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Evaluation of monosex culture of GIFT and non-improved strains of Nile tilapia *Oreochromis niloticus* in recirculating tanks

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Abstract

In all-male culture of the non-improved tilapia strains based on manual sexing, females are discarded because their growth is slower than that of males which results in a wastage of effort and undue expenses in growing the females to sexable size. This study was, therefore, conducted to compare the yield and growth performance of monosex culture of the Genetically Improved Farmed Tilapia (GIFT) and non-improved strains (NS) of the Nile tilapia, *Oreochromis niloticus*. Males and females having mean weights of 120.4 and 96.5 g were stocked separately in 0.43 m^3 tanks at 100 fish/m^3 and fed commercial pellets (35% protein) for 158 days. Results showed that GIFT males had significantly higher mean weight (628.4 g), daily growth rate (3.19 g fish/day), specific growth rate (1.03%/day), gross yield (59.3 kg/m^3) and better feed conversion ratio (1.4) than the other treatments, whereas the non-improved females had the lowest growth parameters, survival, gross yield and the poorest feed conversion ratio. Results also indicated that non-improved males and GIFT females had similar growth rates (2.16 and 1.92 g/fish/day, respectively). These results indicate that routine size-grading and manual sexing of the GIFT strain between production phases would result in populations of a single sex majority and uniform size. Intensive culture of GIFT populations would greatly eliminate the unwanted recruitment and the need to discard the females as is the case with the slow-growing non-improved females, and thus increase production rate and profitability.

Keywords: Monosex culture, Growth, Feed conversion, GIFT, Nile tilapia

Introduction

Nile tilapia is an important food fish that has been transplanted to many different parts of the world by man. It has several advantageous characters like general hardiness, easy breeding, rapid growth, flexible feeding habits and good taste that makes it easy to culture in various aquaculture systems and under a wide range of environmental conditions. Therefore, Nile tilapia is considered as the most popular species of tilapia cultured around the globe.

Tilapia exhibit remarkable growth dimorphism where males grow at faster rate and attain larger size than females and utilize feed more efficiently (Tave 1995). Therefore, the culture of male tilapia population is an obvious

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goal for the farmers and is preferred over the commonly practiced mixed-sex population since it is economically important for consistent homogeneous and rapid growth and has the advantage of increasing the fish yield and the profitability of the farm. Moreover, male monosex resolve the problem of unwanted spawning and recruitment leading to stunting as experienced in mixed-sex population. The discrepancy in the growth performance between male and female tilapia is multi-factorial. It is believed to be related to channeling of energy from somatic growth toward egg production in females (Rakocy and McGinty 1989; Baroiller and Borel 1997), anabolic effects of the male sex steroids and growth hormones, genes linked to sex determination and greatly reduced feeding activity of brooding females (Toguyeni et al. 1997a; Toguyeni et al. 2002). In aquaculture, a population of male tilapia fry can be achieved through hormonal sex reversal, interspecific hybridization and the production of genetically improved male tilapia. However, each method has it own disadvantages including the possible impact on the health and environment, or the difficulty of its application and unreliability. A complementary approach has been used for selective breeding of tilapia for faster growth.

The Genetically Improved Farmed Tilapia (GIFT) strain was developed through selective breeding of eight African and Asian strains of the Nile tilapia *Oreochromis niloticus* (Gupta and Acosta 2004). It exhibits faster growth rate and higher survival than the non-improved strains of the Nile tilapia. (Dey and Gupta 2000). However, in all-male culture practices based on manual separation of sexes, the females are usually discarded resulting in a waste of about 50% of the fish produced and of the feed expenses used to grow the females to the sexable size. In a mixed-sex culture study, Ridha and Cruz (2002) showed that males of non-improved Nile tilapia and the females of the Genetically Improved Farmed Tilapia (GIFT) strains were growing at more or less similar rates. At the end of the experiment, the GIFT females and the males of the non-improved strains attained comparable mean body weights of 251.2 g and 257.4 g, respectively. If verified true, the manual sexing of the GIFT strain by the farmer would have the advantage of raising each sex separately without the need to discard the females. Most studies conducted to evaluate growth performance of tilapia males and females were carried out using mixed-sex populations. The objective of this study was therefore to evaluate the actual growth performance, feed conversion ratio, survival rate and gross yield of monosex culture of the males and females of the improved (GIFT) and the non-improved strains (NS) of the Nile tilapia *Oreochromis niloticus* cultured separately in intensive recirculating tanks.

