Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v37i4.25978

Genotype by sex interaction at different phases during Nile tilapia culture period

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ABSTRACT. Co(variance) components and genetic parameters were estimated for performance and morphometric traits in male and female Nile tilapia at different growth periods to verify the need for separate selection programs for the two genders. Data set contained information on 1,720 animals, collected in cage system. Two-trait analyses using Bayesian methodology were conducted and the records of males and females were considered distinct traits. Rates of additive genetic variance, phenotypic and heritability were higher for females in estimates for morphometric traits and higher for males in performance traits. Whereas common hatchery environment showed higher relative importance for males, the nursery caused greater variations in females. The reduction of the genetic correlation rates caused by growth increased the difference between genders and indicated the treatment of males and females as a distinct feature selection.

Keywords: *Oreochromis niloticus*, sexual dimorphism, Bayesian inference.

Interação genótipo e sexo em diferentes fases do período de cultivo de tilápias do Nilo

RESUMO. Estimação de componente de co(variância) e parâmetros genéticos foram obtidos para as características de desempenho e morfométricas de machos e fêmeas de tilápias do Nilo em diferentes períodos de cultivo, a fim de verificar a necessidade de programas de seleção distinto para os sexos. O conjunto de dados continha informações de 1.720 animais, coletadas em quatro biometrias e sistema de tanques rede. Realizaram-se análises bicarácter, utilizando a metodologia bayesiana e consideraram-se os registros de machos e fêmeas como características distintas. Os valores de variância genética aditiva, fenotípicas e herdabilidade foram maiores para as fêmeas nas estimavas para as características morfométricas e maiores para os machos nas características de desempenho. Nos machos, o ambiente comum de larvicultura apresentou maior importância relativa. No entanto, nas fêmeas, o ambiente que causou maior variação foi o de alevinagem. As reduções dos valores de correlação genética com o avanço do período de cultivo acentuaram as diferenças entre os sexos e indicaram a necessidade de tratar machos e fêmeas como características de seleções distintos.

Palavras-chave: *Oreochromis niloticus*, dimorfismo sexual, inferência bayesiana.

Introduction

Nile tilapia males revealed a higher growth rate when compared to females. The difference depends on several factors such as species capacity, ingestion, feed conversion, environmental factors and behavior (Toguyeni et al., 2002). Phenotypic differences between males and females in most water species are of great commercial interest. Since the differences are quantitative, several genes may be expressed in different manners between the genders, for instance, greater growth and late sexual maturity in female salmonids (Kause, Ritola Paananen, Mäntysaari & Eskelinen, 2003).

Nguyen, Khaw, Ponzoni, Hamzah and Kamaruzzaman (2007) did not report genetic differences in Nile tilapias when they studied heredity for body weight and body shape in males and females, suggesting that there was no need of any differentiated selection between the genders. Non-different genetic correlations in studies by Rutten, Komen and Bovenhuis (2005a) show that body weight is controlled by the same genes in males and females.

Sexual dimorphism in the Nile tilapia is a fact, although the need of selection programs for males and females has never been reported (Lind et al., 2015; Lozano et al., 2014). This has been due to the fact that growth is involved with gender-determining genes rather than with the reproduction onset (Toguyeni et al., 2002). Several studies are required to identify the differences

between males and females due to increase in growth rates because of animals with high genetic capacity. If differences are detected, the use of different selection programs will be required to increase selection accuracy and genetic gain.

Current assay investigates the need for distinct selection programs for males and females by estimating co(variance) components, effects of a common environment, hereditability, genetic and phenotypic correlations for performance and morphometric traits of Nile tilapias in four different phases during the cultivation period.

Material and methods

Data obtained from the PeixeGen Research Group of the State University of Maringá, Maringá, Paraná State, Brazil, contained information on 1,720 animals from 58 families, coupled to pedigree information on 5,600 animals. Details on the formation process of the families have been described by Yoshida et al. (2013). Cultivation period ranged between June and October 2009 in cages at the Nile Tilapia Production Unit in the Rio do Corvo, Diamante do Norte, Paraná State, Brazil (22°39′21″ S; 52°51′36″ W). Two 6 m^3 (2 x 2 x 1.5 m) cages were used, with the same density and with specimens of all families in both cages.

