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Comparative growth and performance of two generations of tilapia (*Oreochromis niloticus*)

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ABSTRACT. The growth of generations of the Genomar Supreme Tilapia (GST) strain, specifically G20 and G25, was evaluated. Tilapias 8 g were reared in a recirculating aquaculture system with 0.25 m^3 tanks, 80 fish m^{-3}, with four replicates. During growth, eight fish from each tank were weighed and measured at day 1, 30, 60, 90, 120, 150, 180 and 210. Survival, weight gain, feed conversion and batch homogeneity were determined. Weight-age data were fit to Gompertz model. In addition, absolute and relative growth rates and weight and age at inflection were determined. Final weight showed 26.7% higher in G25 when compared to G20 (920.05 and 725.87 g, respectively). The feed conversion and homogeneity indexes were better in G25 than G20. The estimate of asymptotic weight was higher in G25 (1202.0 g) when compared to G20 (912.7 g). G20 presented smaller weight (335.76 g), age (108.87 days) and absolute growth rate (4.87 g day^{-1}) when compared with G25 (442.19 g, 113.77 days and 6.41 g day^{-1}). Carcass characteristics were similar, but G25 presented about 25% higher fillet weight than G20. After five years in the GST breeding program, results indicated that a sustained improvement of harvest weight was achieved, as well as 6 to 10% gain in performance by generation.

Keywords: absolute growth rate; genetic improvement; Gompertz model; growth curve; recirculating aquaculture system; Supreme tilapia.

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Introduction

Genetics has the potential to improve the productivity of cultured aquatic species (Hulata, 2001). Several strains have been developed and improved along the years. Since 1971, some of these strains have been officially imported and produced in Brazil (Moreira, Hilsdorf, Silva, & Souza, 2007; Massago et al., 2010). A few notable examples include the Chitralada strain from Thailand, imported in 1996 from the Asian Institute of Technology; the GenoMar Supreme Tilapia (GST) strain, imported in 2002 from Philippines; and the Genetically Improved Farmed Tilapia (GIFT) strain from Malaysia, imported in 2005 from WorldFish (Massago et al., 2010; Rodriguez-Rodriguez et al., 2013; Dias, Freitas, Arranz, Villanova, & Hilsdorf, 2016).

In the Philippines, 70% of farmed tilapia is either GIFT strain or of GIFT-derived origin (Hamzah et al., 2014). The GST strain is of GIFT-derived origin after having applied DNA fingerprinting as an identification tool and changing to a revolving mating scheme in order to complete the generation after nine monthly batches. DNA typing increased selection intensity and provided shorter generation interval and operational benefits (El-Sayed, 2006). The GST strain in Brazil is generation 14 corresponding to Supreme tilapia commercialized by Aquabel Pisciculture. Year by year, Genomar has continued the improvement program with the most recent production of generation 26.

In order to select families in a breeding program, it is necessary to monitor and control genetic variability throughout the generations, which may decrease as a result of crossbreeding among related individuals (Romana-Eguia, Ikeda, Basiao, & Taniguchi, 2004). Low genetic variability can lead to a decline in zootechnical performance, resulting in phenotypic characteristics of low economic, or undesirable, interest (Oliveira et al., 2011). Loss of genetic variability can result from inadequate planning of reproduction, reduction of effective numbers of breeding animals, crossing between very close individuals and intense selection (Petersen et al., 2012). Therefore, evaluating effectiveness and the gains obtained from any improvement program is always recommended.

This study aimed to evaluate the growth of two generations of GST Nile tilapia strain (*Oreochromis niloticus*), 20 and 25. A set of weight data according to age was adjusted in non-linear models.

Material and methods

The experiment was carried out at the Agency of Agribusiness Technology in São Paulo State (APTA), Presidente Prudente, Brazil. Tilapia fingerlings of approximately 8 g were grown in a water recirculating system containing tanks of 0.25 m^3, initial density of 80 fish m^{-3}, with four repetitions (tanks). A constant flow of water of 1,500 liters h^{-1} was maintained in each case. The system was equipped with temperature control, filter and ultraviolet treatment. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed by the authors.