Materials and methods

Fish and design of experiment

Two strains of the Nile tilapia *Oreochromis niloticus* were tested, namely: Non-improved Ismaelia strain (NS); imported from the Aquasafra (Bradenton, FL, USA) and maintained in Kuwait, and the 6th generation of the Genetically Improved Farmed Tilapia (GIFT) strain imported from the Bureau of Fisheries and Aquatic Resources-National Freshwater Fisheries Technology Center (BFAR-NFFTC), Department of Agriculture, Philippines. Hand-sexed males and females of the GIFT and the non-improved strains of the Nile tilapia were stocked separately in 0.43 m^3 square fiberglass tanks (1.0 × 1.0 × 0.43 m) within a recirculating water system. The mean weights of the males and females were 120.4 and 96.5 g, respectively. Due to the nature of faster growth behavior of the males in both strains, it was not possible to obtain fish of uniform size at the start of the experiment (Palada-de-Vera and Eknath 1993).

The fish were stocked at 30 fish/tank (100 fish/m^3; 8.7-12.3 kg/m^3). Each treatment was triplicated. The fish were fed with 4.5 mm commercial tilapia pellets (Provimi, Greece) containing 35% protein until the end of the experiment. Initially, fish were fed at a rate of 5.0% of the total body weight/day, then decreased gradually to 2.5% body weight/day. The total daily amount of food was offered to the fish at three equal portions at 08:00, 11:00 and 14:00 h. Water temperature was maintained at 29.0 ± 2.0 ˚C using titanium immersion heaters (AREA Inc, Homestead, Florida, USA).

Water quality parameters were monitored every two weeks using HACH kit (HACH, Loveland, CO, USA). All quality parameters remained within the acceptable range for tilapia growth. All fish in each tank were weighed and counted every 24-48 days to assess growth and to adjust feeding rate. The experiment lasted for 158 days. On termination, the fish were weighed in bulk and counted. The means of growth parameters and of feed utilization were calculated as follows:

Total weight gain/fish = final fish weight (g) – initial fish weight (g) (Chiu 1989).
Daily growth rate (DGR) = total weight gain/fish ÷ culture days (Chiu 1989).
Specific growth rate (SGR) = 100 (Ln mean final weight – Ln mean initial weight)/culture days (Chiu 1989).
Feed conversion ratio (FCR) = total weight of dry feed given ÷ total weight gain (Boonyaratpalin 1989).
Fish survival (%) = 100 (final total fish number ÷ initial total fish number) (Ridha 2006).
Gross yield (GY) = final total fish weight ÷ tank water volume (Ridha 2006).
Condition factor (K) = 100 (fish weight) fish/length^3 (Crab et al. 2009).

Statistical analysis

Treatment means of the above parameters were subjected to one-way ANOVA at 5% significance level and Duncan's new multiple range test. The effect of sex and strain and their interactions on the final individual mean weight, specific growth rate, feed conversion ratio, survival and gross yield were analyzed using the two-way ANOVA at 5% level of significance. The statistical analysis was performed using the SPSS statistical package program (SPSS 1996).

