice and daily commencing from the first day of stocking. Proximate composition of the feeds was analyzed according to AOAC method, nitrogen free extract (NFE) by subtraction. Floating *Mega feed* was supplied in early stage and sinking *Saudi Bangla* feed was supplied after 35 days of rearing for daily ration. Proximate composition (% dry matter) of the supplementary floating *Mega feed* (crude protein, crude lipid, crude fiber, ash, moisture and nitrogen-free extract) of experimental feeds was 30.0%, 3.0%, 10.0%, 17.0%, 12.0% and 28.0%; and sinking *Saudi Bangla* feed (crude protein, crude lipid, crude fiber, ash, moisture and nitrogen-free extract) was 30.0%, 6.0%, 07.0%, 18.0%, 12.0% and 27.0% respectively. At the beginning of the experiment feed was supplied at a rate of 60% (1st month), followed by 20% (2nd month) and 7% (till harvesting) of their body weight. Half of the feed was supplied at 09:00 AM and remaining was supplied at about 05:00PM. The feed was supplied by spreading method manually.

2.6 Water Quality Parameters and Recycling

The physicochemical parameters of pond water were monitored every ten days interval throughout the experimental period between 09.00AM to 10.00AM. Parameters such as temperature (°C), dissolved oxygen (mg/l), pH, alkalinity (ppm) and ammonia (mg/l) were determined at fortnightly of pond. Water temperature was recorded using a Celsius thermometer, transparency (cm) was measured by using a *Secchi* disc of 20 cm diameter, dissolved oxygen, pH were measured directly using a digital electronic oxygen meter (YSI, Model 58, USA) and an electronic pH meter (Jenway, Model 3020, UK) and total alkalinity was determined by titrimetric method in laboratory. Water recycling method is developed regularly for controlling pollution of excretory product of individual and plankton bloom. Inlet and out let system of water body was to be processed and sometime water was recycled by a pump machine to maintain ecosystem of the ponds.

2.7 Sampling of Fish

Fish sampling was done at fifteen days interval in the morning at around 09.00AM to 10.00AM During each sampling fish were caught by cast net and minimum weight of 15 fishes was taken by precision weighing balance (accuracy up to 0.1 g).

2.8 Growth Parameters

The following parameters are used to evaluate the growth of fish such as weight gain (g), average daily weight gain (g), percent weight gain, specific growth rate (SGR), food conversion ratio (FCR), survival rate (%) and production (kg/ha/100 days).

2.8.1 Weight gain

$$\text{Weight gain (g)} = \text{Mean final weight (g)} - \text{Mean initial weight (g)}$$

2.8.2 Average daily weight gain

$T_2 - T_1$ = Express the duration of the experimental period.

$$\text{Average weight gain} = \frac{\text{Mean Final weight (g)} - \text{Mean Initial weight (g)}}{T_2 - T_1}$$

2.8.3 Specific growth rate (SGR)

$$\text{SGR (\%)} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \times 100$$

where, W_2 = Mean final weight (g)

W_1 = Mean initial weight (g)

T_2 = Time at end of the experiment

T_1 = Time at start of the experiment

2.8.4 Food conversion ratio (FCR)

$$\text{FCR} = \frac{\text{Total feed supply (dry weight)}}{\text{Total live weight gain}}$$

2.8.5 Survival rate

The survival rate of each treatment was calculated from the each species survived at the end of the experiment. The survival rate was estimated by the following formula;

$$\text{Survival Rate} = \frac{\text{Number of Fish Harvested}}{\text{number of Fish stocked}} \times 100$$

2.8.6 Production

The production of each species for each treatment was determined by multiplying the average gained in weight (g) of each species of fish by the total number of fishes that survived at the end of the experiment. Production was calculated by the following formula:

$$\text{Production} = \text{No. of harvested fishes average final weight increase of fishes.}$$

2.9 Data Analysis

The data obtained on the growth of fish, FCR, survival rate and production were statistically analyzed to see whether the influence of different treatments on the growth (weight) and production of fishes were significant or not significant using significant test.

