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Research Article

Perfect Stocking Density Ensures Best Production and Economic Returns in Floating Cage Aquaculture System

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ABSTRACT

A density dependent research was conducted on *Oreochromis niloticus* to determine the growth performance, body composition, survivability, yield and financial returns in floating cage fish culture system in a tributary of Tetulia River, Bhola. Juvenile monosex tilapia with an average weight of 40.2 g were stocked in 5 floating net cages at a density of 1000 (C1), 1200 (C2), 1500 (C3), 1800 (C4) and 2000 (C5) respectively. Fish were fed with a commercial floating feed twice daily in all the treatments. After 120 days, growth in terms of body final length and weight, weight gain, percent weight gain, specific growth rate, daily weight gain, gross and net production of fish were calculated and found C3 were comparatively higher than others. Survival rate was decreased with increasing stocking density. According to cost benefit analysis (CBA), stocking density 1200 per cage was the most suitable but it should not rise more than 1500 per cage for commercial monosex tilapia culture in cage aquaculture system.

Keywords: Cage culture; Stocking density; Growth performance; Monosex Tipalia; FCR; Lotic ecosystem

INTRODUCTION

Floating cage aquaculture is an excellent way of fish culture by utilizing natural resources like rivers, lakes, flood plain areas, estuaries, seas, and reservoirs otherwise unworthy for traditional aquaculture [1]. This profitable fish culture technique is most important to the landless people as they can use communal water bodies for fish culture in cages [2]. A comprehensive fish culture in cage has already been developed successfully in Europe, Asia and America. This technique first started in Kampuchea at late 1800 s, since then, cage culture was practicing in both marine and freshwater environments in many countries throughout the world. Though, aquaculture activities in Bangladesh are yet concentrated mainly in pond (lentic ecosystem) based culture system, however, fish production by cage aquaculture system using different water resources was about 3,523 MT in 2017-2018 fiscal year [3]. Cage culture of fish in lotic ecosystem has some benefits for instance; minimum mortality rate, higher growth rate [4], less chance of disease attack and predation, harvesting is easy and fish can culture at high stocking density. Cage aquaculture in open water bodies could provide an opportunity for increasing fish food production and mitigating protein demand in the nation.

Tilapia is the species of choice which is cultured widely in the most tropical, subtropical and temperate regions [5-7] due to their high growth rate, marketable value, adaptive capacity and rough handling [8,9]. Formerly, tilapia was taken as food fish mainly by the people of Africa and Asia where its culture was for subsistence and mainly in freshwater ponds. But at present, after carps, it is deemed to be the second most important cultured species in the world. In mixed sex tilapia culture practice, female tilapia reproduces at premature stage which results overcrowding, feed competition and poor growth performance [10]. For the time being, culture of sex-reversed male Nile tilapia, *Oreochromis niloticus* has been paid great attention as a result of their sexual dimorphism, males grow significantly faster, larger and become more or less uniform in size compared to females. In cage aquaculture, stocking density has a direct inverse relationship with growth performance, specific growth rate, survival rate, food conversion ratio, body composition, and production of fish [11,12]. Determination of optimum stocking density is prerequisite for the maximization of tilapia production in cage culture system. The aim of this present study was to explore the suitable stocking density of monosex Nile tilapia, *Oreochromis niloticus* as a potential culture species and economic analysis in floating cage culture system in a tributary of Tetulia River, Bhola.

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MATERIALS AND METHODS

Experimental site

The present study was conducted in a tributary of coastal Tetulia River under Bhola district, southern Bangladesh. Although the area is under expose coast but the study site (22° 38' 54.0" N 90° 36' 48.6" E) was more than 85 km away from the Bay of Bengal coast (Figure 1). The duration of the study was four months from May 2019 to August 2019.

Cage construction and installation

Five floating cages (GI pipe framed) covering an area of 6 m × 3 m × 2 m (L × W× H) has been installed in the river supported by vacuum plastic drum (250 liters) to make the cage floating. A synthetic nylon cage net (mesh size 1.5 cm) with a cover net (mesh size 2.5 cm) at the top and a fine meshed net (20 cm depth) according to surface water level was tied with cage frame. Cover net prevent fish from escaping by jump and predation by bird while fine meshed net impedes floating feeds to forsake from the net and to reduce the access of floating trash from outer surface. The bamboo poles were covered with cage frame for easy movement, feeding and sampling of the experimental fish. To maintain internal area of cage six breaks were used as sinker from outside the cage net. The cage was set in an area having water current maximum 6 inch per second during high and low tide. All five cages were attached by iron made clam one after another to minimize the overall cost (Figure 2). The whole cage structure was tied with anchors by nylon rope to facilitate easy floating and moving of whole cage on water level.