Results and discussion

Effect of strain and sex on growth performance

At the end of the experiment, mean weight, daily growth rate and specific growth rate differed significantly among the four treatments (Figure 1). The GIFT males had the highest values for mean weight (628.4 g), daily growth rate (3.19 g/fish/day) and specific growth rate (1.03 %/day), while the non-improved females had the lowest values (Table 1). On the other hand, the non-improved males and the GIFT females had close values for mean weight (458.9 g and 408 g, respectively), daily growth rate (2.16 and 1.93 g/fish/day, respectively) and specific growth rate (0.86 and 0.87%/day), however, the difference was statistically insignificant (Table 1). This indicates that GIFT females and NS males were growing at a comparable rate and thus, supporting the earlier findings reported by Ridha and Cruz (2002) for mixed-sex Nile tilapia, where females of the GIFT strain and males of the non-improved strain attained a comparable mean body weights of 251.2 g and 257.4 g, respectively. DGR and SGR ranges obtained in this study were comparable with those reported by Ridha (2006). Mean weight in all treatments showed a trend of linear increase with time. The faster DGR and SGR of the GIFT females allowed the fish to reach the minimum marketable size of 250 g earlier than the non-improved females (Mather and Nandlal 2000; Rahman et al. 2004).

Condition factor (K) is essentially a measure of relative bone growth and is a good indicator for the robustness and well being of the fish. In this study, K values differed significantly among treatments and ranged between 2.15 to 2.41 (Table 1). Lower K values indicate that fish are relatively growing in length more than in weight and have more elongate shape. Crab et al. (2009) suggested that in ponds, K values less than 1.8 is an indication for poor culture conditions whereas K values greater than 2 indicate good fish and culture conditions.

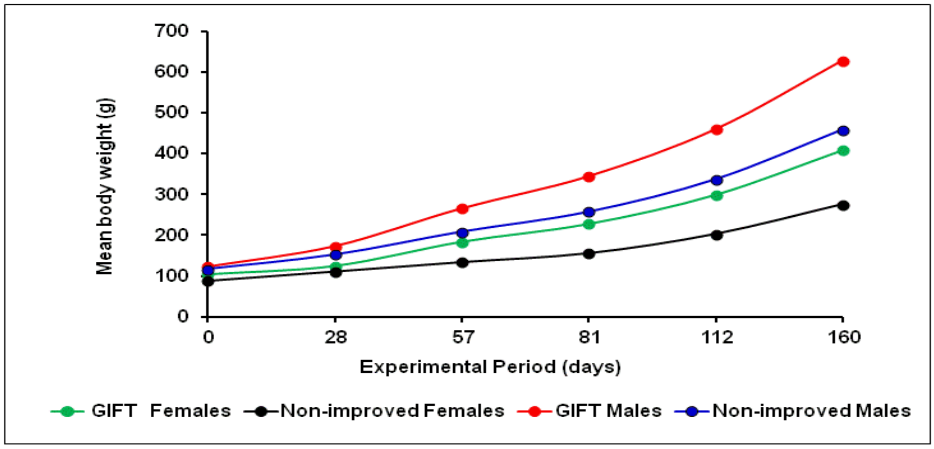

Fig. 1. Growth curve for the different treatments

Two-way ANOVA showed that growth parameters were significantly ($P < 0.05$) affected by strain and by sex. However, no interaction ($P > 0.05$) was observed between strain and sex for mean weight, daily growth rate, specific growth rate and condition factor was observed (Table 2). Data analyzed irrespective of strain i.e. effect of sex, indicated that males had significantly higher growth performance than the females but both sexes had similar condition factor values (Table 3). Males were 58% heavier than the females and showed 73% faster daily growth rate. On the other hand, data analyzed, irrespective of sex i.e. effect of strain, showed that the GIFT strain had significantly higher mean weight, daily growth rate, specific growth rate and condition factor than the non-improved strain (Table 4). This superior growth of the GIFT strain and of tilapia males is well documented in the literature. In this monosex study, the discrepancy in growth capacities between sexes can be attributed mainly to the genetic differences between males and females (Toguyeni et al. 1997b) rather than to energy channeling in females from somatic growth toward reproduction or social interactions that affects feed intake as the case in mixed-sex. Rahman et al. (2004) reported higher individual body weight and yield in chicken-fish integrated ponds stocked with manually separated male GIFT than female GIFT and mixed-sex GIFT population.