3. RESULTS

3.1 Physicochemical Parameters of the Pond Water

The result of the water quality parameters such as temperature (°C), dissolved oxygen (mg/L), pH, alkalinity (mg/L) and ammonia (mg/L) were recorded monthly during the experimental period is shown in Table 2.

3.1.1 Water temperature (°C)

The mean values of water temperature were 29.75°C and 29.0°C in Vietnamese *koi* in T₁ and T₂ respectively. Also the mean values of water temperature were 29.20°C and 29.5°C in Thai *koi* in T₃ and T₄ respectively. The range of water temperature were 27.25 to 32.25°C in Vietnamese *koi* in T₁, 26.34 to 31.66°C in Vietnamese *koi* in T₂, 26.80 to 31.20°C in Thai *koi* in T₃ and 27.51°C to 31.49°C in Thai *koi* in T₄. Temperature of different treatment was not significantly different (P>0.05).

3.1.2 Dissolved oxygen (mg/L)

During the study period, the mean values of the dissolved oxygen content of the water were 5 mg/l and 4.8 mg/l in Vietnamese *koi* in T₁ and T₂ respectively. Also the mean values were 5.1 mg/l and 4.7 mg/l in Thai *koi* in T₃ and T₄ respectively. The highest value of Dissolved oxygen content was in Vietnamese *koi* in T₂ in July while the lowest value was in Thai *koi* in T₃ in June. The

mean values of transparency was significantly different (P<0.01).

3.1.3 pH

The mean pH values were recorded from 7.9 and 8.1 in T₁ and T₂ respectively for Vietnamese *koi*. Also the pH content during the experiment was varied from 8.2 and 7.8 in T₃ and T₄ respectively for Thai *koi*. The highest value (8.4) of pH was in Thai *koi* in T₃ on May, 2019 while the lowest value (6.60) was recorded from Vietnamese *koi* in T₂ on June 2019. The mean value of PH was not significantly different (P>0.01)

3.1.4 Ammonia (mg/L)

The mean ammonia content during the experiment was 0.08 mg/land 0.11 mg/l in Vietnamese *koi* in T₁ and T₂ respectively. Also, the mean ammonia content during the experiment were 0.10 mg/l and 0.17 mg/l in Thai *koi* in T₃ and T₄ respectively. The highest value (0.13 mg/l) of ammonia content was from Thai *koi* in T₃ and the lowest value (0.04 mg/l) was from Vietnamese *koi* in T₁. The mean values of ammonia were not significantly different (P>0.01).

3.1.5 Alkalinity (mg/L)

The range of alkalinity content of the experiment was varied from 159 to 171.22 ppm in Vietnamese *koi* in T₁ and 123.63 to 138.53 ppm in Vietnamese *koi* in T₂, 132.95 to 147.45 ppm in Thai *koi* in T₃ and 145.96 to 158.04 ppm in Thai *koi* in T₄. The highest value (158 mg/L) of alkalinity content was recorded from Thai *koi* in T₃ and the lowest value (121 mg/l) was from Vietnamese *koi* in T₁. The mean values of alkalinity was significantly different (P<0.01).

3.2 Growth Performance

Growth performance of Vietnamese *koi* and Thai *koi* in term of weight (g) gain under different treatments for a period of 100 days is presented in the Table 3 and Fig 2. For the evaluation of growth performance of Vietnamese *koi* and Thai *koi* in four treatments in terms of final weight (g) gain, mean weight (g) gain, average daily weight gain (g), specific growth rate (SGR% per day), food conversion ratio (FCR), production (Kg/ha days) and survival rate were calculated, shown in Table 3.