Fish collection and stocking

The present study was based on five different stocking densities of monosex tilapia like 1000, 1200, 1500, 1800 and 2000 designated as C1, C2, C3, C4 and C5, respectively. Sex-reversed monosex male tilapia, *Oreochromis niloticus* having mean weight 40.2 g were transported from hatchery to the experimental site and they were kept in a hapa for 24 hours for adjustment with environment and taking initial length and weight individually in 'cm' and 'g' with the help of a measuring scale and a digital electronic balance with an accuracy of 0.01 g. Finally, each cage was randomly stocked with monosex tilapia according to density selected for present study.

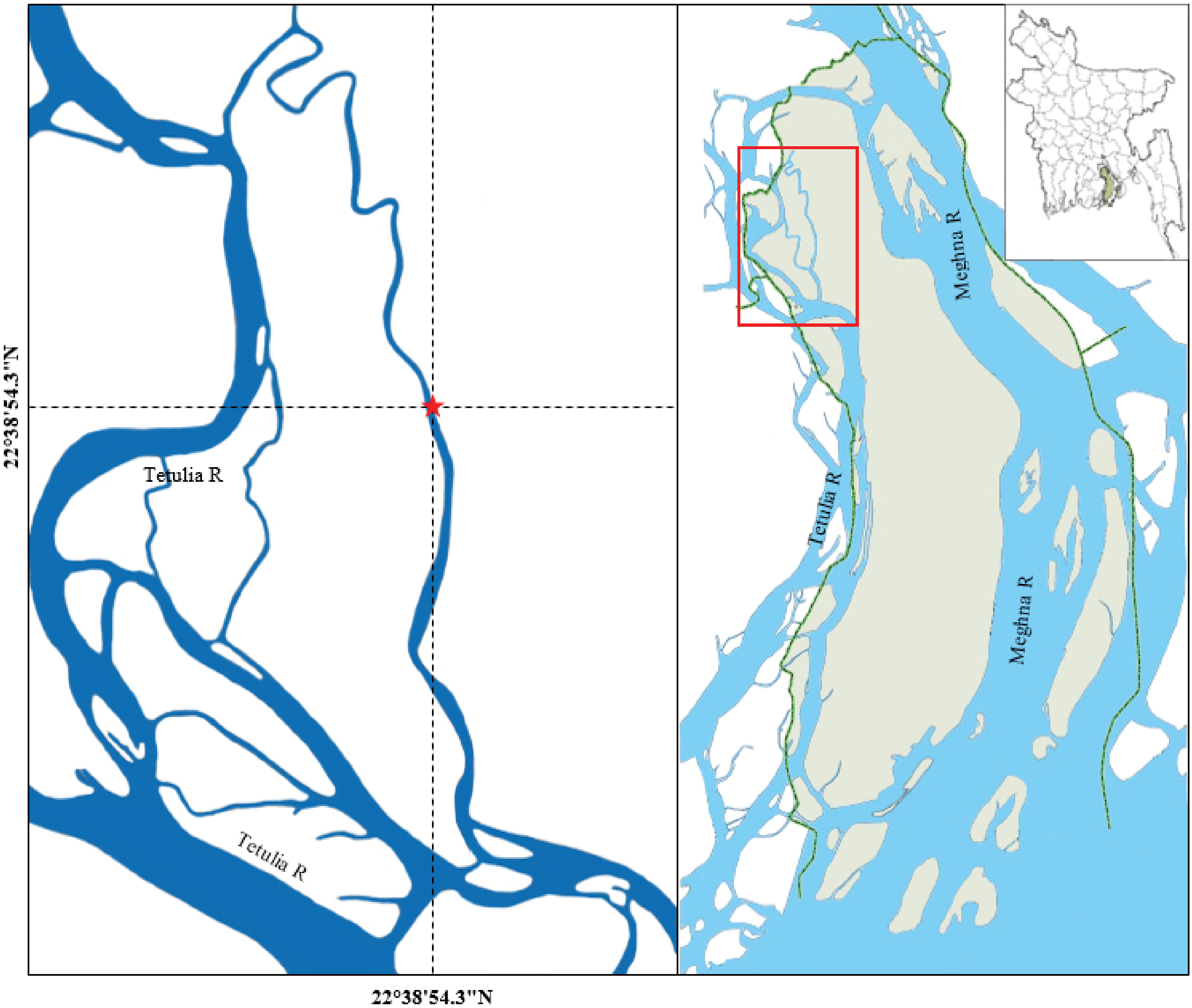

Figure 1: Location of experimental site of Nile tilapia culture under floating cage aquaculture in Tetulia river tributary.

