

**PRELIMINARY STUDY ON GROWTH, FEED CONVERSION AND PRODUCTION  
IN NON-IMPROVED AND IMPROVED STRAINS OF THE NILE TILAPIA  
*Oreochromis niloticus***

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**Abstract**

The culture of an improved tilapia strain characterized with fast growth rate and low feed conversion ratio would have great economic benefit for the farmers by improving the production potential of fresh tilapia. Two experiments were conducted consecutively in triplicates to evaluate and compare the mean weight (MWT), daily growth rate (DGR), feed conversion ratio (FCR), survival and production rate (PR) in the non-improved strain (NS) of the Nile tilapia, *Oreochromis niloticus* with two selected strains obtained from the Philippines namely the Genetically Improved Farmed Tilapia (GIFT) strain and the FAC selected tilapia referred to as selected line (SL) from the swim-up fry stage to 1.0 g (Experiment 1) and from 1.0 g to 20 g (Experiment 2). The NS served as the control treatment. In Experiment 1, swim-up fry having mean weight of 0.01 g were stocked in 0.12 m<sup>3</sup> tanks at density of 1650 m<sup>-3</sup>, whereas in Experiment 2, fingerlings with 1.37 g mean weight were stocked in 0.42m<sup>3</sup> tanks at a rate of 300 fish m<sup>-3</sup>. The fish in both experiments were hand-fed 4-5 times daily with marine feed (Biomar 50% crude protein).

Water temperature was maintained at 29.0 ± 2.0°C. The two experiments lasted for 42 and 56 days, respectively. In both experiments, results showed significant differences in growth (P<0.05) between the NS group and both the GIFT and SL groups. Both groups had significantly higher MWT, faster DGR, lower FCR and higher PR than the NS group. Unlike in Experiment 1, no significant difference was evident in survival between the three groups. In Experiment 1 the improvement in the SL group over the NS group for the MWT, DGR and PR was 77.9, 72.9 and 33.6%, respectively, whereas in Experiment 2, the improvement for the same parameters were 58.7, 57.8 and 54.5%, respectively. These results demonstrate the advantage and potential of culturing the SL or the GIFT strain in improving the production of fresh tilapia, reducing the production cost and increasing the profitability of tilapia farms in Kuwait.

**Introduction**

Tilapia farming in Kuwait is in its early stages. However, research on tilapia was initiated in the late 1970s by the Aquaculture, Fisheries and Marine Environment Department (AFMED) of the Kuwait Institute for Scientific Research (KISR) to accelerate the

333development of aquaculture sector in Kuwait and to investigate the feasibility of culturing tilapia under the country's local environmental conditions. The research projects covered a range of topics including the determination of the reproductive potential of some tilapia species and the mass production of tilapia fry (Al-Ahmad *et al.* 1986, Hopkins *et al.* 1989), extending the restricted spawning season to a year-round spawning (Ridha *et al.* 1998) and improving seed production (Ridha and Cruz 2000). Research also focused on utilizing the abundant seawater available to culture saline-tolerant tilapia species such as *O. spilurus* in land-based tanks and floating seawater net cages (Cruz and Ridha 1991) and to utilize the limited amount of underground low-salinity (2 to 10 mg L<sup>-1</sup>) water available in some areas of Kuwait. Studies also evaluated simple systems for integrating the culture of the Nile tilapia *O. niloticus* with already existing agricultural farms without increasing the utilization of groundwater (Al-Ameeri *et al.* 2000).

At present it is estimated that about 65 farms grow *O. niloticus* and *O. spilurus* with a total annual production of 110 tons (Al-Ahmed 2004). The high production cost is reflected in a high selling price (US\$4.5-6.0/kg) and is a result of the slow growth rate, poor feed conversion and inadequate seed supply which represent major constraints hindering the expansion of the tilapia farming industry in Kuwait. Therefore, an adequate and dependable supply of quality tilapia fingerlings that can grow at a maximum rate in a short time would allow the hatchery operators and growers to increase their production cycles per season.