The water temperature of the recirculation system was maintained at 26°C. The dissolved oxygen and temperature were monitored daily, and pH, ammonia, nitrite and nitrate were monitored weekly. The oxygen was 5.95 (0.23), and pH was 6.43 (0.49). The maxima of ammonia, nitrite and nitrate were 0.21 (0.05), 0.46 (0.21) and 33.5 (19.3), respectively.

The fish were fed three times a day with the same commercial diet specific for each growth stage (46% CP until 15 g, 42% CP until 100 g, and 36% CP until final weight). Throughout growth, eight fish from each tank were individually weighed from days 1, 30, 60, 90, 120, 150, 180 and 210 days of cultivation. The amount of provided feed was measured biweekly, according to fish biomass from each tank.

Performance measures were determined, such as survival, weight gain, feed conversion and homogeneity of the batches (coefficient of variation), in each period. Feed conversion was obtained by calculating the ration between feed intake and gain in biomass in each period. Finally, standard length (SL) was calculated, as well as head length (HL), body height (BH), body width (BW), and body perimeter (BP) in relation to SL.

The experiment was carried out in a completely randomized design, and two-way ANOVA was performed with four replicates (tanks). The following statistical model was used: $Yijk = \mu + Gi + Aj + GAij + eijk$, where μ is the global medium, Yij is observation k in generation j and age i, Gi is the generation effect i where i = 1 and 2, Aj is age effect j where j = 1, 2 ... 8, GAij is the generation and age interaction effect, and eijk is the error associated with each observation, i.e., NID $(0,\sigma^2)$ by assumption.

All weight data were fitted to the Gompertz model, given by $y = A\exp(-Be^{-Kx})$, calculating the absolute (AGR) and relative (RGR) growth rates and weight and age at the inflection point, according to Santos, Mareco, and Silva (2013).

Confidence intervals at 95% of probability were used to compare the curve parameters for each generation. Equations and R^2 statistics were provided. The estimates were obtained by weighted least squares, due the lack of homoscedastic variance between the day 1 and 210 and considering autoregressive errors according to Santos, Yoshihara, Freitas, and Reis Neto (2008), using Model Procedure on software SAS, SAS OnDemand for Academics, Copyright© 2020 SAS Institute Inc.

Results and discussion

The initial weights were 7.77 (0.63) and 7.25 (0.46) for the Supreme tilapia strain G20 and G25, respectively, and they were similar ($p > 0.05$). Only two fish died up to day 150, representing very high survival. Only in the last weeks of experimentation did mortality result from bacterial infection. Some fish became apathetic, reducing their movement and food consumption, losing scales and exhibiting rashes. The mortality rate at this stage was 10% in G25 and 5% in G20 ($p > 0.05$). This mortality in G25 could be associated to higher biomass of this strain per tank at the end of the experiment (from day 180 until 210) and this occurred only in a unique tank.

Table 1 summarizes the performance measurements for both generations each 30 days of rearing. After day 30, G25 already presented higher weight gain, better feed conversion and batch homogeneity than G20 ($p < 0.05$). This difference in weight gain between generations was about 15%, increasing to 50% at day 150, and finishing with 20% at day 180. Final weight showed a difference of about 26.7%, higher in G25 when compared to G20 (920.05 and 725.87, respectively). Feed conversion was always smaller; however, statistical differences were not found ($p > 0.05$). The homogeneity index was better in G25 than G20 in all periods with statistical difference at day 30, 60, 90 and 150 ($p < 0.05$).

Table 1. Medium of performance variables and standard deviation of two generation (GN) from GST strain cultivated in recirculating aquaculture system.