During the evaluation period of production performance, the animals received a commercial diet composed of 2,800 kcal kg^{-1} digestible energy, 28% crude protein, 4.0% ether extract, 2.5% calcium, 0.9% phosphorus and 150 mg kg^{-1} vitamin C. Diet was provided three times a day following feed instructions of the distributor, taking age and biomass of fish and water temperature into account.

Four measurements were undertaken at intervals of approximately 37 days during the five-month culture period in the caged water tanks. Data on gender, live weight, standard length, width, height and daily weight gain (DWG) of each specimen, obtained by the ratio of live weight in each measurement and age, was registered. DWG1, DWG2, DWG3 and DWG4 refer respectively to daily weight gains till the first, second, third and fourth measurements. Table 1 shows the age of animals and phenotypic means of the analyzed traits in each biometry.

Estimate of the components of (co)variance and genetic parameters was calculated by two-traits analyses in which weights, weight gains and morphometric traits of males and females were distinct features, as follows:

$$\begin{bmatrix} Y_1 \\ Y_1 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix}\begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix}\begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} C_1 & 0 \\ 0 & C_2 \end{bmatrix}\begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + + \begin{bmatrix} W_1 & 0 \\ 0 & W_2 \end{bmatrix}\begin{bmatrix} w_1 \\ w_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where, γ_i = observation vectors of the characteristics for males (1) and females (2); β = vectors of environmental effects for males (1) and females (2), taking the caged water tank as fixed effect and age as co-variable; *a*, *c*, *w* and *e* are vectors of direct additive genetic effects, common environment effect of larva culture (due to the maintenance of the animals with their dams from spawning till the end of the reproduction season), effect of common nursery environment (related to the management in maintaining specimens of families in hapas distributed in different sites in nurseries) and of randomized errors respectively for males (1) and females (2); *X*, *Z, C* and *W,* which are the matrixes of incidents of identifiable environmental effects, direct genetic additives, common larva and nursery culture environment respectively for males (1) and females (2).

Table 1. Age (days) and phenotypic means in performance, morphometry and quantity (n) of males and females and their respective standard deviation (±SD) in different measurements (MEA) of the Nile tilapia.

MEA	Age (days)	Weight (g)	DWG (g)	SL (cm)	H (cm)	W (cm)
			Males n = 973			
1	170±22.46	84.92±25.46	0.50±0.14	12.30±1.19	4.89±0.53	2.39±0.30
2	210±22.46	137.97±40.82	0.66±0.18	14.84±1.40	5.87±0.72	1.41±0.52
3	256±22.46	213.60±60.78	0.83±0.22	17.33±1.64	6.79±0.75	3.16±0.45
4	285±22.46	296.47±82.33	1.04±0.27	19.56±1.75	7.52±0.81	3.34±0.34
			Females n = 747			
1	173±20.61	71.72±20.56	0.42±0.12	11.67±1.16	4.61±0.48	2.26±0.27
2	213±20.61	110.25±31.74	0.52±0.14	13.86±1.31	5.41±0.72	2.30±0.42
3	259±20.61	160.68±45.00	0.62±0.17	15.98±1.43	6.12±0.66	2.89±0.35
4	288±20.61	219.30±59.92	0.76±0.20	17.85±1.61	6.72±0.70	3.05±0.32

DWG: daily weight gain; SL: standard length; H: height; W: width.

If *a, c, w* and *e* have normal multivarious set distribution, then

$$\begin{bmatrix} a \\ c \\ w \\ e \end{bmatrix} \sim NMV\left\{\begin{bmatrix} \phi \\ \phi \\ \phi \\ \phi \end{bmatrix}, \begin{bmatrix} A\sigma_a^2 & \phi & \phi & \phi \\ \phi & I_h\sigma_c^2 & \phi & \phi \\ \phi & \phi & I_c\sigma_w^2 & \phi \\ \phi & \phi & \phi & I_n\sigma_e^2 \end{bmatrix}\right\}$$

$$\mathrm{E}(\gamma_i) = X\beta;$$

$$\mathrm{Var}(\gamma i) = Z_i A Z_i'\sigma_a^2 + C_i C_i'\sigma_c^2 + W_i W_i'\sigma_w^2 + I_n\sigma_e^2;$$

where A is the kin matrix between the animals; σ_a^2 is the direct additive genetic variance; σ_c^2, σ_w^2 and σ_e^2 are variances of common environmental effects of larva culture, nursery and residues, respectively; I_h identity matrix of the order h, with h equal to the number of hapas of the larva culture; I_c identity matrix of the order c, with c equal to the number of hapas of nursery; I_n identity matrix of the order n, with n equal to the number of observations.