In tilapia, sexual dimorphism for growth is well documented (Baras and M elard 1997) where males grow larger than females (Tave 1995). Therefore, the production of an all-male population is more profitable than a mixed-sex population. In recent years, much of the research has been conducted to develop techniques to produce all-male tilapia fry. The most important techniques are manual sexing, the production of a monosex population through hormonal sex reversal and interspecific hybridization and the production of genetically improved male tilapia (GMT) through breeding of YY "super-males". Popma and Lovshin (1996) and Little (1998) reviewed the advantages and disadvantages of these techniques.

Recently, the Genetically Improved Farmed Tilapia (GIFT) strain developed through selective breeding in a base population derived from eight strains of the Nile tilapia, *Oreochromis niloticus* exhibited faster growth rate up to 60% and higher survival rate up to 50% than the local strains of the Nile tilapia currently farmed in the Philippines (Eknath and Velasco 1993; Eknath *et al.* 1993; Macaranas *et al.* 1993; Bentsen *et al.* 1998). In countries like Kuwait where the use of hormones in animal production is banned, the GIFT strain could be considered as a potential alternative to the aforementioned techniques to improve tilapia production and profitability of the farms.

The objective of the present study was therefore, to evaluate and compare the growth rate, feed conversion ratio, survival and production rate of the GIFT strain and a selected line of the Nile tilapia with an existing non-improved strain in first nursery stage from the swim-up fry to 1.0 g and in second nursery stage from 1.0 g to 20 g.

## Materials and methods

### *Test fish*

Three tilapia strains were tested: (1) Non-improved Nile tilapia *Oreochromis niloticus* (NS) which was the offspring of a pure stock of the of Egyptian Ismaelia strain imported from the Aquasafra, Inc., Florida, USA, (2) the Genetically Improved Farmed Tilapia strain of the Nile tilapia referred as GIFT from the Philippines and (3) the FaST selected line, also from the Philippines. The Philippine selected strains were imported in 1999 from the Bureau of Fisheries and Aquatic Resources-National Freshwater Fisheries Technology Research Center (BFAR-NFFTRC), Department of Agriculture, Philippines. The GIFT strain introduction were progeny produced from mass spawning of the family material from 6<sup>th</sup> generation of the Genetically Improved Farmed Tilapia (GIFT) Project (Eknath and Acosta, 1998). The selected line (SL) originated from a mass spawning of the 13<sup>th</sup> generation of selection FAC Selected Tilapia (FaST) produced from within family selection of *O. niloticus* (Bolivar and Newkirk, 2002).

The experiments described here were carried out on first generation fry of the introduced fish. As soon as the introduced stocks were received as fry (0.1 g average weight), they were grown separately in two 2 m<sup>3</sup> square fiberglass tanks (2.0 x 2.0 x 0.5 m, L x W x H) to the spawning size. Preliminary spawning trials were carried out to obtain enough fry to carry out the experiments and to establish the GIFT and SL stocks at the Aquaculture, Fisheries and Marine Environment Department (AFMED), Kuwait Institute for Scientific Research (KISR).

### *Experimental design*

Two experiments were conducted consecutively. Three treatments were tested in each experiment, Treatment 1 is the non-improved strain (NS) and served as the control treatment, Treatment 2 is the (GIFT) strain and Treatment 3 is the selected line (SL). Three tanks were assigned for each treatment. In Experiment 1, swim-up fry having mean body weight of 0.01 g were stocked in 120 liter rectangular fiberglass tanks (1.0 x 0.4 x 0.3 m, L x W x H) provided with a continuous flow of dechlorinated filtered freshwater and aeration. The flow rate in each tank was approximately adjusted at a rate of 0.12 L min<sup>-1</sup>, to give about 1.4 turnovers per day. The swim-up fry were stocked at a density of 1650 m<sup>-3</sup> (200 fry tank<sup>-1</sup>). The fish were hand-fed daily 4-5 times with powdered marine feed (Biomar, France) containing 50% crude protein. The proximate composition of the feed is presented in Table 1. The fish were fed at 20% of the total body weight per day for the first two weeks. The feeding rate was then reduced to 15% day<sup>-1</sup> for another two weeks and finally reduced to 10% day<sup>-1</sup> for the rest of the experiment. The experiment lasted for 42 days.