Table 1. Initial and final body weights, daily growth rate, specific growth rate, feed conversion ratio, survival and gross yield of males and females of Nile tilapia*

Parameter	GIFT ♀	Non-improved ♀	GIFT ♂	Non-improved ♂
Stocking data				
Initial body weight (g)	104.2	88.8	123.4	117.2
Fish/tank	30	30	30	30
Fish density (kg/m^3)	10.4	8.7	12.3	11.7
Harvest data				
Final body weight (g)	408.0 ± 16.6^b	275.5 ± 15.6^c	628.4 ± 16.5^a	458.9 ± 38.3^b
Daily growth rate (g/fish/day)	1.93 ± 0.04^b	1.18 ± 0.08^c	3.19 ± 0.08^a	2.16 ± 0.22^b
Specific growth rate (%/day)	0.87 ± 0.05^b	0.72 ± 0.04^c	1.03 ± 0.01^a	0.86 ± 0.03^b
Feed intake (g)	13674.3	8963.7	19658.0	15723.3
Feed conversion ratio	1.62 ± 0.02^b	2.14 ± 0.25^a	1.40 ± 0.10^b	1.57 ± 0.06^b
Survival (%)	94.4 ± 2.9^a	84.4 ± 4.4^b	94.5 ± 4.0^a	98.9 ± 1.1^a
Gross yield (kg/m^3)	38.6 ± 2.5^b	23.3 ± 2.3^c	59.3 ± 2.6^a	45.4 ± 4.1^b
Condition Factor (K)	2.41 ± 0.01^a	2.24 ± 0.01^b	2.37 ± 0.02^a	2.15 ± 0.07^b
Fish > 300 g (%)	68.8 ± 6.3^b	33.3 ± 6.7^c	100.0 ± 0.0^a	87.5 ± 0.0^a

*Values in the same row having the same superscripts do not differ significantly ($P > 0.05$). Values are means ± SEM.

In tilapia culture, size-grading and manual sexing is commonly practiced by fish producers (Rakocy and McGinty 1989) to obtain homogenous fish size that minimize cannibalism and size variability among harvested fish. Baras and Melard (1997) reported that males in *O. niloticus* start to grow faster than females at an early age (3.5-4.0 g) and become significantly bigger than females at size 20-30 g (Toguyeni et al. 1997b). Balarin and Haller (1979) reported that after three gradings the fish populations consisted of up to 70% males.

Therefore, results of this study may suggest that routine size-grading and manual sexing of the GIFT strain between production phases would result in populations with a majority of single sex and uniform size. The culture of these populations under intensive conditions would greatly eliminate the unwanted recruitment and increase production rate.

Table 2. Two-way ANOVA (P- values) for the effects of strain, sex, and their interaction for the different growth parameters

Effect	MWT	DGR	SGR	K	FCR	Survival	GY
Strain	0.000	0.000	0.002	0.000	0.030	0.433	0.001
Sex	0.000	0.000	0.002	0.092	0.016	0.064	0.000
Strain*Sex	0.459	0.281	0.817	0.979	0.214	0.065	0.824

Table 3. Effect of sex on final body weight, daily growth rate, specific growth rate, feed conversion ratio, survival and gross yield of Nile tilapia*

Parameter	Males	Females	Difference (%)
Final body weight (g)	543.7 ± 42.2^a	341.8 ± 31.3^b	59.0
Daily growth rate (g/fish/day)	2.68 ± 0.25^a	1.55 ± 0.17^b	72.9
Specific growth rate (%/day)	0.95 ± 0.04^a	0.79 ± 0.04^b	20.0
Feed conversion ratio	1.48 ± 0.05^b	1.88 ± 0.16^a	21.3
Survival (%)	96.7 ± 2.11^a	89.4 ± 3.3^a	8.2
Gross yield (kg/m^3)	52.4 ± 3.8^a	30.9 ± 3.7^b	41.0
Condition Factor (K)	2.28 ± 0.06^a	2.30 ± 0.04^a	
Fish > 300 g (%)	95.0 ± 3.1^a	47.5 ± 9.6^b	

*Values in the same row having the same superscripts do not differ significantly ($P > 0.05$). Values are means ± SEM.

