Bangladesh J. Zool. **50**(2): 239-250, 2022 ISSN: 0304-9027
eISSN: 2408-8455

EFFECTS OF STOCKING DENSITY ON PRODUCTION PERFORMANCE OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) GROW-OUT CULTURE IN CAGES

Md. Robiul Awal Hossain[1], Md. Eilious Hosain,
Anika Tabassum and Md. Niamul Naser*

Department of Zoology, Faculty of Biological Sciences, University of Dhaka, Dhaka 1000, Bangladesh

Abstract: A 120-days cage grow-out production performance of Nile Tilapia, *Oreochromis niloticus* was conducted in the Dakatia river, Echoli, Chandpur to identify an optimal stocking density. The three stocking densities were used at 30, 50 and 70 tilapia m^{-3} under three treatments with triplicate. The initial average weight of tilapia fingerlings at 32.31±9.59 g was stocked. Final weight, specific growth rate and survival were significantly ($p < 0.05$) higher in the 30 tilapia m^{-3} stocking density than those in the 50 and 70 tilapia m^{-3} stocking densities. The best food conversion ratio at 1.47 was found in the 30 tilapia m^{-3} stocking density and followed by 2.0 and 2.90 in the 50 and 70 tilapia m^{-3} stocking densities, respectively. The production was comparable ($p > 0.05$) between the 50 and 70 tilapia m-3 stocking densities; however, the net profit was higher ($p < 0.05$) in the 50 tilapia m-3 stocking density group compared to two other stocking density groups. This study suggests a stocking of density at 50 tilapia m^{-3} to increase Nile Tilapia *O. niloticus* productivity in riverine cage culture system.

Key words*:* GIFT tilapia, cage culture, stocking density, benefit-cost analysis.

INTRODUCTION

Genetically improved farmed tilapia (GIFT), developed through selective breeding protocol of several strains of Nile tilapia, *Oreochromis niloticus* that is one of the key aquaculture species worldwide (El-Sayed 2002, Kumar and Engle 2016). More recently, Tran *et al.* (2021) stated that the GIFT strain had a faster growth rate at 27% and 36% in monoculture and polyculture systems when compared to non-GIFT tilapia in Bangladesh. It can be cultured in freshwater and brackish water environments using various monoculture and polyculture techniques including earthen pond, recirculating aquaculture system, raceway, biofloc system and cage culture in the pond, Lake and riverine system. Currently, this species is being played enormous role in supporting the tilapia value chain actors include hatchery operator, nursery owner, grow-out farmers, small holders, tilapia wholesalers and retailers at worldwide in improving of income

*Author for correspondence: <mnnaser@du.ac.bd> , [1]*Bangladesh Fisheries Research Institute, Riverine Station, Chandpur-3602, Bangladesh;*
 DOI: https://doi.org/10.3329/bjz.v50i2.62056

generation, employment opportunities and subsistence (Kaminski *et al*. 2018, Moyo and Rapatsa 2021, Uddin *et al*. 2019)

In recent years, Bangladesh has ranked third and fourth, respectively, in Asia and the world for tilapia production; and this fish is being cultured in earthen ponds, rice fields and cages (DoF 2020, Kunda *et al.* 2021). The tilapia farming with various aquaculture candidate like Indian majour carp (*Labeo rohita*, *Catla catla*, *Cirrhina mrigala*), common carp *Cyprinus carpio*, silver carp *Hypophthalmichthys molitrix*, pangas *Pangasianodon hypophthalmus*, mola *Amblypharyngodon mola*, giant river freshwater prawn, *Macrobrachium rosenbergii* and Asian tiger shrimp *Penaeus monodon* are recognized as economically viable and enhancing fish productivity and aquaculture commodity business (Henriksson *et al.* 2015, Hu *et al.* 2019, Deb *et al.* 2022, Rahman *et al.* 2021). Furthermore, these aquaculture systems have created many job opportunities among the aquaculture entrepreneurs, small holders, aquaculture commodity sellers and consumers through a market channel (Ahmed *et al.* 2012, Henriksson *et al*. 2015, Hu *et al.* 2019). However, tilapia aquaculture are considered as an imperative option for income generation and resilience to climate change adaptation in Bangladesh (Rahman *et al*. 2021, Tran *et al.* 2021).