Table 1. Proximate composition of the feed.

Composition	Content (%)	Composition	Amount/kg
Crude Protein	50.0	Vitamin A	20,000 IU
Crude Fat	18.0	Vitamin D <sub>3</sub>	2,500 IU
Crude Fiber	1.0	Vitamin E	200 mg

In Experiment 2, fish of the NS, GIFT and the SL groups having mean body weights of 1.1, 1.2 and 1.8 g, respectively, were stocked in 0.42 m<sup>3</sup> fiberglass square tanks measuring 1.0 x 1.0 x 0.42 m (L x W x H). The effective volume was about 300 liters. The fish tanks were attached to a 0.42 m<sup>3</sup> biofilter tank within the same recirculating water system. Extruded polypropylene plastic chips and polyethylene blocks with a specific surface area of 200 m<sup>2</sup>/m<sup>3</sup> were used as biofilter media. The fish were stocked at a density of 300 fish m<sup>-3</sup> (90 fish tank<sup>-1</sup>) and were initially fed at a rate of 10% total body weight per day with 0.3 mm marine pellets (Biomar, France) containing 50% crude protein (Table 1) for the first two weeks. The feeding rate was then reduced to 7.5% day<sup>-1</sup> for another two weeks and finally reduced to 5% day<sup>-1</sup> for the rest of the experiment using 1.5 mm pellets. The water flow rate in each tank was adjusted to 0.85 L min<sup>-1</sup> to give four turnovers day<sup>-1</sup>. On a daily basis, 20-30% of the culture water was replaced with new water. The experiment lasted for 56 days.

#### ***Water quality monitoring***

In both experiments, water temperature was maintained throughout the study at 29.0 ± 2.0 °C using immersion heaters. The following quality parameters were regularly monitored every two to three weeks: dissolved oxygen (DO), pH, total ammonia-nitrogen (TAN), nitrite-nitrogen (NO<sub>2</sub>-N) and nitrate-nitrogen (NO<sub>3</sub>-N). An Orion portable meter model A-20 and YSI portable meter model 55 were used to measure DO. The concentration of TAN, NO<sub>2</sub>-N, NO<sub>3</sub>-N and pH was determined using the HACH test kit (HACH Company, USA).

#### ***Statistical analysis***

In both experiments and on a weekly basis, the total fish biomass in each tank was determined to adjust the amount of food and to calculate the growth rate. At the end of each experiment, the means of body weight (MWT), daily growth rate (DGR), feed conversion ratio (FCR), survival rate and production rate (PR) were determined. DGR was calculated as total weight gain per fish ÷ culture days. FCR was calculated as total weight of dry feed given ÷ total weight gain. Survival was determined as 100 (final total fish number ÷ initial total fish number) and PR as final total fish weight ÷ water volume. The means of the above parameters were subjected to one-way analysis of variance at α = 0.05 and Duncan's new multiple range test using the SPSS statistical package (SPSS 1996).

## **Results**

#### ***Growth performance***

In Experiment 1, the SL group had significantly higher mean body weight and daily growth rate (1.38 g and 0.033 g fish<sup>-1</sup> day<sup>-1</sup>, respectively) than the GIFT and the NS groups

(Table 2). The lowest values for the MWT and DGR were observed in the NS strain (0.78 g and 0.018 g fish<sup>-1</sup> day<sup>-1</sup>, respectively).

The difference in MWT and DGR in the SL over the NS group was 77.9% and 72.9%, respectively. In Experiment 2, the GIFT and the SL groups had higher MWT of 21.7 and 23.7 g, respectively and faster DGR of 0.37 and 0.38 g fish<sup>-1</sup> day<sup>-1</sup>, respectively than the NS fish (14.6 g and 0.24 g fish<sup>-1</sup> day<sup>-1</sup>, respectively). The difference in the GIFT and the SL groups in MWT compared to NS was 48.7 and 58.4%, respectively and 52.2 and 57.8 %, respectively for the DGR (Table 3). In both experiments and in the three strains, the MWT and DGR increased linearly with time.