Table 2. Physico-chemical characters of water ponds of Vietnamese *koi* and Thai *koi* (*Anabas testudineus*) during the experimental period

Parameter	Vietnamese <i>koi</i>		Thai <i>koi</i>		Remarks
	T ₁	T ₂	T ₃	T ₄	
Temperature (°C)	29.75 ±2.5 (27.2- 32.25)	29.0 ±2.66 (26.34-31.66)	29.20 ±2.00 (26.80-31.20)	29.5±1.99 (27.51-31.49)	NS
Transparency (cm)	24.22 ±4.66 ^a	30.18 ±4.50 ^c	26.55±5.50 ^b	32.64±2.30 ^d	S
pH	7.9 ±0.4(7.1-8.3)	8.10±0.6(7.5-8.7)	8.2±0.5(7.7-8.7)	7.8±0.8(7.0-9.4)	NS
DO (mg/L)	5.0±1.1(3.9-6.10)	4.8±1.4(3.4-6.2)	5.1±1.2(3.9-6.3)	4.7±1.6(3.1-6.3)	NS
Total alkalinity (mg/L)	165.11±6.11 ^a (159-171.22)	131.08±7.45 ^d (123.63-138.53)	140.20±7.25 ^c (132.95-147.45)	152±6.04 ^b (145.96-158.04)	S
Ammonia (mg/L)	0.08±0.01(0.07-0.09)	0.11±0.02(0.09-0.13)	0.10±0.01(0.09-0.11)	0.17±0.03(0.14-0.20)	NS

Note: Figure in the same row having the same superscript are not significantly different ($p>0.05$). Figure in the parenthesis indicates the range

Table 3. Growth performance, survival and production of Vietnamese *koi* and Thai *koi* after 100 days of rearing; mean±S.D. with ranges in parentheses (Figure in the same row having the different superscript varied significantly ($p>0.05$). Figure in the parenthesis indicates the range)

Parameters	Vietnamese <i>koi</i>		Thai <i>koi</i>	
	T ₁	T ₂	T ₃	T ₄
Initial length(cm)	0.75 ± 0.01	0.75 ± 0.01	0.75 ± 0.01	0.75 ± 0.01
Final length(cm)	16.5±4.05 ^a	15.56±4.88 ^b	12.02±4.46 ^c	11.85±5.02 ^d
Initial weight (g)	0.20 ±.01	0.20 ±.01	0.20 ±.01	0.20 ±.01
Final weight(g)	109.60±3.22 ^a	80.44±4.44 ^b	68.30±3.55 ^c	57.67±4.78 ^d
Net weight gain (g)	109.40±3.02 ^a	80.24±4.14 ^b	68.10±3.35 ^c	57.47±4.48 ^d
Average Daily Growth (g)	1.09±0.01 ^a	0.80±0.01 ^b	0.68±0.01 ^c	0.58±0.01 ^d
Specific Growth Rate (SGR)%	2.74±0.01 ^a	2.61±0.02 ^b	2.53±0.01 ^c	2.46±0.02 ^d
Survival Rate (%)	90.2 ± 2.08 ^b	75.50 ±3.38 ^c	91.00 ± 1.77 ^a	73.50 ± 3.50 ^d
FCR	1.70±0.01	2.10±0.01	1.80±0.01	2.08±0.01
Production(kg/ha)	17092±101.44 ^a	15000±188.01 ^b	10746±109.55 ^c	10469±188.86 ^d

3.2.1 Weight gain

The mean initial weight of Vietnamese *koi* in all the treatments was 0.20 g. The mean weight gains of Vietnamese *koi* at the end of the experiment were 109.40 g and 80.24 g in T₁ and T₂ respectively. The mean initial weight of Thai *koi* in both the treatment was also 0.20 g. The mean weight gain of Thai *koi* at the end of the experiment was 68.10 g and 57.47 g in T₃ and T₄ respectively. Thus an increased weight gain was recorded from Vietnamese *koi* when compared with Thai *koi* (Fig. 2). There was no significant (P<0.01) difference in initial weight of fish under all treatments. Weight gain in between Vietnamese *koi* in T₁ and Thai *koi* in T₃ were significantly different with each other (P<0.01). Weight gain in Vietnamese *koi* in T₂ and Thai *koi* in T₄ were also significantly different with each other (P<0.01).

