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Effects of Stocking Density on Growth and Production Performance of Cage Reared Climbing Perch (*Anabas testudineus*) of High Yielding Vietnamese Stock

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Abstract: Different growth and production parameters of cage cultured Vietnamese climbing perch (*Anabas testudineus, Bloach*), locally known as koi, were studied. Fishes were reared in bamboo framed net cages under three different stocking densitiesina single experimental culture cycle of 4 months (July to October, 2013). The experimental earthen pond at Sher-e-Bangla Agricultural University (SAU) campus, Dhaka, was installed with a total of nine $1m^3$ (1m x 1m x 1m) cages; wherein 100 fish m^{-3}, 150 fish m^{-3} and 200 fish m^{-3} were set as the different stocking densities demarked as treatment T_1, T_2 and T_3 respectively with three replications each. Mean initial length and weight of the fries were 4.21± 0.114, 4.42± 0.023 and 4.51± 0.047 cm for T_1, T_2 and T_3, respectively. Mean initial weight for the same treatments were 1.62 ± 0.089, 1.54 ± 0.045 and 1.60 ± 0.0097 g, respectively. Whereas the mean harvesting length and weight for T_1, T_2 and T_3 recorded were 16.63± 0.119, 16.12± 0.039, 16.67± 0.093 cm and 105.54±1.84, 118.60±2.535, 112.49±2.10 g, respectively. T_2 showed the highest length and weight gain after harvesting ($P<0.05$). The specific growth rate of T_2 was found significantly different among treatments and again T_2 resulting the highest figure of 3.60±0.003 (%). The same treatment had the highest survival rate of 62.66 ± 4.66 (%) with a mean of 57.44±2.36 (%). However, no significant difference among treatments was observed for survival rate ($P>0.05$). Finally, the gross yield (kgm^{-3}) was 7.929±0.92 in T_2 ($P<0.05$) which was highest among all the treatments and T_2 returned back lowest production of 3.39 ± 0.307 kg m^{-3} which was significantly lower than the yield found in remaining treatments.The gross revenue earned from selling of fish at a price of 220 Tk kg^{-1} were 747.98 ± 67.54, 1744.5 ± 203.6 and 1665.1 ± 187.7 Tk m^{-3} in T_1, T_2 and T_3, respectively. Whereasthe values,in terms of net profit, stood at 418.3 ± 141.16, 779.0 ± 170.73 and 62.00 ± 43.40 Tk m^{-3} for the same treatments, respectively. Therefore, the cage with 150 fishes (T_2) showed promising growth, yield and survival rate which could be recommended to adopt. However, more trials are suggested to optimize the stocking density and feeding regime for better production performance and profit.

Key words: Vietnamese Climbing perch · Anabas · Cage culture · Stocking density · Yield

INTRODUCTION

The climbing perch (*Anabas testudineus,* Bloch) is a well known member of the Anabantoidie family which derived their name for bearing labyrinth like accessory-breathing organ. This fish species, indigenous to South and Southeast Asia including Bangladesh, Pakistan, Nepal, Srilanka, Burma, Thailand, Vietnam, Indonesia, Singapore and China, is found in fresh and brackish waters mostly in ponds, swamps and lakes of these regions [1]. This fish, due to its air breathing ability and tolerance against adverse environmental conditions, is very hardy in nature,can thrive well in low dissolved oxygen (DO) and able to aestivate during the dry season [2].

In Bangladesh this fish, locally known as Koi, is highly esteemed for its highly nourishing quality and prolonged freshness out of water and a valuable diet for sick and convalescent [3]. It is also believed to have medicinal properties such as disease prevention; and slowing down the ageing process for females [4, 5]. This fish is suitable for cultivation in ponds, reservoirs and rice field. Though International Union of Conservation of Nature (IUCN) enlisted *A. testudineus* as

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not threatened perch fish in Bangladesh [6] but due to rough and unplanned water management policy like irrigation, over exploitation, illegal practice of capture fisheries and various ecological changes in its natural habitat, this native species has now come under considerable pressure and considered as endangered in some areas [7-9].