#### ***Feed conversion ratio***

In Experiment 1 (see Table 2), the GIFT and the SL treatments had significantly lower ( $P < 0.05$ ) feed conversion ratio (0.80 and 0.83, respectively) than the NS treatment (0.89). In Experiment 2, the lowest FCR value was observed in the GIFT treatment (0.96) and was significantly lower than that in the SL and NS treatments (Table 2). However, in both experiments the difference in FCR in the GIFT and SL over the NS fish was small (Table 3).

#### ***Survival***

In Experiment 1, the SL group had the lowest survival (75.2%). Most of the mortality in this group occurred shortly after stocking, and no mortality was observed during the progress of the experiment. The feed ration in this group was adjusted accordingly. On the other hand, survival in the NS and GIFT groups were high (Table 2). In Experiment 2, survival in the three groups was high (Table 2) with no significant difference among them.

#### ***Production***

In Experiment 1, the production of 1.0 g fry in the SL and the GIFT treatments was 1.71 and 1.54 kg m<sup>-3</sup>, respectively. These rates were higher than the rate of 1.28 kg m<sup>-3</sup> obtained in the NS group. However, the difference was not statistically significant ( $P > 0.05$ ). The difference in the production in the SL and the GIFT fish over the NS fish was 33.6 and 20.3%, respectively. In Experiment 2, the production of the 20 g tilapia differed significantly ( $P < 0.05$ ) among the three groups. The SL group had the highest production (6.80 kg m<sup>-3</sup>), followed by the GIFT group (6.18 kg m<sup>-3</sup>). The lowest production was in the NS group (4.35 kg m<sup>-3</sup>). The SL treatment had a difference of 54.4 % in fish yield/m<sup>3</sup> over the NS strain.

#### ***Water quality***

The average of water quality parameters is presented in Table 4. In both experiments the different quality parameters were close to each other and were within the safe limits. No significant differences in water quality were detected between the treatments.

Table 2. Growth rate, feed conversion, survival and production rate of the non-improved, GIFT, and selected line of Nile tilapia.

Parameter	Experiment 1			Experiment 2		
	Non-improved strain	GIFT strain	Selected line	Non-improved strain	GIFT strain	Selected line
<b>Stocking data</b>						
Number/tank	200	200	200	90	90	90
Mean weight (g)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	1.1 ± 0.02	1.2 ± 0.03	1.8 ± 0.03
Stocking rate (No/m <sup>3</sup> )	1650	1650	1650	300	300	300
<b>Harvest data</b>						
Duration (days)	42	42	42	56	56	56
Mean weight (g)	0.78 ± 0.04 <sup>b</sup>	0.82 ± 0.05 <sup>b</sup>	1.38 ± 0.06 <sup>a</sup>	14.6 ± 0.61 <sup>b</sup>	21.7 ± 0.91 <sup>a</sup>	23.7 ± 0.72 <sup>a</sup>
DGR (g fish <sup>-1</sup> day <sup>-1</sup> )	0.018 ± 0.001 <sup>b</sup>	0.021 ± 0.002 <sup>b</sup>	0.033 ± 0.001 <sup>a</sup>	0.24 ± 0.01 <sup>b</sup>	0.37 ± 0.017 <sup>a</sup>	0.38 ± 0.012 <sup>a</sup>
FCR	0.89 ± 0.002 <sup>a</sup>	0.80 ± 0.001 <sup>b</sup>	0.83 ± 0.002 <sup>b</sup>	1.04 ± 0.003 <sup>a</sup>	0.96 ± 0.02 <sup>b</sup>	1.06 ± 0.009 <sup>a</sup>
Survival rate (%)	98.8 ± 0.67 <sup>a</sup>	98.2 ± 0.93 <sup>a</sup>	75.2 ± 4.04 <sup>b</sup>	99.6 ± 1.59 <sup>a</sup>	98.3 ± 1.20 <sup>a</sup>	95.2 ± 1.0 <sup>a</sup>
Production rate (kg m <sup>-3</sup> )	1.28 ± 0.059 <sup>a</sup>	1.54 ± 0.18 <sup>a</sup>	1.71 ± 0.02 <sup>a</sup>	4.35 ± 0.13 <sup>c</sup>	6.18 ± 0.22 <sup>b</sup>	6.80 ± 0.18 <sup>a</sup>

Data are means of three replicates ± SEM.