3.2.2 Average daily weight gain (g)

Average daily weight gain of Vietnamese *koi* and Thai *koi* at the end of the experiment were 1.09 g, 0.80 g, 0.68 g and 0.58 g, in T₁, T₂, T₃, T₄ respectively. Average weight gain in Vietnamese *koi* in T₁ and Thai *koi* in T₃ were significantly different (P<0.01). Also in Vietnamese *koi* in T₂ and Thai *koi* in T₄ average weight gain was significantly different (P<0.01) in significance test.

3.2.3 Specific growth rate (%)

During the investigation of mean specific growth rate (SGR) in T₁, T₂ of Vietnamese *koi* were 2.74, 2.61 respectively and in T₃, T₄ of Thai *koi* were 2.53, 2.46 respectively. SGR values were significantly (P<0.05) different in T₁ and T₃ and also there was a significant difference of SGR in T₂ and T₄.

3.2.4 Food conversion ratio (FCR)

The mean values of FCR for Vietnamese *koi* in T₁ and T₂ were 1.70 and 2.10 respectively. In

case of Thai *koi*, the mean values of FCR in T₃ and T₄ were 1.80 and 2.08 respectively. There was no significant (P<0.01) differences in FCR of fish among the treatments.

3.2.5 Fish production (kg/ha)

The mean production of Vietnamese *koi* in T₁ and T₂ were 17092 kg/ha and 15000 kg/ha, whereas, the mean production of Thai *koi* in T₃ and T₄ were 10746 kg/ha and 10469 kg/ha, respectively. Production of T₁ and T₃ of both the species were significantly higher (p<0.01) than T₂ and T₄. However production of Vietnamese *koi* in both the treatment were also increased significantly (P<0.01) when compared with Thai *koi*.

3.3 Survival Rate (%)

The mean survival rates of fish at the end of the experiment were 90.2, 75.50 in Vietnamese *koi* in T₁ and T₂ respectively. Also survival rates of Thai *koi* were 91.00 and 73.50 in T₃ and T₄ respectively. Significantly higher survival rate was obtained in Thai *koi* in T₃ (91%) and lower rate was in Vietnamese *koi* in T₁ (71.5%).

3.4 Economic Return Analysis

A simple economic analysis was performed to estimate the net profit from the Vietnamese *koi* and Thai *koi* culture operation. The cost of production was based on the Mymensingh whole sale market price of the input used in the year 2019. The selling price of the Vietnamese *koi* and Thai *koi* was in Tk. 160/Kg, Tk. 140/Kg, Tk. 140/Kg, Tk. 125/Kg in T₁, T₂, T₃, T₄ respectively. It was observed that, the highest net return (Tk 640141 /ha/100 days) was obtained from T₁ of Vietnamese *koi* and lowest net return (Tk-327998 /ha/100 days) was obtained from the T₄ of Thai *koi* (Table 4).



Fig. 2. Vietnamese *koi* and Thai *koi* at the end of the experiment

4. DISCUSSIONS

4.1 Water Quality Parameters

Water quality is of utmost importance in fish farming. Similarly, growth, feed efficiency and feed consumption of fishes are normally controlled by few environmental factors [28]. In the culture of *Anabas testudineus*, water quality parameters that are monitored include temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia, and nitrites.

4.1.1 Water temperature (°C)

The water temperature of the experimental ponds was more or less similar in both the treatments of Vietnamese *koi* and Thai *koi*. The maximum temperature (32.2°C) was recorded in Thai *koi* in T₄ on 01 June, 2019 which was due to high intensity of sunlight and minimum temperature (27.25°C) was recorded in Vietnamese *koi* in T₁ on 03 May, 2019, this might be due to moderate intensity of sunlight. Ahmed et al. [29] found maximum temperature was 38.0°C during August which was higher than normal and found minimum temperature (31.8°C) during July. Ahmed et al. [25] observed that the value of average temperature was 31.5°C during April and May from four oxbow lakes of the Mymensingh area. Ahmed et al. [30] recorded water temperature ranging from 19.5 to 29.5°C, in December and January. However, the temperature as observed in the present study appeared to be suitable for fish culture.

