Journal of Aquaculture and Fish Health Vol. 11(2) - June 2022
DOI : 10.20473/jafh.v11i2.28207

Evaluation of Growth Performance of Three Strains of Nile Tilapia *Oreochromis niloticus* (L., 1758) Reared in Brackishwater Ponds and Relationship of Growth with Water Physicochemical Parameters

Mizanur Rahman Washim[1*], A.K.M. Shafiqul Alam Rubel[1], Debashish Kumar Mondal[1], Shawon Ahmmed[1], Md. Hashmi Sakib[1], Syed Lutfar Rahman[1] and Md. Latiful Islam[1]
[1]Bangladesh Fisheries Research Institute, Brackishwater Station, Paikgacha, Khulna-9280, Bangladesh

*Correspondence :
mizanbfri15@gmail.com

Received : 2021-07-12
Accepted : 2022-03-07

Keywords :
ESNT, GIFT, Growth, Monosex, Nile tilapia, Strain

Abstract

This study was executed to resolve the argument on the growth superiority of three Nile tilapia strains *viz*., the existing strain of Nile tilapia (ESNT), genetically improved farmed tilapia (GIFT), and sex-reversed Monosex cultured in brackishwater pond and to comprehend the relationship of water physicochemical parameters with growth. The analogous age group of fish each weighing 0.62±0.09 g with iso-stocking density (5ind./m^2) and 120 days culture tenure was considered. The physicochemical variables were at an optimal level over the entire culture period. However, dissolved oxygen had strong positive correlation (r=0.742, p=0.022) and ammonia showed strong negative correlation (r= -0.822, p=0.007) with mean fish weight. The study revealed that weight gain by GIFT strain was nearly 25.9% and 5.10% higher than Monosex and ESNT strain, respectively. The highest final mean body weight was achieved in the GIFT strain (223±8.60 g) and there was a significant difference among the strains. The GIFT strain scored the highest SGR of 16.85%/day with no significant variance across the strain. GIFT strain gave significantly (p<0.05) higher gross fish yield (9789.70 Kg ha^{-1}) along with best FCR (1.23) and survival (87.80%), and differed significantly among the three strains. The ESNT strain showed the closest isotropic growth while the other two had allotropic growth patterns. Thereby, the results established that strain difference significantly (p<0.05) impacted the growth parameters, and GIFT was the best strain. Overall results greatly minimize the controversy on the growth pattern of different strains of Nile tilapia reared in brackishwater ponds, Bangladesh.

INTRODUCTION

Along with being the world's 3rd inland fish producer, Bangladesh ranked 4th in tilapia production in the world and 3rd in Asia (FAO, 2018). Tilapia is described as the most important aquaculture species of the 21st century and is a widely cultured fish in Bangladesh to meet the ascending protein demand (Rahman *et al.,* 2012). An incredible development in Bangladesh's tilapia farming was achieved from 1999 to 2015 (Hussain *et al*., 2017). Farming of tilapia in Bangladesh has mainly been practiced in freshwater impoundments, ranging from small-scale backyard facilities, integrated rice-fish systems to large-scale improved-extensive and semi-intensive cultural ponds or in cages installed in rivers and reservoirs. Alongside, Bangladesh has 2,58,553 ha shrimp and prawn farming area (Department of Fisheries, 2019), of which 2,15,232 ha brackishwater spaces locally called *ghers* are generally used for the culture of brackishwater shrimp, *Penaeus monodon*. Undoubtedly, these large brackishwater bodies have fantastic options to be used for cultivating tilapia, since innumerable uses of freshwater for agriculture, industrial and domestic purposes progressively limit the freshwater-based aquaculture (Suresh and Lin, 1992). Additionally, it is believed that most of the tilapia are tolerant to brackish water with a wide range of salinity (Saha and Khatun, 2014) and environmental conditions (Tran *et al*., 2019). Moreover, most of tilapias used in high salinity cultural approaches are hybrid strains (Watanabe *et al*., 2002; El-Zaeem *et al*., 2012).

Over the last few decades (1974-1984), along with the existing strain of Nile tilapia (ESNT) and improved strain e.g., GIFT and sex-reversed monosex tilapia was introduced in Bangladeshi aquaculture. Currently, progressive farmers and entrepreneurs of the coastal region have been leaning to introduce sex-reversed monosex and GIFT tilapia besides ESNT in their *gher* system for maximizing production and profit margin. The scantiness of information on the true performance of improved Nile tilapia strain makes it difficult to measure critical yield gaps and identify effective strategies and interventions required to address them (Tran *et al*., 2021). Moreover, farmers suffer from indecision before stocking about growth superiority.