Feeding and rearing

Fish were fed with commercial floating pellet feed contained 26.2% crude protein, 5.95% crude lipid, 14.23% crude ash and 9.43% moisture at 3-5% of initial body weight twice daily (8 a.m. and 4 p.m.) by dividing total amount of feed into two equal rations. Manual feeding was done by hand cautiously to ensure proper ingestion of feed. Monthly near about 20% of fish in each treatment were sampled in order to determine length and weight of fish and the amount of feed were controlled as per changes of body weight in each cage. Supplied feed and dead fish were documented to determine the food conversion ratio (FCR). The cages were hauled from water at every 15 days interval for cleaning purposes and to check the net if any damage occurred.

Sampling and data analysis

After taking length-weight data randomly for at least 20% of fish at monthly basis, all fish were harvested after 120 days of trial period and then fish were counted, measured (length) and weighed for each cage offish individually. To determine the growth response, yield and survivability of experimental fish, the following parameters were calculated:

Weight gain (%) = (Final weight-initial weight) × 100/Initial weight

Average daily weight gain (ADWG)=(Final fish weight-initial fish weight)/days

Feed Conversation Ratio (FCR)=Weight of feed given (g)/fish weight gain (g)

Specific Growth Rate (SGR%)=100 × (ln final wt-ln initial wt)/days.

Survival Rate (SR%)=100 × (Number of fish survived/number of fish stocked)

Gross yield=fish production (kg)/cage (18 m^3)

Net yield=Fish production (kg)/m^3 of cage

Statistical analysis

All statistical analyses were performed using Microsoft excel 2013 and IBM SPSS Statistics 20.

Economic analysis

After the termination of experiment, an economic analysis was performed to estimate the net return and benefit cost ratio on the basis of different stocking densities of monosex tilapia. The following simple equation was used according to Asaduzzaman et al. [13].

R=I-(FC+VC+Ii)

Where, R=Net return, I=Income from monosex tilapia sale, FC=Fixed costs, VC=Variable costs and Ii=Interest on inputs

The benefit-cost ratio was determined as:

Benefit cost ratio (BCR)=Total net return/Total input cost

At the end of the experiment, all fish were sold and the prices of fish were attributed to the Bhola local fish market price in July 2019 and expressed in Bangladeshi taka. The local price per kg of monosex tilapia was 150 BDT for more than 350 fish (C1 and C2), 145 BDT between 300 to 350 g (C3) and 140 BDT for less than 300 g fish (C4 and C5).

RESULTS

During the experimental period, monthly length and weight basis increments of growth are shown in Figure 3. It is clearly visible that, growth of fish (length) was comparatively low in the first month which impacted on body weight. The highest mean final length and weight was observed in C1 followed by C2, C3 and C4 and C5.

At the end of the experiment, we got highest and lowest as well as mean value of body weight. Maximum mean body weight (468.2 g) was observed in C1 with minimum mean body weight 344.63 g and maximum mean body weight 562.4 g. Although the minimum mean value (291.8) was observed in C5, however, maximum (569.7 g) and minimum value (141.9 g) of body weight was also obtained from this cage (Figure 4).

In case of survivability, all cage fishes were more than 90% survival rate. C1 and C2 showed maximum survival rate during the study period which was more than 95% while lowest survivability was observed in C5 and the rate was below 94.2% (Figure 5). No mortality was observed in C1 cage in last two months while the mortality of C2 cage was constant in second and third month. No significant differences were found in survival rate of C1, C2 and C3 during the four months of study period.