4.1.2 Dissolved oxygen (mg/l)

Dissolved oxygen of a water body is very important factor for fish culture. Fishes live in a water body of insufficient dissolved oxygen thereby become physiologically weak and for this physiological weakness fishes become easily attacked by diseases. During the experimental period dissolved oxygen content of the ponds were found between 4.7 to 5.12 mg/l. Ahmed et al. [31] recorded that dissolved oxygen ranged from 6 to 8.5 mg/l. Chakma et al. [32] found dissolved oxygen varied from 3.50 to 14.00 mg/l in six experimental ponds which were much lower and higher than the required dissolved oxygen for fish culture. Ahmed et al. [29] recorded that dissolved oxygen contents in their experimental ponds ranged from 5.5 to 18 mg/l. Halim et al. [14] recorded dissolved oxygen ranged from 1.2 to 8.5 mg/l Hossain [4] recorded DO values of fish ponds ranging from 3.8 to 6.9

mg/l and 2.04 to 7.5 mg/l respectively at Mymensingh region. From the above discussion, it may be concluded that the oxygen content of the experimental ponds were within the good productive range.

4.1.3 pH

During the study period the pH value were recorded as 7.9 ±0.4, 8.10±0.6, 8.2±0.5 and 7.8±0.8 from T₁, T₂, T₃ and T₄ respectively. Ahmed et al. [31] found pH range from 6.5 to 8.5. While, Chakma et al. [32] recorded pH range between 7.44 and 7.66. Ahmed et al. [29] also measured pH from their experimental ponds which were ranged from 7.10 to 8.00. Ahmed et al. [25] found pH value of 7.00 to 7.55 from April 2006 to March 2007 in four beels like Shidlong, Gangni, Buka and Kailla of Mymensingh. Most natural water had pH values ranged from 6.5 to 8.5. Wahab et al. [24] reported that pH was always around 6.0 in BAU campus, Mymensingh. The present findings were within acceptable range required for fish culture 6.5 to 8.5.

4.1.4 Ammonia

Ammonia is one of the most important pollutants in the aquatic environment because of its relatively highly toxic nature and its ubiquity in surface water systems. During the experimental period ammonia (mg/l) were 0.08 mg/l and 0.11 mg/l in T₁ and T₂, 0.10 mg/l and 0.17 in T₃ and T₄. Ahmed et al. [31] found ammonia level ranged from 0.001 to 0.03 mg/l. Ahmed et al. [2] found ammonia ranged from 0.04 to 0.02 in the experimental ponds. Chakma et al. [32] found ammonia in very minute amount (<0.09 mg/l) in his experiment. Ahmed et al. [25] also observed ammonia varied from 0.56 to 0.83 mg/l. Similar experiment was conducted in nine earthen ponds in Field Laboratory of Bangladesh Agricultural University, Mymensingh and observed that ammonia level varied from 0.10 to 0.49 mg/l. The level of ammonia less than 0.2 mg L⁻¹ is suitable for pond fishery. Thus it could be mentioned here that the present finding were within acceptable range required for fish culture.

4.1.5 Alkalinity

Total alkalinity has little direct effect on fishes but indirectly the well-being of fish may be affected by total alkalinity, because water of low values of alkalinity are generally biologically less productive than those with high values. During the present experiment alkalinity range was

varied from 159 to 171.22 ppm in Vietnamese *koi* in T₁, 123.63 to 138.53 ppm in Vietnamese *koi* in T₂, 132.95-147.45 ppm in Thai *koi* in T₃ and 146 to 158 ppm in Thai *koi* in T₄. The highest value (174 mg/l) of alkalinity content was recorded from Vietnamese *koi* in T₁ and the lowest value (123 mg/l) was recorded from Vietnamese *koi* in T₂. Karim [33] found alkalinity was 115.42 ppm, 121.28ppm, 120.57 ppm in T₁, T₂, and T₃ respectively in his experiment. Thus it could be mentioned that present findings were within acceptable range required for fish culture.