To date no comprehensive study has been performed on the comparative performance of monosex, GIFT along with the existing strain of Nile tilapia (ESNT) in brackishwater system with same culture condition under corresponding period. As a consequence, controversy exists about the growth superiority of these three strains individually. Additionally, there is a paucity of information in Bangladesh on the relationship of water quality parameters with fish growth. Given the above perspective, this study aimed to evaluate the growth highness of these strains under the homogeneous environmental conditions in brackishwater ponds and the relation of growth with water physicochemical parameters.

METHODOLOGY

Place and Time

The experiment was carried out in April-July, 2019 at the nine brackishwater earthen ponds located inside the pond complex of brackishwater station, Bangladesh Fisheries Research Institute (BFRI), Paikgacha, Khulna-9280.

Research Materials

The materials used in this research were three strains of Nile tilapia (*viz*. monosex, GIFT, ESNT), nine rectangular ponds (50 m×20 m×1 m), nylon net, bamboo frame, dolomite for liming, Rotenone, urea and TSP fertilizer, and floating pellet diet (Mega feed manufactured by Spectra Hexa Limited, Bangladesh).

The tools used in this research were a measuring scale and a digital electronic balance (Radwag, Model WLC 1/A2, Poland), thermometer, secchi disc, portable DO meter (YSI digital DO meter, Model 58, HANNA Company, USA), handheld pH meter (Digital pH meter, Model HI 98107 HANNA Company, USA), hand-held optical refractometer (Code 44-881, Bellingham-Stanley, UK), and ammonia test kit (API, Mars Fishcare, USA).

Research Design

The altitude in the sense of growth of three Nile tilapia (*O. niloticus*) strains viz. Monosex, GIFT, and ESNT were tested under similar environmental conditions and a homogeneous period with a stocking density of 5 ind./m^2 where the culture period lasted for four months (April-July, 2019). The relation of physicochemical parameters with growth was also investigated. Nine rectangular ponds in a Complete Randomized Design (CRD) way, with an average area of 0.1 ha (50 m×20 m×1 m) each were selected for the study replicating each group thrice.

Work Procedure

Pond Preparation

Primarily ponds were completely drained out and re-excavated with dyke renovation and then allowed to sun dry for 7-10 days. About 25 m^2 area of each pond was enclosed with a nylon net fastened with a bamboo frame for in-pond nursing (2 weeks). Liming (Quick lime:dolomite 1:1) with a dose of 250 kg/ha of soil was done and then filled with tidal water from river Shibsha up to 1 m depth. Rotenone with a dose of 36.5 kg/ha was applied for the eradication of unwanted fishes. Fertilization was accomplished with urea and TSP as much as 2.5 and 3.0 ppm, respectively for quick development of water color and production of plankton in the water column.

Origin of Experimental Fish and Stocking

The fingerlings of GIFT and sex-reversed monosex strains each weighing 0.62±0.09 g (mean±SD) and measuring 3.22±0.05 cm total length was purchased from Mega tilapia hatchery, Jessore established by Spectra Hexa Limited and the ESNT strain having an average weight of 0.62±0.10 g was collected from commercial hatchery situated in Satkhira district. Thereafter, fry was kept in a 10 L circular vessel for 1 hour of adjustment with brackish water salinity by continuous dropping down of pond saline water. The initial length and weight of fish were recorded individually in 'cm' and 'g' with a measuring scale and a digital electronic balance (Radwag, Model WLC 1/A2, Poland), respectively. Finally, the fry was randomly released to the in-pond nursery with three tilapia strains simultaneously according to the experimental design.

Grow-out Trial and Feeding Management

Primarily commercial floating pellet diet (Mega feed manufactured by Spectra Hexa Limited, Bangladesh) *e.g.,* powder form and starter crumble containing 35% crude protein per 15% body weight/day was applied during the first two months and 5% body weight/day for the rest two months. The total feed quantity was divided into two equal rations for feeding a day at 10:00 and 17:00 hours. Approximately 10% of fish in each strain group were sampled every week and 2 weeks to determine fish weight and length, and the feed amounts were adjusted accordingly.

Physicochemical Parameters

Water quality variables *viz.* temperature (°C), transparency (cm), dissolved oxygen (DO) (mg/L) concentration, pH, total alkalinity (mg/L) and ammonia (mg/L) were measured at weekly intervals in the morning between 09:00 and 10:00 a.m. A standard centigrade thermometer was used to measure surface water temperature in situ. Transparency was recorded by using a Secchi disc. DO level was quantified with a portable DO meter (YSI digital DO meter, Model 58, HANNA Company, USA). Water pH was monitored by using a handheld pH meter (Digital pH meter, Model HI 98107 HANNA Company, USA). Salinity was measured using a hand-held optical refractometer (Code 44-881, Bellingham-Stanley, UK). Total alkalinity was measured by the titrimetric method (APHA, 2008). Ammonia levels were measured by using an ammonia test kit (API, Mars Fishcare, USA).