Considering the importance of this species in nutritional, economics and biodiversity the cultivation of Koi fish is becoming increasingly popular among the aquaculturists of Bangladesh. Among various production inputs, the choice of fast growing species with desirable aquaculture traits is a prerequisite for augmenting fish production in culture based fisheries. Natural food based culture of major carp is still in practice in Bangladesh but carp culture could not be widely practiced in the shallow and seasonal ponds. In this regard, Koi fish are an excellent option for growing in the shallow and seasonal ponds and cages as the country enjoys very suitable climatic and ecological conditions for culture of warm-water species [10-12].

Cage aquaculture has some certain advantages over other aquaculture systems that are potentially important in terms of uptake by rural poor and landless people. Growing fish in existing unutilized or underutilized ponds or open water bodies like rivers and floodplains, ease of feeding, ease of stocking and harvesting, less expense associated with treating or preventing disease, easier stock management and monitoring compared with pond culture are among major beneficial point of cage culture [13]. In addition to that if cages were constructed and maintained properly, it could be useful for years [14]. This points out that the fish could be easily cultured for several cycles with same cage installment.

Because of Koi's ability to withstand marginalized poor quality water and breathe atmospheric air, the fish still exists in the ecosystem of Bangladesh as a common species [15]. Considering the fact that *A. testudineus* has high growth rate, Thai Koi, a high yielding exotic variety was introduced in culturing pond of Bangladesh in 2002. But due to the failure of maintaining proper hatchery ethics in the fry production phase, inbreeding has resulted the receding of high yielding characteristics of Thai Koi. To overcome this problem, Sharnalata Agro Fisheries Ltd., Mymensingh, came forward and they brought the brood stock of high yielding Koi from Vietnam in 2010 and successfully produced fry on commercial scale. According to the claim of aforementioned hatchery, these Vietnamese breed is very fast growing which almost four times faster than that of conventional Thai variety. Moreover the colour of this Vietnamese perch resembles with the colour of their native counterpart which made them very much lucrative to the consumer.

Unfortunately, there are no published literature regarding growth and production performance of cage reared Vietnamese Koi in Bangladesh. So, the present study was undertaken to bridge this information gap and to develop and optimize the rearing technology of Vietnamese high yielding perch in cages through an on-station trial which would facilitate the farmers to utilize their water bodies, even the fallow one, more profitably. The specific objective of this experiment includefinding out of best stocking density of Vietnamese perch in cages with a recommended feeding regime. Therefore, it is expected that outcome of this research finding would play an important role to alleviate protein deficiency and upgrading socioeconomic status of the general people of Bangladesh by enhancing production of this high valuedspecies.

MATERIALS AND METHODS

Pond Selection and Preparation: The experiment was conducted at the pond of Fisheries and livestock farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Experimental cages were set in the rectangular pond with an area of 1.75 acres and an average depth of 2 m where rainfall was the main source of water. Field trial was carried out for a period of 120 days from 23 June to 20 October, 2013. Before starting the experiment, the pond, fully exposed to prevailing sunlight, was cleaned of aquatic vegetation. Liming ($CaCO_3$) was done at a rate of 250 kg ha^{-1} to disinfect and improve water quality.

Cage Construction and Installation: Nine cube shaped $1m^3$ (1m×1m×1m) cages were constructed using bamboo frame, black nylon net (8-10 mm mesh size) and nylon twine. One edge of upper side of cages were kept open and tied with nylon threads to facilitate various management activities including supplying feed, sampling of fishes during data collection.Cages were installed keeping 15 cm of it above the surface of pond waterwhich permits each cage havinga volume of 0.85 m^3 water. All cages, installed with plastic floats, were attached with a bamboo made walkway in such a way that they can adjust their position automatically with the increase and decrease of pond water level. Cage walls were cleaned to facilitate unhindered water flow by removing unused feed particles, algae or dirt with the help of nylon brush, fortnightly.