For two-traits analyses,

$G = A \otimes G_0$, in which G_0 is the matrix of the characteristics´ genetic (co)variances;

$P = I_h \otimes P_0$, in which P_0 is the matrix of the (co)variances relative to the effect of larva culture common environment;

$C = I_c \otimes C_0$, in which C_0 is the matrix of (co)variances relative to the effect of the nursery´s common environment;

$R = I_n \otimes R_0$ in which R_0 is the matrix of residual (co)variances.

Multiple Trait Gibbs Sampler for Animal Models (MTGSAM) was employed (Van Tassell & Van Vleck, 1995), which executes Bayesian estimates; normal a priori distribution may be taken into account for additive genetic effects, common environment of larva culture, nursery and residual. Inverted wishard distribution was taken into account for (co)variance components.

Initially 500,000 cycles were performed and increased till convergence was attained. Sampling interval comprised 10 cycles after the elimination of the first 50,000 cycles, totaling at least 45,000 samples. Hedielberger & Welch test (Cowles, Best & Vines, 1995) was employed to evaluate chain convergence, implemented in Convergence Diagnosis and Output Analysis (CODA), of R (version 2.12.0).

Results and discussion

All samples converged in the two-traits analyses by Bayesian methodology. Results showed increasing rates of additive and phenotypic genetic variance for the two genders. The males´ genetic variances were greater when compared to the females´ for weight and DWG, whereas the opposite was detected for the morphometric traits. Ratio of genetic and phenotypic variance rates between the genders decreased for weight and DWG over time. In the case of morphometric traits, variance ratios were higher than 1.40, in spite of oscillations mainly in intermediate biometry, with a reduction in rates throughout the measurements (Tables 2 and 3).

Hereditability estimates for weight and DWG ranged between medium and high magnitude (Table 4). Morphometric traits in females revealed high greatness rates which remained constant during the evaluation period, whereas hereditability in males ranged between medium and low magnitude (Table 5).

Table 2. Estimates of additive genetic (σ_a^2), phenotypic (σ_p^2),residual (σ_e^2) variance rates for males and females of their respective variances for performance in different measurements (MEA).

	MEA	Males		Females		σ_a^2♀/σ_a^2♂	σ_p^2♀/σ_p^2♂
		σ_a^2	σ_p^2	σ_a^2	σ_p^2		
Live weight	1	249	639	161	424	0.670	0.664
		129 - 407	567 - 730	70 – 341	365 - 515	0.32 - 1.47	0.55 - 0.81
	2	600	1591	348	953	0.579	0.599
		301 - 981	1414 - 1812	146 - 729	825 - 1148	0.27 - 1.30	0.50 - 0.73
	3	1167	3587	610	2041	0.522	0.569
		561 - 1970	3203 - 4063	260.5 - 1246	1793 - 2389	0.23 - 1.25	0.48 - 0.68
	4	2596	6813	1238	3734	0.477	0.548
		1211 - 4396	6018 - 7800	553 - 2297	3273 - 4333	0.21 - 1.10	0.46 - 0.65
Daily Weight Gain	1	0.007	0.021	0.006	0.015	0.777	0.697
		0.003 - 0.012	0.018 - 0.024	0.002 - 0.01	0.013 - 0.017	0.34 - 1.67	0.58 - 0.84
	2	0.011	0.035	0.007	0.022	0.605	0.634
		0.005 - 0.02	0.031 - 0.04	0.002 - 0.013	0.019 - 0.026	0.24 - 1.46	0.53 - 0.76
	3	0.017	0.054	0.008	0.030	0.449	0.566
		0.007 - 0.031	0.048 - 0.061	0.003 - 0.016	0.027 - 0.035	0.17 - 1.16	0.48 - 0.67
	4	0.029	0.083	0.012	0.045	0.422	0.544
		0.011 - 0.053	0.073 - 0.096	0.004 - 0.024	0.004 - 0.023	0.16 - 1.15	0.46 - 0.65

Table 3. Estimates of additive genetic (σ_a^2), phenotypic (σ_p^2), residual (σ_e^2) variance rates for males and females of their respective variances for morphometric traits in different measurements (MEA).