Day	GN	Weight (g)		WG (g)		FC		BHI	
30	G20	31.08	(2.37)a*	23.33	(2.22)b	1.25	(0.13)a	7.67	(0.60)a
	G25	34.14	(1.16)a	26.89	(1.25)a	1.03	(0.04)b	3.40	(0.12)b
60	G20	95.62	(6.59)b	64.54	(7.66)b	1.38	(0.16)a	24.45	(5.81)a
	G25	115.72	(5.40)a	81.58	(6.12)a	1.20	(0.10)a	15.39	(2.59)b
90	G20	255.74	(21.95)b	160.12	(15.80)b	1.33	(0.10)a	18.70	(4.24)a
	G25	324.69	(13.58)a	208.97	(17.91)a	1.22	(0.09)a	11.97	(1.90)b
120	G20	396.32	(33.63)b	140.58	(27.25)a	1.37	(0.25)a	18.51	(3.91)a
	G25	478.51	(45.65)a	153.81	(33.28)a	1.57	(0.27)a	12.63	(5.62)a
150	G20	497.66	(35.48)b	101.34	(23.45)b	1.77	(0.50)a	23.55	(3.02)a
	G25	634.25	(66.84)a	155.74	(29.33)a	1.33	(0.20)a	13.11	(6.68)b
180	G20	639.60	(51.19)b	141.94	(15.94)b	1.48	(0.16)a	19.86	(3.99)a
	G25	805.36	(74.88)a	171.11	(9.03)a	1.44	(0.08)a	13.69	(6.63)a
210	G20	725.87	(47.58)b	86.27	(34.49)a	2.43	(1.10)a	18.06	(3.58)a
	G25	920.05	(91.38)a	114.70	(35.20)a	2.26	(1.58)a	16.28	(7.01)a

*Values followed by different letters, in the same row, are not equal by Tukey test at 5%. WG, weight gain; FC, feed conversion, BHI, bath homogeneity index.

At day 60 of cultivation, the size standard of the batches is present in Figure 1. Table 2 shows the global performance at day 210. The difference in weight gain between generations was about 29.4% (912.8 compared to 705.13 for G25 and G20, respectively). G25 showed higher specific growth rate (2.31 g day^{-1}) than G20 (2.15 g day^{-1}), as well as feed intake and better feed conversion (p =0.09) when compared to G20.

Figure 1. Random sample image of fish of each generation from GST strain at day 60th of culture. A) G20; B) G25 (ruler size = 20 cm).

Table 2. Mean (±SD) of global performance variables and standard deviation of two generations from GST strain at day 210 in recirculating aquaculture system.

Generation	WG (g)		SGR (g day^{-1})		Feed Intake (kg)		FC	
G20	705.13	(66.45)b	2.15	(0.08)b	12.86	(0.36)b	1.46	(0.10)a
G25	912.80	(91.53)a	2.31	(0.06)a	15.16	(0.31)a	1.32	(0.10)a

*Values followed by different letters in the column, are not equal by F test at 5%. WG, weight gain; Wex, final weight predicted by exponential model; SGR, specific growth rate; FC, global feed conversion (p =0.09).

Table 3 presents the estimated parameters of the Gompertz model. The adjusted weight data from both generations were good (high R^2Adj), presenting applicable estimates and trustworthiness. The estimate of asymptotic weight 'A' was higher in G25 (1202.0) when compared to G20 (912.7). The growth rate 'K' in relation to maturity presented no differences between generations. The final estimate at day 210 was about 29.7% higher in G25 (938.65 g) when compared to G20 (723.62 g). Adjustments to the models are presented in Figure 2.

Table 3. Estimate parameters 'A' and 'K', confidence intervals and final weight at day 210 predicted (We^x) by Gompertz growth model from two generation GST strain.