Table 1: Experimental design lay out

	T_1	T_2	T_3
Replication I (R_1)	T_1R_1 (100 fish m^{-3})	T_2R_1 (150 fish m^{-3})	T_3R_1 (200 fish m^{-3})
Replication II (R_2)	T_1R_2 (100 fish m^{-3})	T_2R_2 (150 fish m^{-3})	T_3R_2 (200 fish m^{-3})
Replication III (R_3)	T_1R_3 (100 fish m^{-3})	T_2R_3 (150 fish m^{-3})	T_3R_3 (200 fish m^{-3})

Table 2: Feeding regime followed during different stages of rearing process

Average weight of Fish(g)	Types of feed supplied	Protein content of feed (%)	Amount of feed supplied (% fish body weight)
0.2-3	Nursery	35	70
3-10	Starter (Crumble)	30	20
10-30	Starter	30	7.4
31->60	Grower	30	4.5

Experimental Design: Three different stocking densities of Vietnamese Koi in cages were tested as T_1, T_2 and T_3 in the experiment, each with 3 replications (Table 1).

Fry Stocking and Rearing Management: Fries were collected from a private hatchery named 'Sharnalata Agro Fisheries Ltd.' from Mymensingh. The average initial mean sizes of fries were 4.21 ± 0.192, 4.42 ± 0.199 and 4.50 ± 0.263 cm in T_1, T_2 and T_3, respectively. The average initial weight of individual fry was 1.59 ± 0.01 g.

Commercial pellet feed (Mega feed, manufactured by Spectra Hexa Feeds Ltd.) for climbing perch in accordance with the age and sizes of the fries were used for feeding purpose.Fishes were fed twice a day at 7 am and 4 pm with two equal split of the ration. Feeding regimes were followed as per DoF guidelines[16] for culturing small indigenous species and were adjusted fortnightly on the basis of body weight (Table 2).

Regular monitoring of the stocked fish was carried out during feed supply. In addition Random sampling was carried out from each cage on fortnightly basis to check the health condition of fishes and any dead fishes were removed from the cage immediately.

Data Collection & Analysis

Water Quality Parameters: Portable digital equipments and kits were used for collectingdata on different water quality parameters.Water temperature (°C) was measured using portable digital thermometer (Digi-thermo WT-2, China) at 10.00 am weekly.Transparency (cm) of pond water was measured with the help of normal Secchi disc of 20 cm size at 12.00 pm weekly. Determination of water pHand dissolved oxygen was carried out portable pH meter(Eco Testr pH2, USA) and DO meter (Lutron PRO, DO-5509, Taiwan), respectively. Important water nutrients like phosphatephosphorus, nitrate nitrogen and ammonia nitrogen concentration (mg l^{-1}) both in pond and cage waterwere determined weeklywith PO_4-P, NO_3-N and NH_3-N paper based test kits (HANNA Instruments, USA), respectively.

Growth and Feed Utilization: Length of the fry/fish was measured using steel made centimeter scale at the beginning and end of the experiment. Weights of fry/fish were measured using 0.01 g precision portable electric balance at the same time. Weight of the supplied feed was recorded strictly every day for calculation of FCR, PER etc.A total of 10 randomly selected individuals were used for taking all length and weight related data. At the end of the period all harvested live fish werecounted and weighed to determine survival rate and yield.

Data Analysis: Specific growth rate (SGR), food conversion efficiency (FCR) and protein efficiency ratio (PER) were calculated as follows: SGR (% / day) = (Ln. Final body weight - Ln.Initial body weight)/days x 100; % Weight gain = (Final body weight -Initial body weight)/ Initial body weight x 100; FCR = Food fed (g dry weight)/ Live weight gain (g); PER = Live weight gain (g)/Crude protein fed (g dry weight). The data were analyzed through one way Analysis of Variance (ANOVA) using SPSS (ver. 16) followed by Duncan's New Multiple Range Test (DMRT) to find out whether any significant difference existed among treatment means. Standard deviation in each parameter and treatment was calculated and expressed as mean ± SD. The level of significance was set at 5% ($P>0.05$).