4.2 Growth Performances of the Vietnamese *koi* and Thai *koi*

The present study finds that there were differences in mean weight gain between Vietnamese *koi* and Thai *koi*. This may also differ in various treatments. The highest mean weight gain was observed in T₁ (109.60 g) of Vietnamese *koi*, whereas, the lowest mean weight gain was noticed from the T₄ (57.47 g) of Thai *koi*. In T₂ of Vietnamese *koi* mean weight was also measured higher (80.44 g) when compared with T₃ (68.10 g) and T₄ (57.47 g) of Thai *koi*. The result indicated that the growth rate of Vietnamese *koi* was higher than that Thai *koi*. It was observed by Pathak [34] the average weight of individual *A. testudineus* range from 33.83 g to 40.05 g in six months culture operation. Present findings are much higher than Pathak [34].

Haque et al. [21] mentioned that average weight of fish were 69.60 g, 65.46 g and 61.15 g in T₁, T₂ and T₃ respectively which were also lower than present findings. According to Karim [33] it was observed that average weight gain of Thai *koi* were 91.00 g, 84.13 g and 76.50 g in T₁, T₂ and T₃ respectively during 98days culture periods which were closely related to the present study. This result is related to Rahman et al. [28] who observed that the average highest weight of individual Thai *koi* was 91.00 g and the lowest was 68.50 g after four months culture. Besides, Kohinoor et al. [22] observed that highest weight gain was 88.89 g and the lowest weight gain of species was 67.83 g in four months culture operation. During the culture period of 100 days stocking density in monoculture and polyculture were 2000/dec and 1000/dec respectively and the final weights were 66.55 g and 90.75 g respectively [35].

At the end of the experiment the highest mean average daily weight gain in Vietnamese *koi* in T₁ was 1.094g/day and the lowest average daily weight gain in Thai *koi* in T₄ was 0.58 g/day. According to Karim [33] the average weight gain were 0.93 g/day, 0.86 g/day, and 0.78 g/day in T₁, T₂ and T₃ respectively which were closely related to the finding of the present study. Whereas, Chakma et al. [32] mentioned average daily weight gain were 1.87 g/day and 1.26 g/day in T₁ and T₂ respectively for Thai pangus for a period of 70 days in 6 experimental ponds situated in Bangladesh Agricultural University.

The result of the present experiment reveals that mean values of SGR of Vietnamese *koi* are 2.74 in T₁ and 2.61 in T₂. In Thai *koi* SGR values were 2.53 and 2.46 in T₃ and T₄ respectively. Higher value of SGR was obtained from Vietnamese *koi* in T₁ which had higher stocking density and the lower value of SGR was obtained from Thai *koi* in T₄ which had lower stocking density. According to Jahan et al. [35] the SGR values were 5.82% in high stocking density and 5.83% in low stocking density which was higher than the present finding. Hussain [1] shows that the SGR values of Thai *koi* in different treatment are 7.35%, 6.93% 6.76% and 6.11% respectively in T₁, T₂, T₃ and T₄ which was higher than the finding of present experiment. Hasan et. al., [13] observed the SGR values were 3.69%, .3.81% and 3.82% in T₁, T₂ and T₃ respectively which were higher than the finding of the present experiment. According to Chakma et al. [32] the SGR values of fish were ranged from 0.94% to 1.13%. On the other hand Akter [36] mentioned the SGR values were 2.54%, 2.44% and 2.39% which were lower than the finding of the present experiment. The SGR value of the experiment was very much similar study of Chakraborty and Haque [8] with similar feed composition.