Fish Sampling, Harvesting, and Estimation of Yield

After termination of the culture period, all fish were harvested separately as per three strains by completely draining out the ponds. Then fish were counted, measured and weighed for each replication. To determine the growth return and yield of experimental fish, the following parameters were considered: Net weight gain (NWG), specific growth rate (SGR), absolute growth rate (AGR), feed conversion ratio (FCR), gross fish yield and survival rate. The length-weight relationship was measured with the following equation:

$W = aL^b$

Where:

W = fish weight (g)
L = fish length (cm)
a = initial growth coefficient
b = growth coefficient

Data Analysis

The data were analyzed with Excel 2016 and SPSS software version 20.0. Descriptive statistics were employed to outline the key characteristics by offering an ordinary precision such as mean and standard deviation. Analysis of variance (ANOVA; $P<0.05$) following Duncan's multiple range test was executed to identify significant differences. Correlation and multiple regression analysis were performed to explore the relationship between fish growth and physicochemical parameters.

RESULTS AND DISCUSSION

The mean values (mean±SD) of water quality parameters over the culture period are summarized in Table 1. Growth increments of all strain groups at every 7 days interval are demonstrated in Figure 1. The results revealed that the water quality variables of all three groups were not significantly different ($P>0.05$) among triplicates except for a little variation in DO and ammonia. Moreover, fluctuations in growth performance among triplicates for all strains were insignificant. The estimated growth parameters for all the strains are furnished in Table 2. The highest and the lowest final mean body weight were observed in the GIFT strain (223±8.60 g) and the ESNT strain (177±6.73 g), respectively. Likewise, net weight gain showed the same aptitude whereas the SGR of the three strains was not significantly different (F=0.215, p=0.813).

As the rearing period increased, SGR exhibited incessant curtailed trends (Figure 2) for all strains, however, there was a robust relationship between fish length and weight. (Table 3). The final body length of three strains was revealed insignificant with the ANOVA test (F=3.490, p=0.099). Contrarily, DMRT analysis exposed that GIFT and ESNT are different in final body length and Monosex was identical with both of them (Table 2). The SGR at the end of the culture period ranged from 13.66-16.85%/day. The highest apparent SGR of 16.85%/day was acquired by the GIFT strain under the following water quality parameters: DO (6.2 mg/l,) pH (6.98), temperature (31.0 °C), salinity (16 ppt) and ammonia was 0.02 mg/l (Figure 3). The survival rate of three strains revealed significantly different (F=19.524, p=0.002), the highest survival rate was acquired by the GIFT strain (87.80%) with the best mean value of FCR was found from the GIFT (1.23) strain while the highest was in ESNT (1.30) ($P<0.05$). Statistical analysis revealed that the GIFT strain had significantly higher gross fish yield (9789.70 kg/ha/120 days) than the other two strains and they differed significantly across the three strains (F=1859.457, p=0.000) (Table 2).

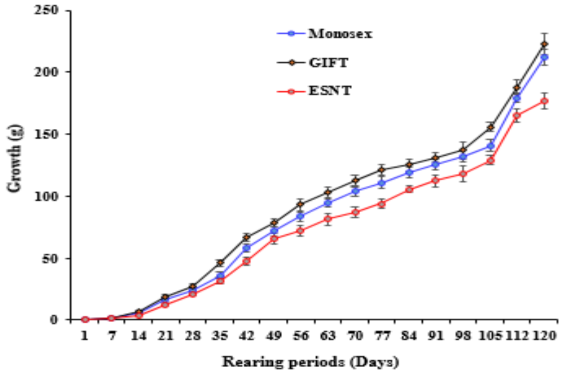

Figure 1. Growth increment of three *O. niloticus* strains across the culture tenure.

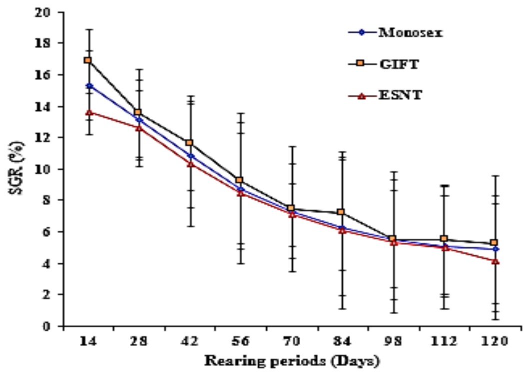

Figure 2. Trends of specific growth rate (SGR) over the culture time for three *O. niloticus* strains.

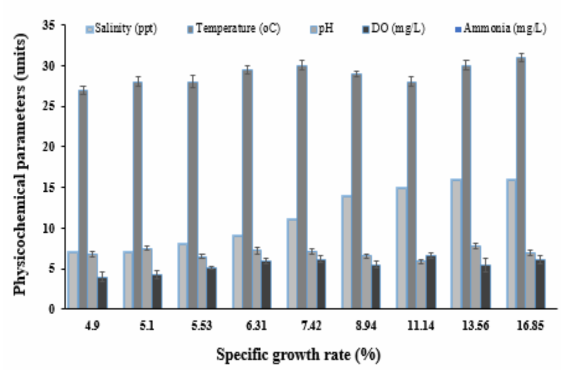

Figure 3. Variation of SGR in GIFT strain with salinity, temperature, pH, DO and ammonia.