RESULTS AND DISCUSSION

Water Quality Parameters: A favorable physico-chemical condition of water is the major pre-requisite for healthy aquatic environment and better production. In the present experiment, significant variation in major water

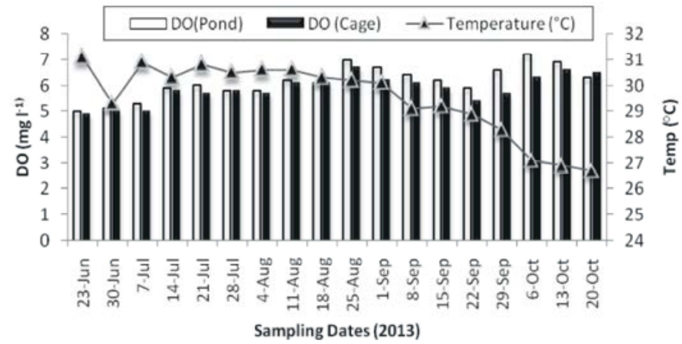

Fig. 1: Dissolved oxygen (DO) and Temperature of experimental pond and cage water recorded on different sampling dates (Common value of water temperature was used for both pond and cage water)

quality parameters under investigation indicated apart from natural factors, influence of stocking density and feeding practices played pivotal role in maintaining a water quality. In other studies on cage culture, it was observed that wastes derived from supplied feed caused variation in water quality parameters inside cage other than outside environment [17].

In the present experiment, physical parameters, like temperature and transparency never differed significantly between pond and cage water samples. Therefore, one common data was counted during analysis and presented in Figure 1. Water temperature recorded ranged from 26.7 to 31.1°C with a mean of 29.49 ± 0.33 °C in both pond and cage water. In a previous experiment of cage-pond aquaculture in the Fisheries Field Laboratory of Bangladesh Agricultural University, Mymensingh, [18] recorded the water temperature ranged from 17 to 30°C which supported by the findings of [19] who recorded the water temperature from 27.2 to 32.4°C in the earthen ponds in Mymensingh which also goes in line with present findings.

The dissolved oxygen content in the experimental pond water and cage water ranged from 5.00 to 7.20 and 4.90 to 6.70, with the mean values of 6.13 ± 0.14 and 5.86 ± 0.12 mg l^{-1}, respectively (Figure 1). Other researchers [20, 21] in their experiment on cage-pond aquaculture of Thai Koi (*A. testudineus*) with Carps found the dissolved oxygen content of 2.3 to 8.0 mg l^{-1} which was more or less similar to the results of current study. Like terrestrial organisms, aquatic fauna also affected by a great extent of different DO concentration in water. Continued exposure to low dissolved oxygen is also considered a precursor to bacterial infection in fish. Concentrations reflect the momentary balance between oxygen supply from atmosphere and photosynthesis on one hand and the metabolic process that consume on the other. Although fish might survive in 0.5 mg l^{-1} dissolved oxygen concentration but most suitable range of DO in a water body for fish culture was suggested from 5.0-8.0 mg l^{-1} [22]. Comparatively lower level of DO was observed in the cage water than in pond water due to higher oxygen consumption by densely populated cages and reduced chance of mixing ambient oxygen with cage water. Though in the present experiment all DO concentrations in pond water were well within the permissible limit but some reading slightly lower than the recommended level were recorded in cages, especially those with high stocking density. However, dissolved oxygen concentration (mg l^{-1}) in pond and cage water did not differ significantly (P>0.05).

Like temperature, common readings of water transparency were recorded both for pond water and cage water in this experiment.The measurement ranged from 31.00 to 43.00 cm with a mean of 38.66 ± 0.79 cm (Figure 2) with an average transparency of 38.66 ± 0.79 cm both in pond and cage water. Water transparency is an important factor and related inversely with plankton abundance and primary productivity. It is generally expressed as the level of pond productivity and indicates the presence or absence of fish food particles. Secchi disk visibility about 20 to 30 cm means the water body is productive, if it is not newly constructed or turbid due to rainfall or borrowing by fish or other organisms [23]. Although present finding indicates the experimental pond as a less productive one but it did not hamper the growth and production performance of the Vietnamese perch as it depends entirely on artificial commercial feed.