Nowadays, tilapia culture in cage has gained more attention in Bangladesh and it was started at 1980s in Kaptai Lake (Ahmed *et al.* 2014, Hossain *et al.*, 2017). The tilapia cage culture technology was undertaken and promoted by the government and non-government organizations (NGOs); that has now been great potential and practicing in Lake and riverine ecosystem which is being played imperative role to augment tilapia production. From this vantage point, the economics and sustainability of this technology could be improved while a proper stocking density can be seen as one of the key factors that affect cage tilapia production. According to Wu *et al.* (2018) stocking density is an imperative influencing factor in *O. niloticus* production systems that has affected its growth, survival and gross and net production. However, the aim of this study was to evaluate the effects of stocking density on growth, survival and production of *O. niloticus* in cage culture system. To properly understand the economics returns of tilapia cage culture in Bangladesh, a benefit-cost analysis was estimated. This research could assist farmers and policymakers in spreading cage tilapia culture.

MATERIAL AND METHODS

Study protocol and feeding: A 120 days experiment was undertaken in Dakatia river, Echoli, Chandpur. The stocking densities were used at 30 individuals m^{-3} (540 tilapia $cage^{-1}$), 50 individuals m^{-3} (900 tilapia $cage^{-1}$) and 70 individuals m^{-3} (12600 tilapia $cage^{-1}$) mono-sex tilapia in three treatments with triplicate. The initial average weights of fingerlings were 32.31±9.59 g. The fishes were fed twice daily, half of the ration in the morning at 10.00-10.30 am and another half in the afternoon at 3.30-4.00 pm with pelletized semi-buoyant feed (floating type) at the rate of 5 - 3% (1^{st} and 2^{nd} months 5% then 3^{rd} and 4^{th} months 4 and 3%, respectively) of total tilapia biomass towards the end of the culture period. Throughout the culture period, sampling was done every 30 days to ascertain the levels of feed and the cage nets were also cleaned once every 30 days.

Fish Sampling, final harvest and growth performance and economic analysis: A total of 50 fishes were randomly selected from each replication, and their individual body wet weights were quantified to the nearest gram. Fish were visually inspected during sampling to look for any potential disease outbreaks. After a 120-day cultivation phase, the final harvest was carried out. Fish survival, biomass and production, final weight, weight gain, relative growth rate, specific growth rate and feed conversion ratio were estimated (Goddard, 1996).

Survival rate (%) = (No. of fishes harvested × 100) / No. of fishes stocked.

Gross production = Average final weight (kg) × No. of fishes harvested.

Net production = Average final weight (kg) – initial weight (kg) × No. of fishes harvested.

Weight gain (g) = final weight – initial weight.

$$\text{Relative growth rate (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

Where, W_1 = Live body weight (gm) at time T_1 (day). W_2 = Live body weight (gm) at time T_2 (day)

Specific growth rate (SGR) (%/day) = G × 100. Where, G is the instantaneous growth rate,

$$G = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1}$$

Where, W_1 = Initial live body weight (g) at time T_1 (day).

W_2 = Final live body weight (g) at time T_2 (day).

Food conversion ratio = total feed fed (dry weight) / live fish weight gain.

An economic analysis was done to calculate the benefit-cost ratio (BCR) of tilapia grow-out production in cage culture. The following calculation was used to estimate the profitability of tilapia grow-out production with cage culture system:

$$R = PbiBi - (PxjXj + TFC)$$

where, *R* = net return, *Pbi* = unit price of *i*th products (BDT kg^{-1}), *Bi* = quantity of *i*th products sold (Kg BDT^{-1}), *Pxj* = unit price of *j*th inputs, *Xj* = quantity of *j*th inputs, *i* = 1, 2, 3, … n, *TFC* = fixed costs (Hosain *et al.* 2021, Uddin *et al.* 2006).
BCR = Total income ÷ Total expenditure.
Profit (BDT) = Total income – Total expenditure

Water quality parameters: The water quality variables were monitored on fortnightly in every month between 09:30 am to 10:30 am for each sampling. These parameters include temperature, water transparency, water depth, current velocity, pH, dissolved oxygen, free carbon dioxide, total dissolved solids, total alkalinity, total hardness, ammonia-N, and nitrite-N. A centigrade thermometer was used to estimate the water temperature (°C). Secchi-disk reading was used to determine the water transparency. A bamboo pole was erected and the water depth was recorded. The velocity meter was used to calculate the current velocity of the flowing water in the cage. By using a Hanna TDS meter, total dissolved solids (TDS) were measured. The chemical parameters such as dissolved oxygen, free carbon dioxide, pH, total alkalinity, total hardness, ammonia-N and nitrite-N were determined (HACH, USA).