Table 1. Mean physico-chemical parameters in three strain respective experimental ponds over 120 days.

Pond	DO (mg/L) (Mean±SD)	Temperature (°C) (Mean±SD)	pH (Mean±SD)	Salinity (ppt) (Mean±SD)	Transparency (cm) (Mean±SD)	Alkalinity (mg/L) (Mean±SD)	Ammonia (mg/L) (Mean±SD)
Monosex	5.21 ± 0.88^{ab}	27.44±2.13	6.29±0.46	11.16±3.94	36.25±3.55	128±17.50	0.03 ± 0.07^{a}
GIFT	5.75 ± 1.28^{b}	28.94±1.70	6.93±0.65	11.44±3.84	38.50±4.10	122±16.00	0.02 ± 0.04^{a}
ESNT	4.88 ± 1.54^{a}	26.75±3.21	6.37±0.82	11.20±4.12	35.40±3.64	134±15.00	0.07 ± 0.13^{b}
F-value	7.23	3.71	2.52	0.43	1.28	1.91	10.50
P-value	0.025	0.089	0.160	0.669	0.342	0.229	0.011

Notes : Means with different superscripts in the same column are significantly different where $p<0.05$ (Analysis: Duncan's Multiple Range Test).

Table 2. Production performance of three strains of Nile tilapia during the study period.

Parameters	Monosex	GIFT	ESNT	F-value	P-value
Initial length (cm)	3.16±0.04[a]	3.28±0.06[a]	3.20±0.04[a]	0.613	-
Final length (cm)	20.82±7.28[ab]	22.69±6.80[a]	19.54±6.64[b]	3.490	0.099
Initial weight (g)	0.62±0.09[a]	0.62±0.12[a]	0.62±0.10[a]	0.000	-
Final weight (g)	212±6.40[b]	223±8.60[a]	177±6.73[c]	66.780	0.000
NWG (g)	211.38±2.77[b]	222.38±3.12[a]	176.38±1.95[c]	66.301	0.000
Weight gain (%)	34093.54±1161.70[b]	35867.74±1326.65[a]	28448.38±1198.29[c]	2233.236	0.000
AGR (g/ind./day)	1.76[a]	1.85[a]	1.46[b]	22.608	0.002
SGR (%)	4.86[a]	4.90[a]	4.71[a]	0.215	-
Feed conversion ratio (FCR)	1.26[b]	1.23[a]	1.30[c]	1.881	0.232
Survival rate (%)	82.40[b]	87.80[a]	76.10[c]	19.524	0.002
Gross fish yield (kg/ha/120 days)	8734.40±12.84[b]	9789.70±92[a]	6734.85±54.83[c]	1859.457	0.000

Notes : Values are means from triplicate groups (n=3) of fish and numbers on the superscripts in each row with different letters are significantly different (*p*<0.05); and a>b>c (Analysis: Duncan's Multiple Range Test).

Table 3. Estimated parameters of length-weight relationship of three Nile tilapia strains.

Strain	Parameters of length-weight relationship			
	'a'	'b'	r	Remarks
Monosex	0.0856	2.47	0.98	< 3: is growth exponent 'b' value that shows allometric growth
GIFT	0.07	2.51	0.97	
ESNT	0.027	2.93	0.98	

Mean fish weight exhibited a strong positive correlation with DO (r = 0.742, p = 0.022) and moderate correlation with temperature (r = 0.635, p = 0.066), transparency (r = 0.404, p = 0.281), and pH (r = 0.390, p = 0.299), while a negative correlation was observed with ammonia (r = -0.822, p = 0.007) and alkalinity (r = -0.460, p = 0.213) (Table 4). In parallel, a positive correlation was also observed between mean fish length and DO (r = 0.534, p = 0.139), temperature (r = 0.420, p = 0.260), transparency (r = 0.262, p = 0.496), pH (r = 0.178, p = 0.648) and a negative correlation between mean fish length and ammonia (r = -0.598, p = 0.007) and salinity (r = -0.212, p = 0.585) (Table 4). In respect of the ESNT pond, 99.7% of the variation in fish weight was explained by the six physicochemical parameters, while the rest two fish strain ponds were 98.9 and 99.3%. For each of the three ponds, the multiple regression analysis generated different R^2 values as indicated in Table 5.

Table 4. Correlation matrix of fish length, weight and physico-chemical parameters.