At the end of 120 days of fish culture in cages, biological performances and production of monosex tilapia at different stocking densities were presented in Table 1. All growth parameters in terms of final length, final weight, weight gain, percent weight gain, average daily weight gain and specific growth rate were decreases from lower to higher stocking densities. Maximum daily weight gain (3.57 ± 0.53 g) in C1 was almost 1.5 times higher than minimum daily weight gain (2.10 ± 0.37 g) in C5. An increasing trend of feed conversion ratio (FCR) was observed with increasing stocking density. The best FCR (1.32 ± 0.07) was found for the stocking density of C1 while highest (1.92 ± 0.07) in C5. Significantly higher gross and net fish production were found in C3 followed by C5, C4, C2 and C1 (Table 1).

In consideration of economic analysis, total cost of inputs in C1 (BDT/cage) was lower than that in C2, C3, C4 and C5 (Table 2). However, a highest total net return (30,955 BDT) was obtained in

Figure 2: Experimental cage construction and set up for the present study (Five cages from right side).

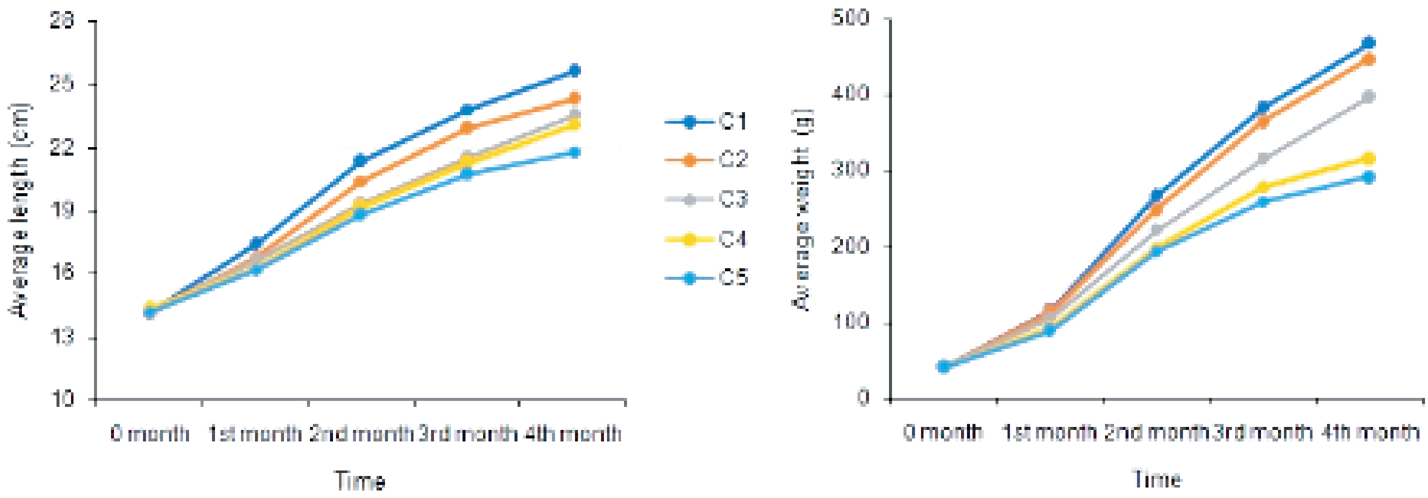

Figure 3: Monthly growth promotion of Nile tilapia at different stocking density under floating cage aquaculture system.

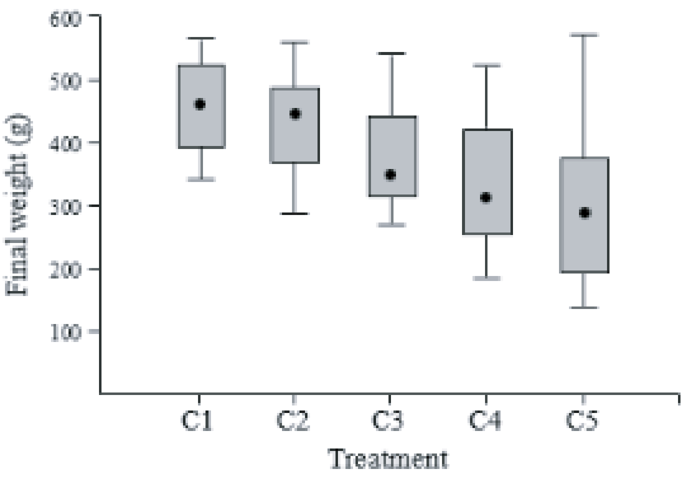

Figure 4: Final weight details of Nile tilapia after four months culture period from May 2019 to August 2019 at different stocking density.