Statistical analysis: Data were statistically analyzed according to the technique of one-way analysis of variance (ANOVA) for the completely randomized design to test the significance of the differences, least significant difference (LSD) and coefficient of variation between treatments and the means of different parameters including monthly growth parameters. Differences were considered significant at the level of 0.1% ($p < 0.001$), 1% ($p < 0.01$) and 5% ($p < 0.05$). All computations and statistical analysis were performed using the facility of computer with spreadsheet software and software package R version 3.0.0. Physicochemical parameters of water quality compared by ranged, mean with standard deviation. Pearson correlation coefficients within physicochemical parameters were determined using software package SPSS version-16.0.

RESULTS AND DISCUSSION

Growth performance parameters:

Final weight (FW)**:** The mean final weight of the tilapia of the various treatments in cage ranged from 202.28 g to 247.27 g in three stocking density groups after the study (120 days). The greatest final weight was 247.27 g in the 30 individuals m^{-3} tilapia stocking density, with the next highest final weights being 231.23 g in the 50 individuals m^{-3} and 202.28 g in the 70 individuals m^{-3}, respectively (Table 1 & 2). The final weight was significantly higher at 30 individuals m-3 tilapia stocking density (p < 0.05) compared to the 50 and 70 individuals m^{-3} tilapia stocking densities (Table 3). Similarly, the highest mean final weight in Nile tilapia was recorded at low stocking density in cage culture when compared different stocking density (Leboute *et al.* 1994).

Weight gain (WG): Throughout the study period, the monthly weight gain fluctuated from 29.32 g to 68.46 g in the 30 individuals m^{-3} tilapia stocking density, whereas in 50 ind. m^{-3}, it ranged from 23.08 g to 68.18 g. While, it jumped from 13.88 g to 59.88 g 70 individuals m^{-3} tilapia stocking density (Table 1 & 2). The monthly weight gain was found significantly different among three treatments in first month ($p < 0.05$) and between 30 and 70 individuals m^{-3} tilapia stocking density in third month ($p < 0.05$) (Table 1). All three treatments, the highest weight gain observed (214.96 g) in the 30 individuals m^{-3} tilapia stocking density followed by 50 individuals m^{-3} (198.92 g) and 70 ind. m^{-3} (169.97 g) tilapia stocking density, respectively (Table 1). The weight gain of tilapia had highly significant different ($p < 0.001$) among the three stocking density groups (Table 3).

Relative growth rate (RGR): The monthly relative growth rate ranged from 38.33% to 100.82% in the 30 individuals m^{-3} tilapia stocking density, from 41.86% to 106.53% in 50 individuals m^{-3}, from 37.01% to 129.61% in the 70 individuals m^{-3} tilapia stocking density, respectively (Table 1). The monthly relative growth rate of tilapia was highly significant different ($p < 0.001$) among three stocking density treatments in first and second months (Table 2). The highest relative growth rate was 68.60% in the 30 individuals m^{-3} tilapia stocking density, while the lowest was 62.24% in the 70 individuals m^{-3} tilapia stocking density (Table 1). Between the three stocking density treatments, there were significant variations in the relative growth rate ($p < 0.001$). (Table 3).