	DO	Temp	pH	Salinity	Transparency	Ammonia	Alkalinity	Mean length	Mean weight
DO	1.0000								
Temp	0.715*	1.0000							
	0.030								
pH	0.717*	0.929**	1.0000						
	0.030	0.000							
Salinity	0.032	-0.004	-0.025	1.0000					
	0.935	0.992	0.949						
Transparency	0.847**	0.309	0.451	0.020	1.0000				
	0.004	0.418	0.223	0.959					
Ammonia	-0.861**	-0.399	-0.312	-0.161	-0.797*	1.0000			
	0.003	0.287	0.413	0.679	0.010				
Alkalinity	-0.795*	-0.482	-0.564	-0.449	-0.794*	0.762*	1.0000		
	0.01	0.189	0.113	0.225	0.011	0.017			
Mean length	0.534	0.420	0.178	-0.212	0.262	-0.598	-0.034	1.0000	
	0.139	0.260	0.648	0.585	0.496	0.089	0.930		
Mean weight	0.742*	0.635	0.390	0.087	0.404	-0.822**	-0.460	0.848**	1.0000
	0.022	0.066	0.299	0.823	0.281	0.007	0.213	0.004	

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Table 5. Coefficient of determination of three Nile tilapia strains showing the degree of variation in growth interpreted by water quality variables.

Strains	*R*	R^2	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R^2	*F* Change	df1	df2	Sig *F* Change
Monosex	0.994[a]	0.989	0.955	14.45996	0.989	29.089	6	2	0.034
GIFT	0.996[a]	0.993	0.971	11.99124	0.993	45.365	6	2	0.022
ESNT	0·999[a]	0.997	0.988	6.40287	0.997	115.559	6	2	0.009

[a] Predictors: (constant), dissolved oxygen, temperature, pH, salinity, ammonia, alkalinity.

At all experimental ponds, the water quality parameters during the study period were similar and lay in the favorable range for rearing *O. niloticus* (Azaza *et al*., 2008). DO level showed the highest (5.75±1.28 mg/L) in the GIFT culture pond and lowest (4.88±1.54 mg/L) levels at ESNT earthen pond, and the difference was statistically significant (F = 7.23, p = 0.025). Riche and Garling (2003) stated that, DO level >5 mg/L is ideal for optimum growth of tilapia which is concomitant with the present study. The recorded temperature (26.75±3.21-28.94±1.70 °C) was much identical to the recommended ideal ranges of 28°C to 30°C (Ngugi *et al*., 2007) for maximum growth of *O. niloticus*.

The pH levels in the three strains' ponds differed in a marginal range of variation and did not vary significantly (p= 0.160) but were within the suitable range as suggested by Bryan *et al*. (2011) and were in the vicinity of pH range as denoted by Haque *et al*. (2016). The salinity of water ranged from 07 ppt to 16 ppt in all of the ponds and it was lowest during stocking and raised to the highest level of 15-16 ppt at 50 days of culture. However, these findings are almost relevant to Saha and Khatun (2014) and Mapenzi and Mmochi (2016) results for Monosex and hybrid tilapia cultured in brackish water and mariculture. Water transparency was found to roughly vary between 35 and 45 cm. These overpassed the maximum limit of the assigned range

(15-40 cm) as recommended by Boyd (1992), but were more or less comparable to the values of Bangladeshi ponds (Haque *et al*., 2015). The mean values of total alkalinity with the ranges (106-150 mg/L) were nearly identical in all three strain ponds were very similar to that as proposed by Boyd (1992) and are correspondent to another author (Rahman *et al*., 2012), suggesting a high potential for primary production. The observed ammonia level (0.02±0.04-0.07±0.13 mg/L) was within the ideal range as the research findings of El-Sherif and El-Feky (2008) and differed significantly (F=10.50, p=0.011). Furthermore, our results are vigorously backed up by El-Shafai *et al*. (2004) who found that the lowest-observable effect concentration on Nile tilapia growth performance is 0.144 mg/L.

In respect of growth performance, all three strains showed an equivalent growth till the first four weeks of the grow-out stage then disparately increased up to the termination of the study. In particular, the GIFT strain always exhibited rank first in growth pattern over Monosex and ESNT strains (Figure 1). In particular, it is crystal clear that fluctuation in growth parameters was significantly (p<0.05) affected by strain difference. The GIFT strain had a significantly (F=66.780, p=0.000) higher final mean body weight compared to Monosex and ESNT strain. The bodyweight of the GIFT strain was nearly 25.9% and 5.10% higher than that of the ESNT and monosex strain, respectively.