Table 4. Effect of strain on final body weight, daily growth rate, specific growth rate, feed conversion ratio, survival and gross yield of Nile tilapia*

Parameter	GIFT	Non-improved	Difference (%)
Final body weight (g)	518.2 ± 50.4^a	367.2 ± 44.9^b	41.1
Daily growth rate (g/fish/day)	2.56 ± 0.29^a	1.67 ± 0.24^b	53.3
Specific growth rate (%/day)	0.95 ± 0.04^a	0.79 ± 0.04^b	20.3
Feed conversion ratio	1.51 ± 0.06^a	1.85 ± 0.17^a	22.5
Survival (%)	94.5 ± 2.22^a	91.7 ± 3.8^a	3.1
Gross yield (kg/m^3)	49.0 ± 4.9^a	34.4 ± 5.4^b	42.4
Condition Factor (K)	2.38 ± 0.02^a	2.20 ± 0.03^b	
Fish > 300 g (%)	87.5 ± 7.9^a	55.0 ± 13.7^b	

*Values in the same row having the same superscripts do not differ significantly ($P > 0.05$). Values are means ± SEM.

Effect of strain and sex on feed conversion, survival and gross yield

The NS females had significantly higher feed conversion ratio (2.14) than the other treatments indicating lower efficiency in extracting nutrients from the food and converting it into flesh (Bhikajee and Gobin 1997). The non-improved males and the GIFT females had similar food utilization efficiency as indicated by the close feed conversion ratio values (Table 1). In fish farming, feed cost accounts for 50% of the operational expenditures (Ahmad and Diab 2008), therefore, any improvement in feed conversion ratio would have a positive impact in reducing the production cost. The above results, therefore, indicate the advantage of culturing either sex of the GIFT strain and males of the non-improved strain in reducing the amount of consumed feed and the production cost. The significantly lower survival (84.4%) encountered in the non-improved females compared with the other treatments was caused by higher mortality encountered in one of the treatment replicates due to failure in supply rather than treatment effect.

Gross fish yield differed significantly among treatments. The GIFT male treatment showed the highest gross yield (59.3 kg/m^3) followed by the non-improved males (45.4 kg/m^3) and the GIFT females (38.6 kg/m^3). The lowest value for gross yield was in the non-improved females (23.3 kg/m^3). The higher gross yield observed in the GIFT strain and of the males can be attributed to the faster daily growth rate and specific growth rate. The gross yield range of 23.3 to 59.3 kg/m^3 obtained in this study is comparable to the range of 30.4 to 55.2 kg/m^3 reported by Ridha (2006) for the same strains. As expected, males of both strains and the GIFT fish had significantly higher

proportion of marketable size fish. In fact, all harvested males of the GIFT strain (100%) and 87.5% of harvested males of the non-improved strain were above the marketable size (300 g). The GIFT females had significantly higher percentage of marketable size fish (68.8%) compared with the non-improved females (33.3%).

Two-way ANOVA showed no significant interaction between strain and sex in feed conversion ratio, survival and gross yield (Table 2). Data analyzed irrespective of strain, showed that males had significantly better feed conversion ratio (1.48), higher survival (96.7%) and significantly higher gross yield (52.4 kg/m^3) than the females (Table 3). On the other hand, data analyzed regardless of sex, indicated that the GIFT strain had better feed conversion ratio (18.4% improvement), higher survival and gross yield values than the non-improved strain. However, the difference in feed conversion ratio and survival between the two strains was not statistically significant (Table 4). Similar results were reported by Ridha and Cruz (2002) for feed conversion ratio where the GIFT strain had 16.6% improvement than the non-improved strain.

Conclusions

The findings of this study proved that females of the GIFT strain and males of the non-improved strain have comparable growth rates and feed conversion ratios. Results also suggest that manual sex segregation of the GIFT strain during the grow-out phase would allow tilapia growers to raise each GIFT sex separately without the need to discard the females as is the case with the slow-growing females of the non-improved strain, thus increasing production potential and profitability.

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