Generation	Estimate parameters				Confidence Intervals				We^x (g)
	A (g)		K (%)		A (g)		K (%)		
					Lower	Upper	Lower	Upper	
G20	912.7	b	0.0145	a	839.1	986.3	0.0137	0.0152	723.62
G25	1202.0	a	0.0145	a	1116.3	1287.6	0.0139	0.0151	938.65

*Estimates followed by different letters, in the same column, are not equal overlapping the confidence intervals at 5%.

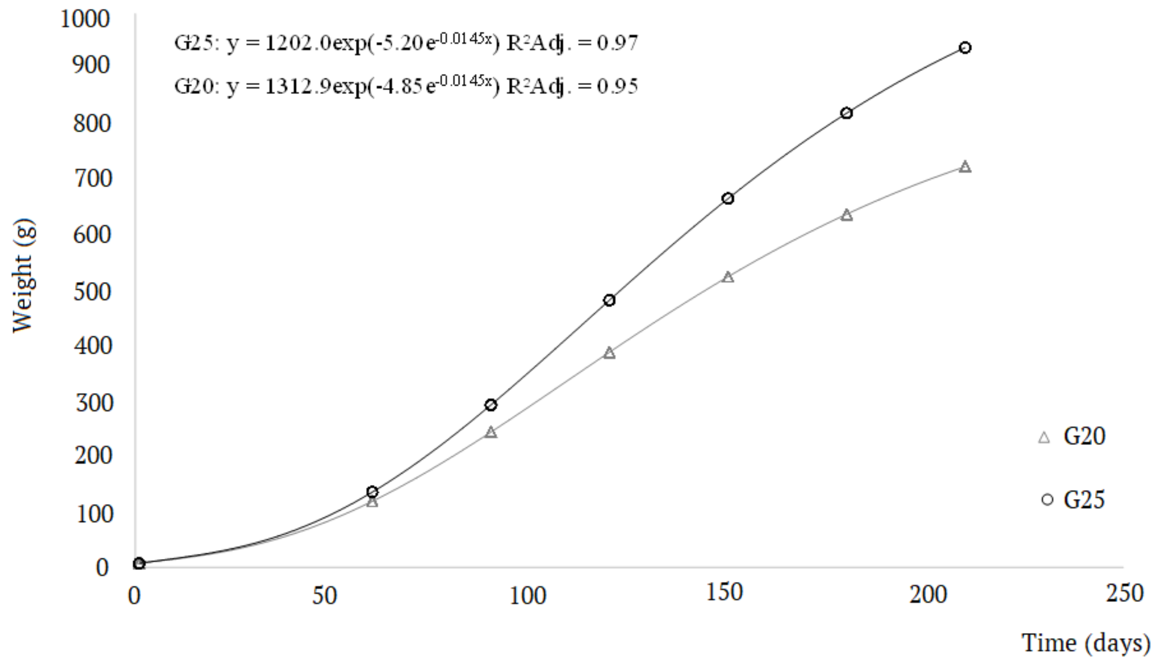

Figure 2. Gompertz growth model from two generation of Nile tilapia Supreme strain. Each point represents the mean estimates of forty fish.

Figure 3 and 4 present the AGR (g day^{-1}) and RGR (%), respectively. G25 presented the highest AGR. In this generation, tilapia above 300 g had AGR about 6 g day^{-1}, while that in G20 was 4.5 – 5.0 g day^{-1}. G25 tilapia also presented higher RGR when compared to G20.

The weight, age at inflexion point, and maximum AGR are presented in Table 4. G20 presented smaller weight (335.76 g), age (108.87 days) and absolute growth rate (4.87 g day^{-1}) when compared with G25 (442.19 g, 113 and 77 days and 6.41 g day^{-1}).

Table 5 presents the morphometric variables and their relationships from different generations of the Nile tilapia Supreme strain ($p < 0.05$). G25 presented highest morphometric measurements, followed by higher final weight. Some differences between generations were found in relation to BH/SL (body height/standard length) where G25 presented a higher ratio (0.419 compared to 0.409 in G20), indicating the greater proportional height of these fish.