These results are in line with the work of Ibrahim *et al*. (2012); Putra *et al*. (2013) and Moses *et al*. (2021), where these authors found that strain variation affects the growth performance of *O. niloticus* in their experiment. In the length-weight relationship, Monosex and ESNT showed a higher correlation than GIFT strain, albeit their R-value was not significantly different. The SGR values at harvesting (4.71%, 4.86%, and 4.90%/day) were not significantly different (F=0.215, p=0.813) across the three strains, but pretty much comparable with the report of Chakraborty *et al*. (2011) and greater than the reported SGR by Ahmed *et al*. (2013). Interestingly, the GIFT strain had an opulent growth performance with slightly lower FCR than the other strains which is in agreement with the work of Thoa *et al*. (2016). However, the present result was slightly higher than the FCR ranges from 1.01 to 1.6 as reported by Diana *et al*. (2004) in the pond culture of Nile tilapia. Thus, it is plausible to say that different strains may generate different FCR under the corresponding environmental conditions.

The reasonably higher survival of GIFT tilapia (87.80%) might be due to the difference in genetic variation (Genetic improvement through selective breeding program) between Monosex and ESNT strains. An observation by Kamaruzzaman *et al*. (2009) showed that monosex of Nile tilapia would be of no advantage over mixed-sex for the GIFT strain under cage culture in earthen ponds. However, in this study, significantly higher gross yields of GIFT tilapia were influenced by their better individual harvesting weight, absolute growth rate, SGR as well as survival. That might be attributed to the superiority of GIFT over other strains. Available reports indicated that the growth of GIFT tilapia is 10-15% superior to other tilapias in many aspects (Dey, 1996). The ESNT strain with growth exponent ‘b’ value of 2.93, is nearly 3, demonstrating a closet isotropic growth pattern that which the fish shape is consistent. The Monosex (2.47) and GIFT strain (2.51), however, had an allotropic growth pattern.

With a bit of fluctuation in physicochemical parameters over the headway of the culture period the SGR increased proportionally. However, SGR was literally higher in the GIFT culture pond corresponding to a DO level of 6.2 mg/l (Figure 3). As a consequence, it is obvious that elevated DO levels influenced the growth of fish positively. Ekubo and

Abowei (2011) also warned that fish are likely to die if DO reaches less than 0.3 ppm for a longer time span. An augmentation in SGR was noted with a parallel increase in temperature. The highest SGR of 16.85%/day was recorded for GIFT strain at a temperature of 31.0 °C (Figure 3) which corresponded to the range of El-Sherif and El-Feky (2009). The largest SGR was also obtained at a pH of 6.98 (near neutral), salinity of 16.0 ppt, and ammonia of 0.02 mg/l in the GIFT culture ponds (Figure 3) which was below the recommended level < 0.2 mg/l of NH_3 for pond fish culture. Consistent with the present findings, Mengistu *et al*. (2020) assigned that, the suitable pH range for fish culture ranges from 6.42 to 8.2.

In our study, mean fish weight had a strong and moderate positive relationship with DO and temperature respectively (Table 4), which is in agreement with Makori *et al*. (2017) where they reported a strong positive correlation of mean weight and length with DO and temperature. The result of the regression coefficient (R^2 = 0.997 to 0.989) indicates that water quality parameters had a strong influence on fish growth (Table 5). The partial regression coefficient determines the direction and size of a regression line's slope (B value). The B values for DO (-0.012) and ammonia (-0.231) in this study bore negative signs, meaning that for every increase in one unit of DO and NH_3, the regression equation predicted a decrease in fish weight of 0.012 g and 0.231 g (dependent variable), respectively. The B values in respect of temperature, pH, salinity and alkalinity had positive signs, indicating that for every one unit rise of these parameters, there was a corresponding increase in fish weight by a certain unit. For example, the regression equation surmised an uplift of 0.22 g of fish weight with every increase of one unit of alkalinity.

CONCLUSION

The GIFT strain outperformed the ESNT and monosex strain regarding different growth parameters, yield and in particular gaining 25.9% and 5.10% more weight gain respectively. Grossly, water quality parameters influenced fish growth but DO and NH_3 comprehensively catalyzed fish growth. These concluding remarks disposing the existing debate about the loftiness of three Nile tilapia strains cultured in the brackishwater pond system of Bangladesh. Nevertheless, further studies are recommended to be carried out for a complete fortification of this disputed issue.

ACKNOWLEDGMENT

We are immensely grateful to the project implementation unit of Bangladesh Agricultural Research Council for funding the research under NATP-2 bearing a project ID: CRG-778.

REFERENCES

Ahmed, G.U., Sultana, N., Shamsuddin M. and Hossain, M.B., 2013. Growth and production performance of monosex tilapia (*Oreochromis niloticus*) fed with homemade feed in earthen mini ponds. *Pakistan Journal of Biological Sciences*, *16*(23), pp.1781-1785. https://doi.org/10.3923/pjbs.2013.1781.1785

American Public Health Association (APHA), 2008. *Standard methods for examination of water and wastewater.* American Public Health Association (APHA). Washington, DC, USA.