Specific growth rate (SGR): The monthly specific growth rate varied from 1.07% day^{-1} to 2.31% day^{-1} in the 30 individuals m^{-3} tilapia stocking density. In case of 50 individuals m^{-3}, it fluctuated from 1.16% day^{-1} to 2.41% day^{-1}, while in the 70 individuals m^{-3} tilapia stocking density, it ranged from 1.04% day^{-1} to 2.76% day^{-1} (Table 1 & 2). The monthly specific growth rate was highly significant different ($p < 0.001$) among the three stocking densities in first and second months (Table 2). The 30 individuals m^{-3} tilapia stocking density had the highest specific growth rate of the three treatments at 1.68 percent per day, while the 70 individuals m-3 stocking density had the lowest value at 1.52 percent per day (Table 1). The specific growth rate was greatly different ($p < 0.001$) among the three stocking density groups (Table 3).

Feed conversion ratio (FCR): The monthly FCR ranged from 1.26 to 1.65 in the 30 individuals m^{-3} tilapia stocking density, from 1.40 to 2.53 and from 1.15 to 3.86 in 50 individuals m^{-3} and 70 individuals m^{-3} tilapia stocking density, respectively (Table 1 & 2).

Table 1. Survival, growth performance and economic analysis of *Oreochromis niloticus* stocked at different densities in cages for 120 days

Parameters	Stocking density			Range	Mean ± SD
	30 tilapia m^{-3}	50 tilapia m^{-3}	70 tilapia m^{-3}		
Initial weight (g)	32.31	32.31	32.31	32.31 - 32.31	32.31±0
Final weight (g)	247.27	231.23	202.28	202.28 - 247.27	226.93±22.80
Weight gain (g)	214.96	198.92	169.97	169.97 - 214.96	194.62±22.80
RGR (%)	68.60	65.61	62.24	62.24 - 68.60	65.48±3.18
SGR (% day^{-1})	1.68	1.63	1.52	1.52 -1.68	1.61±0.08
FCR	1.46	2.01	2.89	1.46 - 2.89	2.12±0.72
Fish harvested (N)	462	737	852	462 - 852	683.67±200.40
Survival (%)	85.61	81.92	67.58	67.58 - 85.61	78.37±9.52
GP (kg $cage^{-1}$)	114.29	170.47	172.24	114.29 - 172.24	142.38±39.72
NP (kg $cage^{-1}$)	99.35	146.64	144.72	99.35 - 146.64	130.23±26.77
Net profit (BDT $cage^{-1}$)	2263	3151	–2478	2263 - 3151	2707±627.91
BCR	1.20	1.19	0.88	0.88 – 1.20	1.09±0.18

The monthly FCR was significantly different (p < 0.001) in first, third and fourth months among the three stocking densities. The stocking density between 30 and 70 individuals m^{-3} and 50 and 70 individuals m^{-3} of tilapia were substantially different during the second month (p <0.01) (Table 2). FCRs were 1.46, 2.01 and 2.89 at the stocking densities of 30 individuals m^{-3}, 50 individuals m^{-3}, and 70 individuals m-3, respectively. While, in the 30 individuals m^{-3}, it was better compared to two other groups, FCR in the 70 individuals m^{-3} tilapia stocking density group was the worst (Table 1). The FCR among three stocking density of tilapia in cages had highly significant differences (p < 0.001) (Table 3). Similarly, Gibtan *et al.* (2008) stated the better FCR at low stocking group and then FCR was increased with increasing of stocking densities for Nile tilapia in a cage culture system.

Survival rate: The range of survival rate of tilapia in cage was from 67.58 to 85.61%. The maximum survival rate was found in the 30 individualsm^{-3} tilapia stocking density (85.61%) followed by 50 individuals m^{-3} (81.92%) and 70 individuals m^{-3} (67.58%) tilapia stocking density, respectively (Table 1). The survival rates of tilapia in the three treatments were highly significant different (p < 0.001) (Table 3). In this study, the lower tilapia survival was in higher stocking density group at 70 individuals m^{-3} which was likely due to food intake competition and foraging spaces of tilapia in cages and these may be resulted stress mortality (Wu *et al.* 2018). *Gross production* (GP): The range of gross production of the tilapia was from 114.29 kg $cage^{-1}$ to 172.24kg $cage^{-1}$. The highest gross production at 172.24 kg $cage^{-1}$ was in the 70 individuals m^{-3} stocking density group and the lowest at 114.29 kg $cage^{-1}$ was in the 30

Table 2. Mean monthly variation of weight gain, relative growth rate, specific growth rate and feed conversion ratio of *Oreochromis niloticus* stocked at different densities in cages for 120 days