Figure 5: Monthly survivability record of Nile tilapia during study period from May 2019 to August 2019.

C3 followed by C2, C1, C4 and C5. In overall, the highest benefit cost ratio (0.598) was found in C2 which was 2.83 times greater than lowest value (0.214) found in C5.

DISCUSSION

In this study, growth in terms of final length, final weight, weight gain, percent weight gain, average daily weight gain and specific growth rate of monosex tilapia were significantly higher in lower stocking density compared to higher stocking densities. Reducing the stocking density in this production system not only improved fish health and water quality but also reduced the feed conversion ratio and production costs, and confirms higher operating income [14]. Albeit a same feed was applied at an equal ratio, the growth performance differed significantly in all the stocking groups. The reason behind this might be due to lower density fishes got more spaces and there was less competition for feeds compared to higher density treatments. This result is in agreement with those reported by Chakraborty et al. [15], for monosex tilapia, Gibtan et al. [9], and Osofero et al. [16], for mixed sex tilapia in cage culture system. In the present study, the overall growth performance of monosex tilapia was higher than Mridha et al. [17], and Moniruzzaman et al. [18] after 4 months culture period. On the contrary, better daily weight gain and final weight at a density of 30 fish/m^3 in overwintered GIFT monosex tilapia was reported by Dan et al. [19]. The performances were lower than our results in case of new season (first production offish after spawning in the season) with same strain of tilapia. Moreover, Dan et al. [19] confirmed that overwinter caged tilapia has better growth performance than that of earthen ponds, whereas in case of new season tilapia the phenomena were opposite. Survival rate and weight gain are the main issues for an effectual cage aquaculture since they determine production performance and profit of the system. Higher biomass of caged tilapia had a negative impact on final body weight of fish [20].

In this experiment, lowest growth performance and survival rate was found in C5. The result perhaps due to limited living spaces, limited surfaces for feeding which might responsible for feed competition and nutritional deficits, consumption of more energy and ultimately increased stress, stunted growth and overwhelming of fishes in net cages for stocking huge number of monosex tilapia [21]. There was a decreasing trend of survivability with increasing stocking density. Some researchers for instance Liti et al. and Abou et al. [22,23] found survival rate 70% and 75% respectively in cage culture of tilapia which were comparatively lower than our result. In this study, treatments C1, C2 and C3 showed more than 95% survivability which is in close agreement with Dan et al. [19]. On the other hand, Conte et al. [1] found comparatively higher survival rate with three times more high stocking density. It has also been established that rearing of *O. niloticus* at high density when water flow is uniform can improve survival rate [24].

Table 1: Growth performance, survivability, feed utilization and yield of Monosex tilapia after 120 days of experimental period.

Parameters	C1	C2	C3	C4	C5
Initial length	14.2 ± 0.8 a	14.1 ± 0.7 a	14.2 ± 0.9 a	14.3 ± 0.8 a	14.2 ± 0.8 a
Final length	25.7 ± 2.2 a	24.3 ± 2.1 a,b	23.8 ± 2.1 b	23.2 ± 2.2 b	22.0 ± 2.3 c
Initial weight	40.2 ± 3.4 a	40.2 ± 3.4 a	40.1 ± 3.2 a	40.2 ± 3.3 a	40.3 ± 3.1 a
Final weight	468.2 ± 31.8a	448.4 ± 29.2 a	398.3 ± 31.4b	316.7 ± 34.1 c	291.8 ± 36.8 c
Weight gain (g)	428.0 ± 22.1 a	408.2 ± 21.5 a	358.2 ± 19.4 b	276.5 ± 17.5 c	251.5 ± 17.2 c
Weight gain (%)	1064.68 ± 42.18 a	1015.42 ± 39.32 a	893.27 ± 34.69 b	687.81 ± 32.78 c	624.07 ± 31.07 c
Average daily weight gain (g)	3.57 ± 0.53 a	3.40 ± 0.49 a	2.99 ± 0.44 b	2.30 ± 0.35 c	2.10 ± 0.37 c
Specific growth rate (%)	1.387 ± 0.20 a	1.377 ± 0.18 a	1.352 ± 0.15 a	1.299 ± 0.09 b	1.280 ± 0.08 b
Feed conversion ratio (FCR)	1.32 ± 0.07 a	1.37 ± 0.08 a,b	1.42 ± 0.05 b	1.70 ± 0.06 c	1.92 ± 0.07 d
Gross yield	462.24 ± 4.51 d	528.12 ± 4.92 c	583.20 ± 4.37 a	540.36 ± 4.16c,b	547.56 ± 4.22 b
Net yield	12.84 ± 1.25 c	14.67 ± 1.32 b	16.20 ± 1.29 a	15.01 ± 1.21 a,b	15.21 ± 1.09 a

Superscripted letters are statistically significant

Table 2: Cost and return analysis of Nile tilapia at different stocking densities after 120 days.