Azaza, M.S., Dhraïef, M.N. and Kraïem, M.M., 2008. Effects of water temperature on growth and sex ratio of juvenile Nile tilapia *Oreochromis niloticus* (Linnaeus) reared in geothermal waters in southern Tunisia. *Journal of Thermal Biology*, *33*(2), pp.98-105. https://doi.org/10.1016/j.jtherbio.2007.05.007

Boyd, C.E., 1992. *Water quality management for pond fish culture*. Elsevier Science Publishers B.V., Amsterdam, the Netherlands, p.318.

Bryan, R., Soderberg, W., Blanchet, H. and Sharpe, W.E., 2011. *Management of fish ponds in Pennsylvania*. http://www.waterresearch.net/Waterlibrary/Lake/waterqualityponds.pdf.

Chakraborty, S.B., Mazumdar, D., Chatterji, U. and Banerjee, S., 2011. Growth of mixed-sex and monosex Nile Tilapia in different culture systems. *Turkish Journal of Fisheries and Aquatic Sciences*, *11*, pp.131-138. https://doi.org/10.4194/trjfas.2011.0117

Dey, M.M., 1996. *Summary of activities on the report on dissemination of genetically improved Nile tilapia in Asia (DEGITA)*. In: M. A. Mazid, M. G. Hussain and M.J. Alam (Editors), Proceedings of the workshop on current status and future strategy for dissemination of genetically improved farmed tilapia in Bangladesh. Bangladesh Fisheries Research Institute, Mymensingh. pp.11-30.

Diana, J.S., Yi, Y. and Lin, C.K., 2004. Stocking densities and fertilization regimes for Nile tilapia (*Oreochromis niloticus*) production in ponds with supplemental feeding, In: Bolivar R., Mair G., and Fitzsimmons K. (eds.), *The 6th International Symposium on Tilapia in Aquaculture, Manila, Philippines*, pp. 467-499.

Department of Fisheries, 2019. *Yearbook of fisheries satistics of Bangladesh, 2018-19*. Fisheries Resources Survey System (FRSS), Department of Fisheries. Bangladesh: Ministry of Fisheries and Livestock.

Ekubo, A.A. and, Abowei J.F.N., 2011. Review of some water quality management principles in culture fisheries. *Research Journal of Applied Sciences, Engineering and Technology*, *3*(12), pp.1342-1357.

El-Shafai, S.A., El-Gohary, F.A., Nasr, F.A., van der Steen, N.P. and Gijzen, H.J., 2004. Chronic ammonia toxicity to duckweed-fed tilapia (*Oreochromis niloticus*). *Aquaculture*, *232*(1-4), pp.117-127. https://doi.org/10.1016/S0044-8486(03)00516-7

El-Sherif, M.S. and El-Feky, A.M., 2008. Effect of ammonia on Nile tilapia (*O. niloticus*) performance and some hematological and histological measures. *8th International Symposium on Tilapia in Aquaculture*, 2008.

El-Sherif, M.S. and El-Feky, A.M.I., 2009. Performance of Nile tilapia (*Oreochromis niloticus*) fingerlings. I. effect of pH. *International Journal of Agriculture & Biology*, *11*(3), pp.297-300. http://www.fspublishers.org

El-Zaeem, S.Y., Ahmed, M.M.M., Salama, M.E., and Darwesh, D.M.F., 2012. Production of salinity tolerant tilapia through interspecific hybridization between Nile tilapia (*Oreochromis niloticus*) and Red tilapia (*Oreochromis* sp.). *African Journal of Agriculture Research*, *7*(19), pp.2955-2961. https://doi.org/10.5897/AJAR12.061

FAO, 2018. *The state of world fisheries and aquaculture 2018-Meeting the sustainable development goals*. Rome.

Haque, M.R., Islam, M.A., Rahman, M.M., Shirin, M.F., Wahab, M.A. and Azim, M.E., 2015. Effects of C/N ratio and periphyton substrates on pond ecology and production performance in giant freshwater prawn *Macrobrachium rosenbergii* (De Man, 1879) and tilapia *Oreochromis niloticus* (Linnaeus, 1758) polyculture system. *Aquaculture Research*, *46*(5), pp.1139-1155. http://dx.doi.org/10.1111/are.12270

Haque, M.R., Islam, M.A., Wahab, M.A., Hoq, M.E., Rahman, M.M. and Azim, M.E., 2016. Evaluation of production performance and profitability of hybrid red tilapia and genetically improved farmed tilapia (GIFT) strains in the carbon/

nitrogen controlled periphyton-based (C/N-CP) on-farm prawn culture system in Bangladesh. *Aquaculture Reports*, *4*, pp.101-111. https://doi.org/10.1016/j.aqrep.2016.07.004

Hussain, M.G., Kohinoor, A.H.M., Rahman, M.M., Rahman, Z. and Nguyen, N.H., 2017. *Bangladesh's tilapia aquaculture industry shows resilience*. Global Aquaculture Advocate. https://www.aquaculturealliance.org/advocate/bangladesh-tilapia/