In the present investigation FCR values were varied from 1.70 and 2.10 FCR values for Vietnamese *koi* in T₁ and T₂ respectively, whereas, for Thai *koi* in T₃ and T₄ were 1.80 and 2.08 respectively. According to Karim [33] the FCR values of Thai *koi* were 1.73, 1.86 and 1.94 in T₁, T₂ and T₃ respectively during 98 days culture period which was closely related to the findings of present experiment. On the other hand Akter [36] mentioned the FCR values from the experiment were 3.44, 3.76 and 3.94 in T₁, T₂ and T₃ respectively which were higher than the present finding. Hasan et al. [13] found the FCR values were 3.99, 3.11 and 3.82 in T₁, T₂ and T₃ respectively which were higher than the finding of

present experiment. Chakma et al. [32] noticed FCR value 2.34 for Thai pungus. In contrast, Jahan et al. [35] unveiled the FCR values were 1.60 in high stocking density and 1.80 in low stocking density which was almost similar to the finding of the present experiment. The fishes might have properly utilized most of the formulated feed and the utilized feed and help in production of Vietnamese *koi* and Thai *koi* in the finding of present experiment [37].

The mean productions of Vietnamese *koi* were 17,092 kg and 15,000 kg in T₁ and T₂ and the productions of Thai *koi* were also 10,746 kg and 10,469 kg in T₃ and T₄ respectively. Such finding of the study is consistent with Chakraborty and Haque [8].

Initial stocking weight and density were similar in Vietnamese *koi* and Thai *koi* in both treatment but production were higher in Vietnamese *koi* in T₁. Although the mean weight gain and total production were higher in Vietnamese *koi* in T₂ which might be due to higher number of fishes. The present result supports the findings of Jahan et al. [35] who achieved the best production (29,146 kg/ha) from higher stocking densities in comparison with that achieved with the lower ones. Thakur and Das [17] and Akhteruzzaman [19] mentioned average yield to be 1,800kg/ha and 450-500 kg/ha respectively in 5-6 months. These results are much lower than the findings of the present experiment. Azim et al. [24] evaluated the production potentials of *koi* in monoculture management at the density of 16,000 ha⁻¹ and obtained a production of 450 kg/ha in 5 months rearing with supplementary feed consisting 50% rice bran, 30% of mustard oil cake and 20% fish meal. Chakraborty and Haque [8] reported that the mean productions (kg/ha) of *koi* fish were 22063.0, 19851.6 and 16381.2 kg in treatment T₃, T₂ and T₁, respectively. Production was higher in treatment T₃ and lowest in treatment T₁. While, Karim [33] mentioned that the production of Thai *koi* were 6,113.25 kg/ha, 6249.1 kg/ha and 6377 kg/ha in T₁, T₂ and T₃ respectively which were lower than the findings of present experiment. It was found by Hussain [1] in the study that the production were 3,620.38 kg/ha, 5,069 kg/ha, 6,401.44 kg/ha and 4,810.64 kg/ha in T₁, T₂, T₃ and T₄ respectively in 75 days which were much lower than the present experimentation. According to Akter [36] the production of the experiment were 1,916 kg/ha in 50,000/ha stocking density, 1,774 kg/ha in 56,250/ha stocking density and 1,431 kg/ha in 62,500/ha stocking density in T₁, T₂ and

T₃ respectively which were lower than the finding of present experiment.