The concentration of hydrogen ion plays crucial role on the productivity of the water body. Figure 2 shows the level of pH in pond and cage water which varied from 7.30-8.00 and 7.50-7.90, respectively. However, the mean values of pH differed significantly (P<0.05) with the

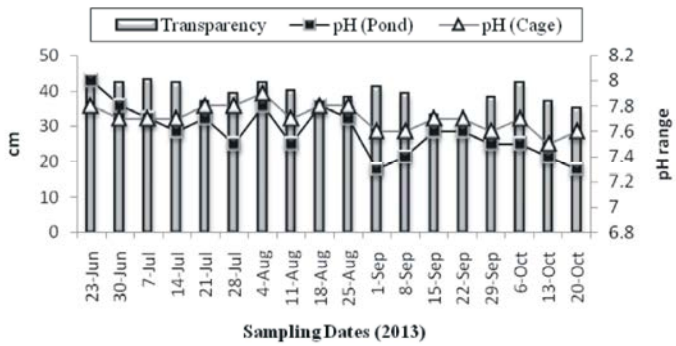

Fig. 2: Transparency and pH of experimental pond and cage water recorded on different sampling dates (Common value of water transparency was used for both pond and cage water)

values of 7.59 ± 0.04 and 7.70 ± 0.02 in pond and cage, respectively. [24] observed a good relationship between pH of pond water and fish production with satisfactory result at pH 6.5 to 9.5. He also observed that water with pH more than 9.5 was unproductive and pH 11.0 was lethal for fish. Circum neutral pH ranging from of 6.65 to 7.94 was recorded by [25] in several earthen carp-prawn poly-culture ponds during month of July to October. [26] and [22] also stated 6.5 to 8.5 as the suitable range of pH for pond fish culture. Therefore, in the present study, the slightly alkaline pH of experimental pond water was in agreement with previous findings of [27] who found elevated pH values in intensive cage culture particularly in summer time due to increased photosynthetic carbon fixation caused by stimulated phytoplnakton production.

Nitrate-nitrogen (NO_3-N) expresses the concentration of nitrate based only on the weight of the nitrogen in the nitrate. Nitrates serve as major precursor of nitrites, which in turn easily combine to form substances dangerous to fishes as well as human. In the present study, NO_3-N concentration in both outside and inside the cage ranged from 0.05 to 0.21 mg l^{-1}(Figure 3-a). The mean values of NO_3-N were 0.12 ± 0.01 and 0.14 ± 0.009 mg l^{-1} in pond water and inside cage, respectively. So, the highest NO_3-N was recorded both in cage and pond water (0.21 mg l^{-1}) during month of September. Most of sampling resulted in almost similar NO_3-N content though some cage water sample showed slightly higher value which could be due to organic load of artificial feed wastes and excreta.

Similar results were reported by [28] who claimed higher nitrates concentration in fish culture ponds with heavy load of microorganisms and decomposed organic matters (used as fertilizers). But pond water and cage water NO_3-N concentration did not varied significantly (*P>0.05*). [29] reported that the range of NO_3-N from 0.06 to 0.1 mg l^{-1} is suitable range for fish culture. Typical levels in surface waters range from 0.005 to 0.5 mg l^{-1} nitrate. However, nitrate is relatively nontoxic to fish and is only considered hazardous at a concentration above 90 mg l^{-1} of NO_3-N [30]. So, in the present study NO_3-N remained within acceptable range for sound aquaculture.

The mean values of phosphate phosphorous (PO_4-P) was recorded 2.088±0.096 and 2.366±0.084 mgl^{-1}in pond and cage water, respectively (Figure 3-b). The highest PO_4-P value was found 3.10 mgl^{-1}in cage water during the month of October; and lowest value was 1.50 mg l^{-1} in the month of September in pond water. [31] reported PO_4-P ranged from 0.11 to 2.0 mg l^{-1} in different earthen ponds at his study which was more or less similar to current findings. [32] observed that 0.2 to 2.8 mg l^{-1} of phosphate-phosphorus is favorable for growth of blue green algae and diatoms. Nevertheless, the differences between pond and cage water was found to be insignificant ($P<0.05$) when analyzed through ANOVA. Almost all of the phosphorus (P) in water remains in the form of phosphate (PO_4) and much of itphosphorus in surface water is bound to living or dead particulate matter. Although the typical range of total PO_4-P for surface waters is 0.015 to 1.5 mgl^{-1}but in the present study, presence of comparatively higher concentration of phosphorus both in pond and cage water could be attributed to the entering of fertilizer runoff water from horticultural research plots located near experimental pond. [33] also opined about similar research findings. Phosphate is considered as an essential plant nutrient and work as a stimulus for plankton andalgae growth which is desirable in ponds for fish culture [34]. But in the present study phosphorous concentration as well as phytoplankton production was not taken into account since the experiment was extensively dependent of nutritionally balanced artificial feed.