In each experiment, means having different superscripts are significantly different (P<0.05) (Horizontal comparison).

Table 3. Difference (%) in mean weight, daily growth rate, feed conversion ratio, and production of the GIFT, and selected line over the non-improved strain.

Parameter	Experiment 1		Experiment 2	
	GIFT strain	Selected line	GIFT strain	Selected line
Mean weight (g)	6.5	77.9	48.7	58.7
DGR (g fish <sup>-1</sup> day <sup>-1</sup> )	15.0	72.9	52.2	57.8
FCR	11.3	8.4	7.3	0
Production rate (kg m <sup>-3</sup> )	20.3	33.6	40.9	54.5

Table 4. Average water quality parameters.

Parameter	Experiment 1	Experiment 2
Total ammonia-nitrogen (TAN) (mg L <sup>-1</sup> )	0.67	0.60
Unionized ammonia (NH <sub>3</sub> -N) (mg L <sup>-1</sup> )	0.0147	0.005
Nitrite (NO <sub>2</sub> -N) (mg L <sup>-1</sup> )	0.22	0.12
Nitrate (NO <sub>3</sub> -N) (mg L <sup>-1</sup> )	3.3	7.0
pH	7.3	7.1
Dissolved oxygen (mg L <sup>-1</sup> )	7.0	6.9
Water temperature (°C)	29.5	28.3

## Discussion

### *Growth performance*

In Experiment 1, the higher mean body weight encountered in fry of the SL group after 42 days suggests superior growth performance that was evident starting from the early stages of life (swim-up fry stage). However, under the conditions of the present study, the discrepancy in growth performance between the GIFT strain and the NS fish was not clear at this stage of life. The faster daily growth rate obtained in the SL and the GIFT treatments would allow the swim-up fry to attain the size of 1.0 g seven to ten days earlier than the NS fry and thus, shortening the duration of the production cycle. This would allow the hatchery operators to increase their production cycles per season. The lower survival encountered in the SL fish could have partly contributed in the difference obtained in mean weight and daily growth rate between the GIFT and SL fish. However, when data of the SL and the GIFT treatments was pooled, it showed better growth performance than the NS group. No data is available in the literature on the growth performance of the improved strains of the Nile tilapia from the swim-up stage. However, for comparison, the mean final body weight obtained in this study for the NS group was higher than the ranges of 0.31 to 0.47 g reported by Al-Ahmed *et al.* (1985) for *O. spilurus* fry stocked in low salinity underground water at a density of 2000 fry m<sup>-3</sup> and reared for 42 days. In the control treatment of a sex reversal experiment, Ridha and Lone (1990) obtained a lower final body weight of 0.23 g than this study, for *O. spilurus* fry stocked at 1.6 fry L<sup>-1</sup>.