Stocking density (fish m^{-3})	Monthly growth parameters: Weight gain (g)				Relative growth rate (%)				Specific growth rate (% day^{-1})				Feed conversion ratio			
	1st month	2nd month	3rd month	4th month	1st month	2nd month	3rd month	4th month	1st month	2nd month	3rd month	4th month	1st month	2nd month	3rd month	4th month
30	29.32^{a}	62.06^{a}	55.05^{a}	68.46^{a}	90.74^{a}	100.82^{c}	44.53^{a}	38.34^{a}	2.14^{a}	2.32^{b}	1.22^{a}	1.08^{a}	1.65^{c}	1.48^{a}	1.45^{c}	1.26^{c}
50	23.08^{b}	59.00^{a}	48.74a^{b}	68.18^{a}	71.44^{b}	106.53^{b}	42.62^{a}	41.86^{a}	1.79^{b}	2.41^{b}	1.18^{a}	1.16^{a}	2.10^{b}	1.41^{a}	2.54^{b}	1.94^{b}
70	13.89 ^{c}	59.88^{a}	41.75^{b}	54.46^{a}	42.98^{c}	129.61^{a}	39.40^{a}	37.01^{a}	1.19^{c}	2.76^{a}	1.10^{a}	1.04^{a}	3.48^{a}	1.15^{b}	3.86^{a}	3.09^{a}
LSD	3.73***	3.52	8.97*	14.12	11.54***	7.42***	9.45	10.84	0.22***	0.12***	0.22	0.26	0.30***	0.15**	0.56***	0.40***
CV (%)	8.45	2.92	9.25	11.10	8.44	3.31	11.21	13.89	6.43	2.40	9.60	11.97	6.26	5.40	10.76	9.55

Means bearing same letter(s) in a column do not differ significantly

*** indicates $P < 0.001$, ** indicates $P < 0.01$; * indicates $P < 0.05$

Table 3. Cost benefit analysis and body parameters of *Oreochromis niloticus* reared in different densities in cages for 120 days

Stocking density (individuals m^{-3})	Parameters									
	FG (g)	WG (g)	RGR (%)	SGR (% day^{-1})	FCR	Survival (%)	GP (kg)	NP (kg)	BCR	NP (BDT)
30	247.27^a	214.96^a	68.61^a	1.69^a	1.47^c	85.61^a	114.30^b	99.29^b	1.20^a	2263^b
50	231.23^b	198.92^b	65.61^b	1.63^b	2.00^b	81.92^b	170.47^a	146.66^a	1.19^a	3151^a
70	202.29^c	169.98^c	62.25^c	1.52^c	2.90^a	67.59^c	172.24^a	144.72^a	0.88^b	-2478^c
LSD	9.36^{***}	9.36^{***}	1.59^{***}	0.04^{***}	0.15^{***}	2.07^{***}	4.17^{***}	4.51^{***}	0.03^{***}	430.36^{***}
CV (%)	2.06	2.40	1.22	1.15	3.56	1.32	1.37	1.73	1.19	22.01

Table 4. Monthly mean values of water quality parameters in cage water during *Oreochromis niloticus* cultivation

Parameters	Months						
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Range**	**Mean ± SD**
Depth of water (m)	3.2	3.2	3.9	4.3	4.1	3.2-4.3	3.74±0.51
Current velocity (cm sec^{-1})	17	20	24	29	32	17-32	24.40±6.18
SD transparency (cm)	54	48	43	41	46	41-54	46.40±5.02
Water temperature (°c)	30.1	31.2	31.7	32.6	32.8	30.1-32.8	31.68±1.09
TDS (mg L^{-1})	10	6	9	8	10	6-10	8.60±1.67
Salinity (‰)	0	0	0	0	0	0	0
DO (mg L^{-1})	5.15	5.63	5.52	4.14	4.12	4.12-5.63	4.91±0.73
Free CO_2 (mg L^{-1})	6.33	7.47	8.83	6.93	5.26	5.26- 8.83	6.96±1.32
pH	7.62	7.75	7.5	7.37	7.62	7.37-7.75	7.57±0.14
T. Hardness (mg L^{-1})	93.8	70.77	57.32	38.44	40.24	38.44-93.8	60.11±23.03
T. Alkalinity (mg L^{-1})	107.6	56.04	33.68	44.55	46.5	33.68-107.6	57.67±29.01
Ammonia-N (mg L^{-1})	0	0	0	0	0	0	0
Nitrite-N (mg L^{-1})	0	0	0	0	0	0	0

individualsm^{-3} tilapia stocking density (Table 1). The gross production exhibited highly significant differences ($p < 0.001$) among the three stocking densities (Table 3).