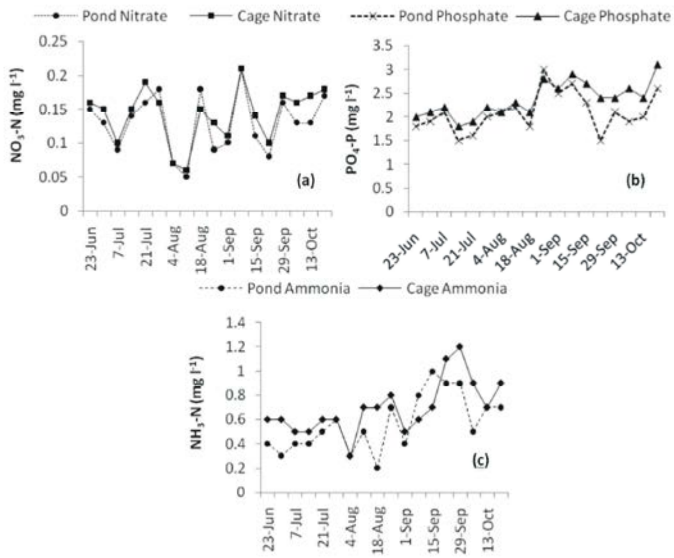

Fig. 3: Concentration (mg l^{-1}) of (a) Nitrate Nitrogen (NO_3-N), (b) Phosphate Phosphorus (PO_4-P) and (c) Ammonia Nitrogen (NH_3-N) in experimental pond and cage water on different sampling dates

Non-ionized ammonia (NH_3) is highly toxic to fish, but ammonium ion (NH_4^+) is relatively less toxic. In this experiment the range of ammonia-nitrogen (NH_3-N) in pond and cage water was 0.12 ± 0.01 and 0.14 ± 0.01 mg l^{-1} respectively (Figure 3-c). The highest nitrate-nitrogen value found was 0.21 mg l^{-1} in the month of September both in pond and cage water and lowest value was 0.20 in the month of August in pond water. The range of mean values of ammonia-nitrogen was 0.566 ± 0.054 and 0.694 ± 0.052 mg l^{-1} in pond and cage, respectively. The highest NH_3-N value was 1.20 mg l^{-1} in the month of September in cage water; and lowest value was 0.20 mg l^{-1} in the month of August in pond water. Findings of the present study was more or less in conformation with report of [20, 35, 36] who recorded a total ammonia of 0.01 to 0.99 mg l^{-1} in their experiment on different fish culture during summer time. In most cases NH_3-N was found in higher concentration in cage water than open pond water and this could be attributed to higher organic load of feed wastes and accumulation of faecal materials in cages. This findings were also in agreement with findings of [37] and [38] in cage-fish integrated carp polyculture pond.

Growth and Production: Details of growth parameter, survival rate and feed utilization parameters (FCR, PER, SGR) under different stocking densities are shown in Table 3. On the basis of increase in body length, T_1 showed the highest value whereas T_2 resulted in the lowest. Mean length gains in three different treatments were found to be significantly different. On the basis of final body weight attained at harvest,the growth results obtained on the basis of body weight from the experiment indicated that the growth rate varied in different stocking densities. On the basis of final growth attained at harvest under T_1, T_2 and T_3 were 105.54±1.84, 118.60±2.535 and 112.49±2.10 g, respectively. The highest harvesting weight was obtained in T_2 and lowest in T_1. The harvesting mean weight showed significant differences ($P<0.05$), when ANOVA was performed.