In Experiment 2, the significantly higher values obtained after 56 days in the SL and the GIFT groups for the MWT (23.7 and 21.7 g, respectively) and for the DGR (0.38 and 0.37 g fish<sup>-1</sup> day<sup>-1</sup>, respectively) compared with the NS group (14.6 g and 0.24 g fish<sup>-1</sup> day<sup>-1</sup>, respectively) suggests that the SL and GIFT fry would reach the size of 20 g ten to fourteen days earlier than the NS fry thereby, reducing the length of the production cycle. However, the higher initial size of the SL fish at stocking is likely to have contributed to the higher harvest biomass encountered in this group. Hussain *et al.* (2000) and Mather and Nandlal (2000) obtained better growth performance in the GIFT strain than the non-improved Nile tilapia for 13 and 11 g fish, respectively. In non-improved *O. niloticus*, Rosati *et al.* (1997) fed 0.4 g fry with 36% protein diet and after 56 days the fry had mean body weight of 20 g with a daily growth rate of 0.35 g fish<sup>-1</sup> day<sup>-1</sup> that is comparable with the growth rate obtained in this study. McAndrew and Majumdar (1989) obtained lower mean body weight of 15.5 g for 3.2 g non-improved Nile tilapia grown in 60 liters tanks for 40 days. In this study, the linear increase in the mean body weight indicates that conditions were favorable for growth and survival and that the maximum carrying capacity of the system was not reached. Beniga and Circa (1997) observed an increase in growth rate with time in 3.3 g selected line, GIFT and non-improved local strains of the Nile tilapia stocked in 10 m<sup>3</sup> floating freshwater net cages at a density of 30 fish m<sup>-2</sup> (12 fish m<sup>-3</sup>) and fed commercial tilapia feed containing 30% crude protein. After 84 days, the selected line and the GIFT fish had 41 and 15.8% higher body weights, respectively and 44.6 and 16.9% faster daily growth rates, respectively, than the local strain. The rates of improvement obtained by Beniga and Circa (1997) were lower than the rates obtained in this study in the SL and the GIFT strains for the MWT (58.4 and 48.7%, respectively) and the DGR (57.8 and 52.2%, respectively). On the other hand, the 69.6 g MWT and the 0.76 g fish<sup>-1</sup> day<sup>-1</sup> DGR reported by Dey *et al.* (2000) for the GIFT strain were higher than the values of 21.7 g and 0.37 g fish<sup>-1</sup> day<sup>-1</sup>, respectively obtained in this study for the GIFT strain. This was probably due to the lower stocking density used by these authors (12 fish m<sup>-3</sup>) compared with the higher density used in this study (300 fish m<sup>-3</sup>). However, the improvement rates obtained in this study in the GIFT fish for the MWT and DGR was higher than the rates of 30% and 17.8%, respectively, obtained by Dey *et al.* (2000) for 1.3 g GIFT tilapia over the non-GIFT strain stocked in ponds in Vietnam for a longer period (138-152 days).

In general, the difference in the mean weight and the daily growth rate between the NS and the GIFT or SL groups encountered in Experiment 2 was more prominent than in Experiment 1 (Table 3).

### ***Feed conversion ratio***

FCR values obtained in the SL and GIFT fish in experiment 1 were better than values obtained in the NS fish (Table 2). This enhancement in FCR suggests efficient food utilization through the extraction of more nutrients from the food and converting it into flesh (Bhijkajee and Gobin 1997). FCR values obtained in Experiment 1 in the NS group was better than the lowest FCR (1.14) reported by Ellis and Watanabe (1993) for red tilapia fry.

In Experiment 2, the FCR of 1.04 obtained in the NS group is lower than the FCR of 1.38 obtained by Rosati *et al.* (1997). Similarly, Bailey *et al.* (2000) had higher FCR value of 1.2 for 4.3 g *O. niloticus* stocked at a lower density of 200 fish m<sup>-3</sup> and fed 32% protein diet for 84 days.

Siraj *et al.* (1988) reported higher mean FCR of 3.31 for 1.2 g red tilapia hybrid fed 35% protein diet for five weeks. In this study, the enhancement in FCR in experiment 2 was realized only in the GIFT group. However, in both experiments the improvement rate in FCR was small. Mather and Nandlal (2000) obtained an improvement of 11.9% in FCR with the GIFT strain over the local Chitralada strain of the Nile tilapia. It appears that the impact of FCR on the production cost would be more significant during the grow-out stages rather than during the fry stages because the amount of the consumed food would be much greater in the grow-out phase.