Variables	Unit price (BDT)	Price/cage (BDT)				
		C1	C2	C3	C4	C5
Fixed cost (FC)						
Cage net	3200/unit	3,200	3,200	3,200	3,200	3,200
Plastic drum	1180/unit	2,832	2,832	2,832	2,832	2,832
GI pipe & bamboo	52/unit (pipe), 480/unit (bamboo)	4,536	4,536	4,536	4,536	4,536
Anchor & rope	90/kg (anchor), 310/kg (rope)	2,200	2,200	2,200	2,200	2,200
Clam & screw nut	85/kg	820	820	820	820	820
Subtotal		13,588	13,588	13,588	13,588	13,588
Variable cost (VC)						
Monosex tilapia	3/juvenile	3,000	3,600	4,500	5,400	6,000
Feed cost	50/kg	25,700	30,800	36,600	37,960	41,692
Subtotal		28,700	34,400	41,100	43,360	47,692
Total		42,288	47,988	54,688	56,948	61,280
Interest on inputs (Ii)	10% annually	1,410	1,600	1,823	1,898	2,043
Total input		43,698	49,588	56,511	58,846	63,323
Financial returns						
Tilapia sale	140-150/kg (Depending on size)	69,317	79,233	87,466	77,882	76,884
Total net returns		25,619	29,645	30,955	19,036	13,561
BCR		0.586	0.598	0.548	0.323	0.214

In cage culture system, principal costs of fish production are feeds and feeding. Significantly lower FCR value in C1 indicates low density stocked fishes might have high efficiency to convert given feed to flesh than fish stocked with high density in terms of growth [22]. The FCR of this study are in line with the values reported by Ahmed et al. and Saha et al. [25,26] but extremely lower than Gibtan et al. [9] and much higher than Shofiquzzoha et al. [27].

In the present study, there was an increasing trend of gross and net fish yield up to C3 with increasing stocking density then decreased sequentially with increasing stocking density. However, the total yield was increased up to C3 then declined at highest stocking density C5. Significantly highest biomass was found in C3 (total weight basis) with stocking density 1500 while Saha et al. [26] found maximum biomass at little bit higher stocking density (1800). The negative correlation between stocking density and fish production at C5 might be postulated for density-dependent mortality and poor growth performance. Final production was directly influenced by stocking density and there must be a limit where mortality will be severe and growth and production will be reduced [28]. Ridha et al. [5] found better growth and production performance in mixed sex GIFT tilapia at T2200, although size of the stocked fish was small. In the present study, production economics was influenced by stocking densities of Nile tilapia. Benefit-cost ratio (BCR) of each treatment was determined on the basis of input costs of fish, feeds and cage materials and it returns from total fish sale. In this experiment, for cage structure comparatively cheap rate bamboo poles were used. Moreover, durable net cages and plastic drums could be use up to 6-10 harvests. So, in initiating year or during the first harvest, the profit index will be lower than in the following years because of the fixed costs. As cage size increases, cost per unit volume decreases. In this study, we used little bit bigger size of cages (36 m^3 each) to reduce input costs. Almost 50-60% input cost is related to feed which is usual in any aquaculture operation. Through the economic analysis we found that C2 attributed best benefit-cost ratio, C3 showed the highest economic return due to preferred market size, low mortality and maximum biomass production. In addition, the lowest economic return was found in C5 possibly due to smallest size, lowest total production and lowest selling price of monosex tilapia which is in agreement with Zonneveld et al. [29].

CONCLUSION

It can be corroborated that on the basis of growth performance and economic return, 1200 per cage is the best stocking density according to cost benefit analysis, but it should not be increased more than 1500 per cage for commercial tilapia culture in cages. However, it could be differed on the basis of size of fish being stocked and type of aquatic environments. This study has implications of sustainable and cost-effective cage culture practices in lotic environment. However, further research could be addressed on the fish stocking size and cage size.

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