The specific growth rate (% per day) of fish in different treatments varied among the treatments. Highest value was obtained in T_2 and lowest in T_1. SGR in T_2 was significantly higher than T_1, while T_3 was not significantly different from T_2, but was significantly different from T_1. FCR was significantly lower in T_2 than in T_1 and T_3. Therefore, SGR and FCR were best for fish in T_2 where 150 fingerlings m^{-3} werestockedinitially. PER was found highest in T_2, followed by T_3 and T_1 successively.

The percentage of survival as recorded in the present study was 74.33 ± 1.45, 89.66 ± 4.66 and 84.33 ± 4.04 for T_1, T_2 and T_3, respectively. The highest survival rate was observed in T_2 and the lowest in T_1. Differences in survival rates among the treatments were found to be not significant ($P>0.05$).[39] also reported similar survival rate of *A. testudineus* ranging from 74-95%. The average yield of Vietnamese Koi was 3.39 ± 0.30, 7.92 ± 0.92 and 7.56 ± 0.85 Kg m^{-3} in T_1, T_2 and T_3, respectively (Figure 4).

Table 3: Different growth, survival rate and feed utilization parametersof Vietnamese Koi under different treatments

Variables	Means (DMRT) Treatment 1	Treatment 2	Treatment 3
Mean initial length	4.21 ± 0.114^{a}	4.42 ± 0.023^{a}	4.51 ± 0.047^{a}
Mean final length	16.63 ± 0.119^{a}	16.12 ± 0.039^{a}	16.67 ± 0.093^{a}
Mean length increase (cm)	12.42 ± 0.164^{a}	11.7 ± 0.072^{b}	12.16 ± 0.049^{a}
Mean individual stocking weight (g)	1.62 ± 0.089^{a}	1.54 ± 0.045^{a}	1.60 ± 0.0097^{a}
Mean individual Harvesting weight (g)	105.54 ± 1.84^{a}	118.60 ± 2.535^{b}	112.49 ± 2.10^{ab}
Survival rate (%)	74.33 ± 1.452^{b}	89.66 ± 4.66^{a}	84.33 ± 4.044^{a}
SGR (% day^{-1})	3.47 ± 0.014^{a}	3.60 ± 0.0033^{c}	3.54 ± 0.0066^{b}
FCR	3.32 ± 0.164^{b}	2.21 ± 0.160^{a}	3.13 ± 0.193^{b}
PER	1.00 ± 0.0473^{a}	1.524 ± 0.117^{b}	1.073 ± 0.121^{a}

*Values in a row with same superscript differ significantly (P<0.05)

Table 4: Cost-benefit analysis of cage cultured Vietnamese koi (*Anabas testudineus*) under different stocking densities

Parameters	Treatments T_1	T_2	T_3	Level of Significance (ANOVA)
Total revenue (TR)	747.98 ± 67.54^{a}	1744.5 ± 203.6^{b}	1665.1 ± 187.7^{b}	*
Total operational cost (Cage construction fingerling, feed & Chemicals, labour, miscellaneous) (TC)	689.29 ± 24.61^{a}	965.53 ± 43.73^{b}	1246.5 ± 103.63^{c}	*
Net return (TR-TC)(Tk m^{-3})	62.00 ± 43.40^{a}	779.0 ± 170.73^{b}	418.3 ± 141.16^{ab}	NS

NS – Not significant (*P>0.05*); * Significant (*P<0.05*)

Mean values with different superscript in same row indicate significant difference (*P<0.05*).

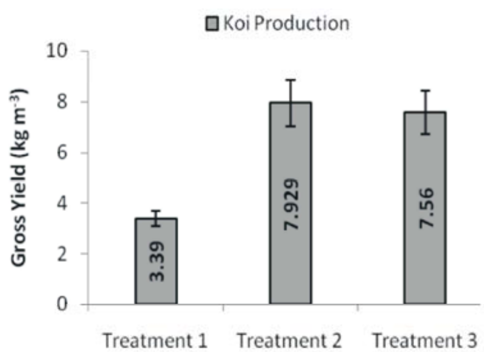

Fig. 4: Gross yield (kg m^{-3}) of Vietnamese climbing perch under different treatments (vertical bars indicate standard deviation)