Table 6 presents visceral and carcass characteristics in relation to total live body weight. Hepatosomatic and visceral index and visceral fat were similar between generations ($p > 0.05$). Carcass and fillet yield and %head were also similar between generations ($p > 0.05$). Fish with greater BH/SL ratio could indicate correspondingly greater fillet or carcass yield, but we did not find this difference between Supreme generations. Actually, many variables affect fillet yield, and it was not possible to show possible differences given by five years of genetic improvement. However, fillet weight was greater in G25 when compared to G20 ($p < 0.05$), and this difference was about 24.6%.

In our previous studies comparing Supreme G25 with other strains in similar conditions in a recirculation system, the Gompertz model was $y = 1967.5\exp(-5.54e^{-0.0106x})$, given the weight estimated at day 210 of about 1082.04 g and weight, age and AGR at inflexion point of 723.8 g, 161.48 days and 7.67 g day^{-1}, respectively. However, feed and tank sizes were different between the experiments. Additionally, a parallel experiment evaluating maximum growth was conducted at different temperatures. G25 cultivated at 26°C presented a final estimate of 819.26 g at day 210 and weight, age and AGR at inflexion point of 482.99 g, 144.38 days and 5.51 g day^{-1}, respectively. The higher performance in this experiment can be attributed to different handling of feed. Actually, fish were fed with a 36% CP diet from 500 g until final weight (about 75 days) compared to 32% CP in the maximum growth experiment.

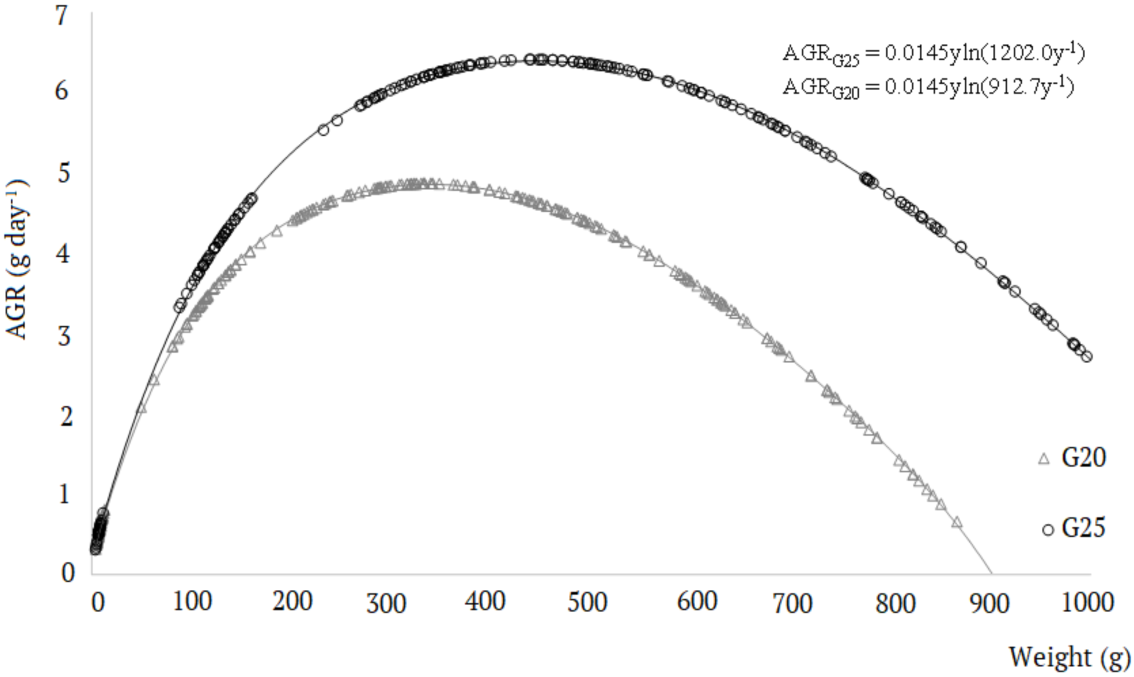

Figure 3. Absolute growth rate (AGR) from two generation (G20 and G25) of tilapia GST. Each point represents the estimate of each observation (n = 240 of each generation).