Net production (NP): The net production of the tilapia was recorded in ranged from 99.35 kg cage^{-1} to 146.64 kg cage^{-1}. Net production also was recorded highest at 146.64 kg cage^{-1} in the 70 individuals m^{-3} and the lowest 99.35 kg cage^{-1} in the 30 individualsm^{-3} tilapia stocking density (Table 1). Net production also showed highly significant differences ($p < 0.001$) among the three stocking densities (Table 3). Rahman *et al.* (2006) postulated that the gross and net production was directly impacted by various stocking densities, which resulted in discrepancies in their study. Thus, their findings supported our recent findings.

Net profit: The detail of net profit determination of this trial is shown in table 1 & 3. Net profit of the three different treatments of the stocking density was found in ranged between 2263 Tk cage^{-1} and 3151 Tk cage^{-1} in the 30 and 50 individuals m^{-3} tilapia stocking density, respectively. In this study, no profit was earned from the 70 individuals m^{-3} group due to loss (-2478 Tk cage^{-1}) (Table 1). Net profit had highly significant different ($p < 0.001$) among the three stocking densities (Table 3). The study showed that net profit decreased with the increasing of stocking density which was in agreement with Dasuki *et al.* (2013).

Benefit cost ratio (BCR): The detail of benefit cost ratio determination of stocking density trial is shown in table 1 & 3. The benefit cost ratio determined in this trial was ranged from 0.88 to 1.20. The better benefit cost ratio was in the 30 individuals m^{-3} (1.20), followed by 50 individuals m^{-3} (1.19) and 70 individuals m^{-3} (0.88) tilapia stocking density, respectively (Table 3). Benefit cost ratio exhibited the highly significant differences ($p < 0.001$) between 30 and 70 individuals m^{-3}, and 50 and 70 individuals m^{-3} tilapia stocking density (Table 3). More recently, Kunda *et al.* (2021) recorded the BCRs at 1.51, 1.49 and 1.19 for the stocking density at 40, 60 and 80 tilapia m^{-3} cage culture, these values were in agreement with this study.

Physicochemical parameters of water: The monthly variations of different physicochemical parameters of cage water are shown in table 4. Water depth ranged from 3.2 m in April to 4.3 m in July. Current velocity of water fluctuated from 17 cm sec^{-1} in April to 32 cm sec^{-1} in August. Secchi-disk transparency varied from 41 cm in July to 54 cm in April. The recorded highest water temperature 32.8°C was in August and lowest 30.1°C in April. Water temperature showed a positive correlation with water current velocity ($p < 0.01$; r = 0.976) (Table 5). Total dissolved solids diverse from 6 mg L^{-1} to 10 mg L^{-1} in the month of May, April and August respectively. Dissolved oxygen varied from 4.12 mg L^{-1} in August to 5.63 mg L^{-1} in May. Free CO_2 fluctuated from 5.26 mg L^{-1} in August to 8.83 mg L^{-1} in June. The water pH ranged from 7.37 in July to 7.75 in May. The total hardness of cage water found lowest 38.44 mg L^{-1} in July and the highest 93.8 mg L^{-1} in April. Total hardness expressed inversely correlated with water temperature ($p < 0.01$; r = - 0.994) and current velocity ($p < 0.05$; r = - 0.958) whereas, positively related with sechi-disk transparency ($p < 0.05$; r = 0.880) (Table 5). Total alkalinity also found lowest 33.68 mg L^{-1} in June and the highest 107.6 mg L^{-1} in April. Total alkalinity had a positive correlation with sechi-disk transparency ($p < 0.05$; r = 0.914) (Table 5). During the study period, salinity, ammonia-N and Nitrite-N were not detected (Table 4). The physicochemical parameters of this study were within the suitable limit in aquaculture (Boyd 1982). Furthermore, water temperature, transparency, total dissolved solids, pH, dissolved oxygen, free CO_2, total alkalinity, total hardness and NO_2-N were in agreement with Ahmed *et al.* (2010) who have evaluated water quality parameters in the Meghna, Gumti, Titas, Hoara and Dakatia rivers.