Ibrahim, N.A., Zaid, M.Y.A., Khaw, H.L., El-Naggar, G.O. and Ponzoni, R.W., 2012. Relative performance of two Nile tilapia (*Oreochromis niloticus* Linnaeus) strains in Egypt: The Abbassa selection line and the Kafr El Sheikh commercial strain. *Aquaculture Research*, *44*(3), pp.508-517. http://dx.doi.org/10.1111/j.1365-2109.2012.03240.x

Kamaruzzaman, N., Nguyen, N.H., Hamzah, A. and Ponzoni, R.W., 2009. Growth performance of mixed sex, hormonally sex reversed and progeny of YY male tilapia of the GIFT strain, *Oreochromis niloticus*. *Aquaculture Research*, *40*(6), pp.720-728. https://doi.org/10.1111/j.1365-2109.2008.02152.x

Makori, A.J., Abuom, P.O., Kapiyo, R., Anyona, D.N. and Dida, G.O., 2017. Effects of water physico-chemical parameters on tilapia (*Oreochromis niloticus*) growth in earthen ponds in Teso North Sub-County, Busia County. *Fisheries and Aquatic Sciences*, *20*, 30. https://doi.org/10.1186/s41240-017-0075-7

Mapenzi, L.L. and Mmochi, A.J., 2016. Role of salinity on growth performance of *Oreochromis niloticus*♀ and *Oreochromis urolepis urolepis*♂ hybrids. *Journal of Aquaculture Research & Development*, *7*(6), pp.1-5. http://dx.doi.org/10.4172/2155-9546.1000431

Mengistu, S.B., Mulder, H.A., Benzie, J.A.H. and Komen, H., 2020. A systematic literature review of the major factors causing yield gap by affecting growth, feed conversion ratio and survival in Nile tilapia (*Oreochromis niloticus*). *Reviews in Aquaculture*, *12*(2), pp.524-541. https://doi.org/10.1111/raq.12331

Moses, M., Chauka, L.J., de Koning, D.J., Palaiokostas, C. and Mtolera, M.S.P., 2021. Growth performance of five different strains of Nile tilapia (*Oreochromis niloticus*) introduced to Tanzania reared in fresh and brackish waters. *Scientific Reports, 11*, 11147. https://doi.org/10.1038/s41598-021-90505-y

Ngugi, C.C., James, R.B. and Bethuel, O.O., 2007. *A new guide to fish farming in Kenya*. Oregon State University, USA.

Putra, N.S.S.U., Lapong, I., Rimmer, M.A., Raharjo, S. and Dhand, N.K., 2013. Comparative performance of four strains of Nile Tilapia (*Oreochromis niloticus*) in brackish water ponds in Indonesia. *Journal of Applied Aquaculture*, *25*(4), pp.293-307. http://dx.doi.org/10.1080/10454438.2013.834282

Rahman, M.M., Mostafa, S.M.D., Mahmood, S., Sarker, S. and Faruk, A.M.D., 2012. Economics of tilapia culture in watershed pond in Bangladesh. *Journal of Aquaculture Research & Development*, *3*(4), 1000141. https://doi.org/10.4172/2155-9546.1000141

Riche, M. and Garling, D., 2003. *Fish: Feed and nutrition. Feeding tilapia in intensive recirculating systems*. http://www.hatcheryfeed.com/hf-articles/141/.

Saha, S.B. and Khatun, M.S., 2014. Production performances of monosex nile tilapia, *Oreochromis niloticus* in brackishwater ponds. *Bangladesh Journal of Zoology*, *42*(2), pp.261-269. http://dx.doi.org/10.3329/bjz.v42i2.23368

Suresh, A.V. and Lin, C.K., 1992. Tilapia culture in saline waters: A review. *Aquaculture*, *106*(3-4), pp.201-226. https://doi.org/10.1016/0044-8486(92)90253-H

Thoa, N.P., Ninh, N.H., Knibb, W. and Nguyen, N.H., 2016. Does selection in a challenging environment produce Nile tilapia genotypes that can thrive in a range of production systems? *Scientific Reports*, *6*(1), 21486. http://dx.doi.org/10.1038/srep21486

Tran, K., Verdegem, M., Wolkenfelt, B., Chadag, M. and Verreth, J., 2019. *The relation between farming practices and tilapia production in small-scale fish farms in Bangladesh. Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems*. Program Report: FISH-2019-06.

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

Watanabe, W.O., Losordo, T.M., Fitzsimmons, K. and Hanley, F., 2002. Tilapia production systems in the Americas: Technological advances, trends, and challenges. *Reviews in Fisheries Science*, *10*(3), pp.465-498. http://dx.doi.org/10.1080/20026491051758