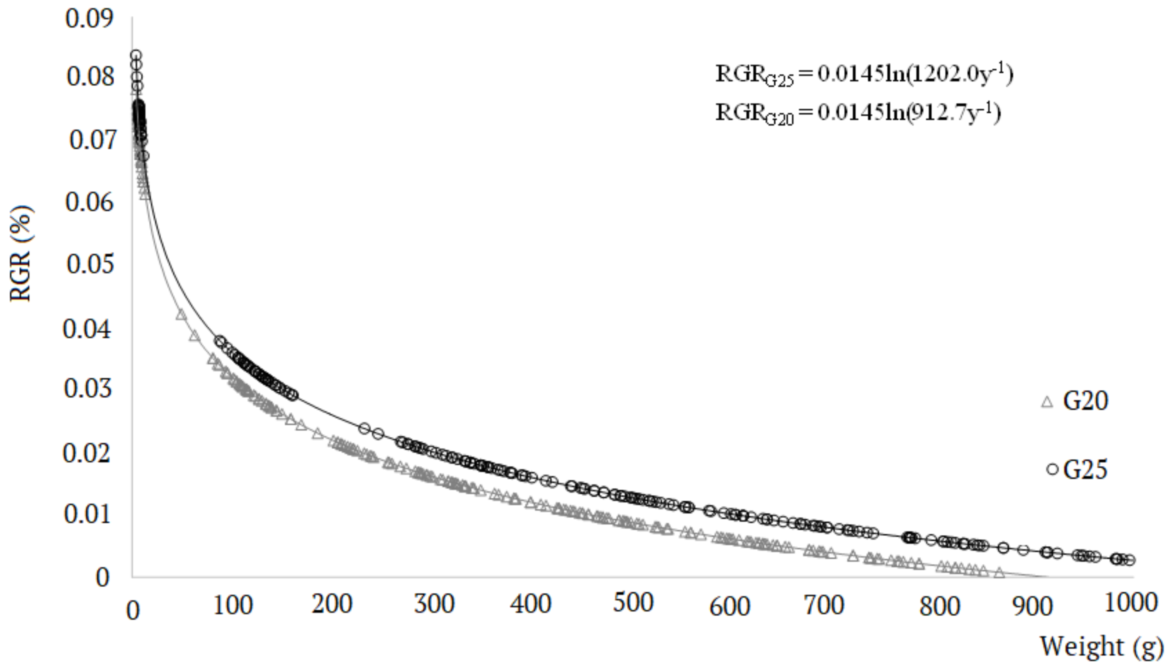

Figure 4. Relative growth rate (RGR) from two generation (G20 and G25) of tilapia GST. Each point represents the estimate of each observation (n = 240 of each generation).

Table 4. Values of weight (g), age (days) and absolute growth rate (g day^{-1}) at inflection point from two generation of Nile tilapia Supreme strain cultivated in recirculation aquaculture system throughout 210 days.

Generation	Weight (g)	Age (days)	AGR (g day^{-1})
G20	335.76	108.87	4.87
G25	442.19	113.77	6.41

Table 5. Mean (±SD) of morphometric variables (cm), their relationships and standard deviation from two generation of Nile tilapia Supreme strains at day 210 of cultivation.