CONCLUSION

The water quality parameters of cage water in Dakatia river, Echoli, Chandpur was suitable for tilapia culture. This study indicates that tilapia final weight, specific growth rate and survival were significantly better in the 30 tilapia m^{-3} stocking density than those in the 50 and 70 tilapia m^{-3} stocking densities. Also, tilapia production was not different between the 50 and 70 tilapia m^{-3} stocking densities; however, the net profit was best in 50 tilapia m^{-3} stocking density compared to other stocking density groups. Therefore, this study recommends a stocking density at 50 tilapia m^{-3} which could be enhanced tilapia production and net return in riverine cage culture system.

LITERATURE CITED

AHMED, M. J., HAQUE, M.R. and HAQUE, T. M. A. 2010. Physicochemical Assessment of Surface and Groundwater Resources of Greater Comilla Region of Bangladesh. *Int. J. of Che. and Environ. Engin.* ***1***: 47-55.

AHMED, N., YOUNG, J. A., DEY, M. M. and MUIR, J. F. 2012. From production to consumption: A case study of tilapia marketing systems in Bangladesh. *Aquac. Int.* ***20***: 51–70.

AHMED, T., JAHEDUL, H.S., ROBIUL, M.R.A., HAIDAR, I., SHAFIQUL A.R. and PRAMANIK, M.H. 2014. Assessment on impact of dietary probiotic supplementation on growth indices of mono-sex tilapia (*Oreochromis niloticus*) cage culture at Dakatia River, Chandpur, Bangladesh. *W. J. of Fish and M. Sci.* ***6***: 441–446.

BOYD, C.E. 1982. Water quality managed for fish culture pond development. In Aquac. And Fish. Sc. Elsevier. Sci. Pub. Co. Amsterdam Oxford, New York. ***9***: 318.

DASUKI, A., AUTA, J. and ONIYE, S. J. 2013. Effect of stocking density on production of C*larias gariepinus* (tuegels) in floating bamboo cages at Kubanni reservior, Zaria, Nigeria. *Bay. J. of Pure and A. Sci.* ***6***: 112 – 117.

DEB, P., DEY, M.M and PRASANNA SURATHKAL, P. 2022. Price transmission and market integration of Bangladesh fish markets. Aquaculture, **560**: 738592

DOF. (2020). Yearbook Of Fisheries Statistics 2019-20. *Fisheries Resources Survey System (FRSS), Department of Fisheries. Bangladesh: Ministry of Fisheries and Livestock*, ***37***: 141.

El-SAYED, A. F. M. (2002). Effects of stocking density and feeding levels on growth and feed efficiency of Nile tilapia (*Oreochromis niloticus* L.) fry. *Aquac. Res.* ***33***: 621–626.

GIBTAN, A., GETAHUN, A. and MENGISTOU, S. 2008. Effect of stocking density on the growth performance and yield of Nile tilapia [*Oreochromis niloticus* (L., 1758)] in a cage culture system in Lake Kuriftu, Ethiopia. *Aquac. Res.* ***39***: 1450–1460.

HENRIKSSON, P. J. G., RICO, A., ZHANG, W., AHMAD-AL-NAHID, S., NEWTON, R., PHAN, L. T., ZHANG, Z., JAITHIANG, J., DAO, H. M., PHU, T. M., LITTLE, D. C., MURRAY, F. J., SATAPORNVANIT, K., LIU, L., LIU, Q., HAQUE, M. M., KRUIJSSEN, F., DE SNOO, G. R., HEIJUNGS, R., ... GUINÉE, J. B. 2015. Comparison of Asian Aquaculture Products by Use of Statistically Supported Life Cycle Assessment. *Env. Sci. and Tech.* ***49***: 14176–14183.