4.3 Survival Rate (%) of the Vietnamese *koi* and Thai *koi*

The experiment recorded the highest survival rate in T₃ (90.20%) of Thai *koi* in low stocking density and the lowest survival rate was also recorded in T₂ (73.50%) of Vietnamese *koi* in high stocking density. Akteruzzaman [19] reported that the survival rate of *Anabas testudineus* varied from 60% to 80%. Karim [33] observed that survival rates of Thai *koi* were varied from 82.03% to 90.00%. But the results of present study were almost similar to the research finding of Kohinoor et al. [22] who observed that the survival rates of Thai *koi* were varied from 79% to 92%. According to Jahan et al. [35] the survival rates were 88.97% in high stocking density and 98.60 % in low stocking density which was higher than the finding of present experiment. Akter [36] noticed that the survival rate of Thai *koi* were 82.00% and 78.00% and 71.00% in T₁, T₂ and T₃ respectively during the harvesting time which were closely related with the survival rate of present experiment. From the research finding of Hussain [1] it could be mentioned that the survival rate of Thai *koi* were 89.11%, 85.99%, 82.21% and 75.72% in T₁, T₂, T₃ and T₄ respectively during the harvesting time. It was found by Hasan et al. [13] that the survival rates were 73.00%, 76.00% and 83.00% in T₁, T₂ and T₃ respectively which has similarity with the survival rate of the finding of present experiment.

A simple economic analysis of the growth performance of fish showed that the highest net profit (Tk/ha/3 months) of 8,72,390 was obtained from Vietnamese *koi* in T₂. The highest net profit in Vietnamese *koi* in T₂ was due to high growth rate and density tolerance of Vietnam *koi* compared to Thai *koi*. Jahan et al. [35] mentioned that the net profit of Thai *koi* was 11,56,207 Tk/ha/year using formulated diet which were much higher than the value obtained in the present investigation. According to Chakma et al. [32] net benefit was 2,07,328.53 Tk/ha/70days and 77,917 Tk/ha/70 days. Hussain [1] observed the highest profit of Thai *koi* was 3,72,290 Tk/ha. Culture of Vietnamese *koi* bears high production potential in Bangladesh context. A number of hatcheries are producing Vietnamese *koi* fry in Bangladesh. Vietnamese *koi* culture can eliminate the customers concern. From this experiment it was found out that Vietnamese *koi* had high growth rate and density tolerance

compare to Thai *koi*. Vietnamese *koi* looked like our native *koi* and had tremendous growth rate which attracts the customer's attention. Economic analysis showed that the net profit from the present experiment might be due to increased mean higher weight of Vietnamese *koi*. So it can be a conclusion that the Vietnamese *koi* has high growth potential in comparison with Thai *koi*. Proper training on culture of this new variety could help in poverty alleviation at rural farmer's level. Income of the rural poor farmers could be increased through derelict household ponds brought under cultivation [38]. All family members especially women can take participation in Vietnamese *koi* culture and could contribute to family income [37].

5. CONCLUSION

Poverty alleviation and food security along with sustainable development are strongly linked [39]. Thus, the country population is increasing; the demand for aquatic food products is also increasing [40,41]. Sustaining fish supplies from capture fisheries will, therefore, not be able to meet the growing demand for aquatic food and modern aquaculture is considered to be an opportunity to bridge the supply and demand gap of aquatic food in most regions of the world [38], [42]. Therefore, Vietnamese *koi* in treatment T₁ could be a good method in this regard for culture and production of adequate quality of Vietnamese *koi* fish through the application of present findings might be extremely helpful to meet up the demand of protein as daily ration and monoculture technique of Vietnamese *koi* can be postulated as the ideal method of choice for a socio-eco-socio-economically sustainable *A. testudineus koi* culture in Bangladesh. But this monoculture technology can be adopted if it is ensured supplying of high variety of Vietnamese *koi*. The results of the present study demonstrated that Vietnamese *koi* has higher growth in comparison with Thai *koi*. Vietnamese *koi* looked like our native *koi* and had lucrative growth rate which attracts the customer's attention. Many of the ponds remain derelict and vast land remains unused, which could be brought under Vietnamese *koi* cultivation. Whereas, Vietnamese *koi* attained marketable size (maximum size of 400g) within 100 days culture period which could be cultured in unused land around household and roadside. In such way marginal farmers can earn money within very short time by culturing Vietnamese *koi*. Moreover, women can also participate in *koi* culture beside their household works and can

contribute to the family income as well as to the sustainable development of Bangladesh.

ETHICAL APPROVAL

The authors confirm that the ethical policies of the journal, as noted on the journal's author guideline, have been adhered to. As per international standard or university standard ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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