Variable	G20		G25	
Weight/SL	26.37	(1.40)b*	28.83	(1.61)a
Standard lenght (SL)	27.85	(3.31)b	32.34	(3.76)a
Head lenght (HL)	8.41	(0.55)b	9.06	(0.47)a
Body height (BH)	10.78	(0.82)b	12.09	(0.87)a
Body width (BW)	5.02	(0.52)b	5.29	(0.33)a
Body perimeter (BP)	26.17	(1.68)b	28.96	(1.98)a
HL/SL	0.319	(0.011)a	0.315	(0.011)a
BH/SL	0.409	(0.020)b	0.419	(0.017)a
BW/SL	0.191	(0.019)a	0.184	(0.012)a
BP/SL	0.993	(0.044)a	1.004	(0.038)a

* Values followed by different letters, in the same row, are not equal (p <0.05).

Table 6. Mean (±SD) of different body variables, in relation to final weight from two generation of Nile tilapia Supreme strains at day 210th of cultivation.

Variable	G20		G25	
HIS (%)	1.78	(0.54)a*	1.64	(0.46)a
VSI (%)	7.54	(1.20)a	7.53	(0.86)a
VF (%)	2.23	(0.90)a	2.41	(0.74)a
Carcass yield (%)	92.46	(1.20)a	92.47	(0.86)a
Fillet weight (g)	198.00	(34.01)b	246.71	(49.77)a
Fillet yield (%)	31.78	(2.70)a	31.34	(1.66)a
Head (%)	30.14	(2.97)a	31.27	(2.28)a

*Values followed by different letters, in the same row, are not equal (p <0.05). HIS, hepatossomatic index; VSI, viscerossomatic index; VF, visceral fat.

Analyses of GIFT breeding program data collected over 10 years (2002-2011) in Malaysia indicated a significant genetic improvement in harvest weight in this population, yielding about 55% of selection response (Hamzah et al. 2014).

GIFT emerged as a valuable strain for filleting, but not by an advantage in fillet yield, which was very similar between both strains, but because of its greater fillet weight owing to greater growth rate. Fillet yields agree with the values reported by Rutten et al. (2004), which are in the range of 26 to 37%. GST is a high-performing strain too, and G25 could bring some advantage in terms of fillet weight, although fillet and carcass yields were similar to those of G20.

Bentsen et al. (2017) reviewed the impact of the GIFT strain and technology, analyzing populations from 1991 to 1995. The GIFT project showed that the application of current methods of traditional farm animal selection technology to a genetically variable population of Nile tilapia resulted in considerable genetic response in growth rate in the range of 10 to 14% per generation across a wide range of farm environments during five generations of selection. However, the project also confirmed that the development of aquaculture selection programs requires long-term external funding. Despite considerable economic benefits on a societal level, it has been difficult to secure the commercial viability of the GIFT program based on revenue from sales of improved brood stock only. Still, descending populations from the original GIFT material have, since the end of the project, been further selected and have performed well under a wide range of farming conditions worldwide, and the technology has been successfully applied by public, as well as private, breeding operations.

In this case, since the GST program started from GIFT, this work has been successful on the basis of G20 and G25 results and the continuous gain in this improvement process. The responses were great enough to suggest that genetic change was being achieved and in the intended direction. This response to selection is comparable to the estimate reported by Eknath et al. (1998) for Nile tilapia. For instance, the gain obtained in Egyptian Nile Tilapia was 5.8% (Rezk et al., 2009) and 12.45, 3 and 13.3% in Nile tilapia reported by Basiao and Doyle (1999), Bolivar and Newkirk (2002) and Gall and Bakar (2002), respectively. The genetic gain per generation achieved in the breeding program of GIFT in Malaysia was 10 to 20% genetic gain per generation in aquatic animals in general (Hulata, 2001).

Conclusion

After 5 years in the GST breeding program, results indicated that a sustained improvement of harvest weight was achieved. Actually, 6 to 10% of gain in performance by generation (year) was found between G20 and G25, showing good genetic variability and proper conduct of the program. Since the gain achieved by selective breeding is permanent, the improved GST year by year must be managed and disseminated for sustainable benefits.

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