HOSAIN, M.E., AMIN, S.M.N., ARSHAD, A., KAMARUDIN, M.S., and KARIM, M. 2021. Effects of carbon sources on the culture of giant river prawn in biofloc system during nursery phase. *Aqua. Rep.* ***19***: 100607.

HOSSAIN, M.R.A., ASHIKUR, R.M., AKTER, S., HOSAIN, M.E. AND NASER, M.N. 2017. Intervention of tilapia cage culture in the River Dakatia: Threaten or blessed to local fish diversity. *Int. J. of Fish. and Aqua. Stu.* ***5***: 228–232.

HU, C., ZHANG, X., REARDON, T. and HERNANDEZ, R. 2019. Value-chain clusters and aquaculture innovation in Bangladesh. *F. Pol.* ***83***: 310–326.

KAMINSKI, A. M., GENSCHICK, S., KEFI, A. S., and KRUIJSSENK, F. (2018). Commercialization and upgrading in the aquaculture value chain in Zambia. *Aquaculture*, ***493***: 355–364. https://doi.org/10.1016/j.aquaculture.2017.12.010

KUMAR, G., and ENGLE, C. R. (2016). Technological advances that led to growth of Shrimp, Salmon, and Tilapia farming. *Rev. in Fish. Sci. and Aqua.* ***24***: 136–152. https://doi.org/10.1080/23308249.2015.1112357

KUNDA, M., PANDIT, D., and HARUN-Al-RASHID, A. (2021). Optimization of stocking density for mono-sex Nile tilapia (*Oreochromis niloticus*) production in riverine cage culture in Bangladesh. *Heliyon*, ***7***: e08334.

LEBOUTE, E. M., SOUZA, S. M. G., AFONSO, L. O. B. and ZIMMERMANN, S. (1994). Preliminary study on the cage culture of all-male Nile tilapias (*Oreochromis niloticus*). *Proceedings of the 4th rio-grande meeting of aquaculture experts*. pp. 151-155.

MOYO, N. A. G., and RAPATSA, M. M. (2021). A review of the factors affecting tilapia aquaculture production in Southern Africa. *Aquaculture*, ***535***: 736386.

RAHMAN, M. M., ISLAM, M. S., HALDER, G. C., and TANAKA, M. 2006. Cage culture of sutchi catfish, *Pangasius sutchi* (Fowler 1937): effects of stocking density on growth, survival, yield and farm profitability. *Aqua. Res.* **37**: 33-39.

RAHMAN, M. L., SHAHJAHAN, M. and AHMED, N. 2021. Tilapia farming in Bangladesh: Adaptation to climate change. *Sustainability*, ***13***: 1–20. https://doi.org/10.3390/su13147657

TRAN, N., SHIKUKU, K. M., ROSSIGNOLI, C. M., BARMAN, B. K., CHEONG, K. C., ALI, M. S. and BENZIE, J. A. H. 2021. Growth, yield and profitability of genetically improved farmed tilapia (GIFT) and non-GIFT strains in Bangladesh. *Aquaculture*, ***536***: 736486. https://doi.org/10.1016/j.aquaculture.2021.736486

UDDIN, M. T., GOSWAMI, A., RAHMAN, M. S., & DHAR, A. R. (2019). How can governance improve efficiency and effectiveness of value chains? An analysis of pangas and tilapia stakeholders in Bangladesh. *Aquaculture,* ***510***: 206–215.

UDDIN, S., EKRAM-UL-AZIM, M., WAHAB, A. and VERDEGEM, M.C.J. 2006. The potential of mixed culture of genetically improved farmed tilapia (*Oreochromis niloticus*) and freshwater giant prawn (*Macrobrachium rosenbergii*) in periphyton-based systems. *Aqua. Res.* **37**: 241–247.

WU, F., WEN, H., TIAN, J., JIANG, M., LIU, W., YANG, C., YU, L., and LU, X. (2018). Effect of stocking density on growth performance, serum biochemical parameters, and muscle texture properties of genetically improved farm tilapia, *Oreochromis niloticus*. *Aquac. Int.* ***26***: 1247–1259.

(Manuscript received on 30 June 2022 revised on 29 August, 2022)