### **Survival**

In the first experiment, the significantly lower survival encountered in the SL group was caused by mortality during stocking, thus resulting in some differences in fish densities among the different treatments which are likely to have impacted upon relative growth rates. No mortality was observed during the progress of the experiment. The mean survival in the three strains was higher than the 67% and 50% reported by Al-Ahmed *et al.* (1985) and by Ridha and Lone (1990), respectively, for *O. spilurus* fry reared in a salinity of 2-5 mg L<sup>-1</sup>.

In Experiment 2, the high survival obtained in the NS (99.6%), GIFT (98.1%) and the SL groups (95.2%) were better than the survival obtained by Dey *et al.* (2000) for 1.0 g GIFT (69%) and non-GIFT (53%) tilapia strains reared in ponds. Beniga and Circa (1997) had lower survival in 3.3 g selected line and non-improved strain fish (85.3 and 86.6%, respectively) than the GIFT strain (94.2%).

### **Production**

At harvest, the SL and GIFT groups exhibited an improvement in the production of the 1.0 g fry by a rate of 33.6 and 20.3%, respectively over the NS fry. This improvement was due to the better growth rate and feed conversion ratio. However, the lower density in the SL group caused by the lower survival might be responsible for some of the differences in production rate between the SL and GIFT fish. However, given the differences in survival production may provide a better indicator of relative merits of the strains under culture conditions. In this study the production obtained in the three strains (Table 2) were higher than the production of 0.857 kg m<sup>-3</sup> and 0.606 kg m<sup>-3</sup> obtained by Al-Ahmed *et al.* (1985) for *O. spilurus* and red tilapia hybrid, respectively, stocked at a higher density (2000 fry m<sup>-3</sup>).

In Experiment 2, the SL and GIFT groups continued to have higher yields than the non-improved strain (Table 2). The 54.5% and 40.9% improvements in production realized in the SL and GIFT strains were higher than the rate of 33.2% reported by Dey *et al.* (2000) for the 1.3 g GIFT strain reared in earthen ponds and higher than the rate of 26.7 and 40% for the GIFT and selected line, respectively reported by Beniga and Circa (1997) in floating freshwater net cages. However, in this study the production criteria for FCR of less than 1.0 kg feed/wet weight gain and the survival rate greater than 95% was met by the SL and the GIFT strains, thereby indicating the advantage of culturing either strain to increase fry yield.

### **Water quality**

In fish culture systems, ammonia is the principal toxic metabolic by-product. The average total ammonia concentration of 0.67 obtained in this study was comparable with the range of 0.2 to 0.6 mg L<sup>-1</sup> reported by Siddiqui *et al.* (1997) and lower than the safe range of 13 to 43 mg L<sup>-1</sup> reported by Sin and Chiu (1983) for red tilapia. The average levels of the unionized ammonia, nitrites and nitrates were within the safe and acceptable ranges. Similarly, the maximum concentration obtained in both experiments for NH<sub>3</sub>-N and NO<sub>2</sub>-N, respectively, were lower than the safe level of 1.05 mg L<sup>-1</sup> and 1.0 mg L<sup>-1</sup> reported by Hassan (1992) and Otte and Rosenthal (1979), respectively. The minimum DO concentration of 6.9 mg L<sup>-1</sup> obtained was close to the optimum level and was sufficient for optimal fish growth. The obtained pH range of 7.1-7.3 was within the tolerance range of 5-11 for tilapia reported by Chervinski (1982). Water temperature during the study averaged 29.5 °C and 28.3 °C in both experiments and was within the optimum range for tilapia survival and growth (Popma and Lovshin 1996).

### **Conclusion**

The results of this study indicated that the selected and GIFT strains of the Nile tilapia had better growth rate, feed conversion ratio and production than the non-improved strain. Therefore, the selected line or the GIFT strain could be considered as a potential strain for improved tilapia production by reducing the production cost and increasing the profitability of the tilapia farms in Kuwait. However, before replacing the existing stocks of the non-improved tilapias such as *O. niloticus* and *O. spilurus* with an improved strain (SL or GIFT), further studies are required to determine the growth of both strains to the market size (>250 g), and to evaluate their reproductive potential.

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