The highest fish production was obtained in T_2 followed by T_3 and the lowest in T_1. However, production of fish differed significantly (P<0.05) among the three treatments. In this experiment, T_2 (cages with 150 fish m^{-3}) showed highest survival rate of Vietnamese Koi. The mean survival rate of T_2 cages was over 61% whereas it wasbelow 53% in case of T_1 (cages with 100 fishm^{-3}) cages. In case of T_3 (cageswith 200 fish m^{-3}) the survival rate was 57% which was also lower than the T_2 but bit higher than T_1. So T_3 had the lowest survival rate. Therefore, it was apparent that the cage with 200 fish m^{-3} was too crowded. Not only for survival rate but also the SGR (%/day) was also found higher in T_2(cages with 150 fish m^{-3}) than both T_1 (cages with 100 fish m^{-3}) and T_3 (cages with200 fish m^{-3}). SGR was lower in T_3, which can be explained as this treatment had highest stocking density. Therefore, such higher stocking density required more feed for fishes,which produced more waste products in 1m^3 cage of higher stocking density than lower one. Besides, this highest stocking density in T_3 also had less dissolved oxygen for more fishes than in T_1 and T_2 as all these cages were 1m^3 in dimension. Along with this temperaturevariation due to higher stocking density can also be a reason for T_3 treatment which caused such variation in SGR [40].

So, both FCR and PER were found to be promising in T_2 (cages with 150 fish m^{-3}) ratherthan T_1 (cages with 100 fish m^{-3}) and T_3 (cages with 200 fish m^{-3}). This obviously resulted in the highest gross yield in T_2. In case of FCR, the statistical analysis showed significant difference among the treatments which is once again can be interpreted into the suitability of stocking density in T_2. Therefore,the highest gross yield was found in T_2 even though T_3 had highest number of fries when released into the cages.

Economic Analysis: The gross revenue earned from selling of fish at market price (220 Tk kg^{-1}) were 747.98±67.54, 1744.5±203.6 and 1665.1±187.7 Tk m^{-3} in T_1,

T_2 and T_3 respectively (Table 1). The highest revenue was observed in T_2 treatment and the lowest in T_1. The ANOVA showed that there was significant difference (*P<0.05*) of gross revenue among treatments. The mean value of operational cost for T_1, T_2 and T_3 were calculated as 689.29±24.61, 965.53±43.73 and 1246.5±103.63 Tk m^{-3},respectively. The highest and lowest operational cost was found in T_3 and T_1 treatment, respectively and significant difference was observed among different treatments. In terms of net profit, T_2 topped among three treatments with average net return of 779.0±170.73 Tk m^{-3} followed by T_3 and T_1 with the value of 418.3±141.16 and 62.00±43.40 Tk m^{-3}, respectively. However no significant difference (*P>0.05*) of net return among different treatments was observed.

The net return of T_2 (cages with 150 fish m^{-3}) was far higher than the T_1 (cages with 10 fish m^{-3}) and T_3 (cages with 200 fish m^{-3}) as T_2 (cages with 150 fish m^{-3}) had all its growth parameters in promising condition. In the present experiment, since the cost-benefit analysis was carried out only for one culture cycle, cost of some physical amenities like bamboo made cages, different containers etc. were included in the operational cost. Net profit level will be increased with the decreasing or production cost if these materials are maintained and preserved properly during and after culture for their use in several culture cycles.

CONCLUSION

From the aforementioned discussion it is evident that Koi fish of high yielding Vietnamese stock showed promising grow thunder Bangladeshi climate and possesses a huge potential for cage aquaculture in this region. Economic analysis also proved the commercial viability for growing this fish, especially in cages which permit farmers to utilize open water bodies and large poly culture pond more efficiently and profitably. It also facilitates the culture management and harvesting procedure, particularly for a fish with a mud borrowing habit. However, the production level as well as profit margin could be pushed to a higher altitude by refining the culture system through introducing of cost effective farm made feed, different cage orientation and testing alternative stocking density patterns.Therefore, further off-farm trials in rural pondson pilot scale basis is suggested which would not only help improve the outcome of present experiment but also make the stakeholders enthusiastic to adopt the scientific cage culture approach for high yielding Vietnamese koi.

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