	MEA	Males		Females		σ_a^2♀/σ_a^2♂	σ_p^2♀/σ_p^2♂
		σ_a^2	σ_p^2	σ_a^2	σ_p^2		
Standard length	1	0.299	1.682	1.340	1.796	4.470	1.068
		0.13 - 0.52	1.52 - 1.87	0.55 - 1.87	1.37 - 2.14	2.16 - 9.80	0.76 - 1.25
	2	0.384	2.325	1.578	2.165	4.105	0.931
		0.16 - 0.68	2.09 - 2.59	0.47 - 2.33	1.58 - 2.64	1.64 - 9.71	0.85 - 1.50
	3	0.426	3.382	1.412	2.531	3.3131	0.748
		0.16 - 0.82	3.05 - 3.76	0.34 - 2.79	1.95 - 3.30	1.09 - 8.26	0.56 - 1.00
	4	0.509	3.907	2.41	3.5151	4.732	0.900
		0.18 - 0.98	3.50 - 4.38	0.55 - 4.12	2.53 - 4.53	1.35 - 13.13	0.82 - 1.60

continue...

...continuation

	MEA	Males		Females		σ_a^2♀/σ_a^2♂	σ_p^2♀/σ_p^2♂
		σ_a^2	σ_p^2	σ_a^2	σ_p^2		
Height	1	0.045	0.330	0.103	0.254	2.253	0.769
		0.03 - 0.08	0.30 - 0.36	0.03 - 0.22	0.21 - 0.32	0.80 - 5.38	0.62 - 0.99
	2	0.054	0.560	0.231	0.496	4.264	0.885
		0.02 - 0.10	0.51 - 0.62	0.07 - 0.45	0.43 - 0.58	1.34 - 11.57	0.74 - 1.07
	3	0.080	0.658	0.205	0.498	2.554	0.757
		0.03 - 0.15	0.60 - 0.73	0.06 - 0.49	0.41 - 0.64	0.85 - 7.24	0.61 - 0.99
	4	0.107	0.761	0.199	0.544	1.873	0.715
		0.04 - 0.20	0.69 - 0.84	0.06 - 0.47	0.46 - 0.69	0.65 - 5.19	0.22 - 1.45
Width	1	0.017	0.099	0.039	0.078	2.230	0.787
		0.01 - 0.03	0.09 - 0.11	0.01 - 0.08	0.06 - 0.10	0.86 - 5.16	0.63 - 1.00
	2	0.026	0.282	0.037	0.177	1.400	0.630
		0.02 - 0.10	0.25 - 0.31	0.01 - 0.08	0.16 - 0.20	0.21 - 1.81	0.54 - 0.74
	3	0.022	0.218	0.033	0.130	1.488	0.597
		0.01 - 0.04	0.20 - 0.24	0.01 - 0.07	0.11 - 0.15	0.53 - 4.10	0.51 - 0.707
	4	0.017	0.137	0.061	0.123	3.627	0.898
		0.01 - 0.03	0.12 - 0.15	0.01 - 0.15	0.10 - 0.17	0.96 - 10.39	0.68 - 1.28

Table 4. Estimates of hereditability rates (h^2); common environment for larva culture (C^2) and nursery (W^2) for the performance traits of males and females of Nile tilapia in two-traits analyses in different measurements (MEA) and their respective reliability intervals.

MEA		Males			Females		
		h^2	C^2	W^2	h^2	C^2	W^2
Live weight	1	0.385	0.029	0.014	0.385	0.010	0.039
		0.22 - 0.57	0.007 -0.082	0.003 - 0.042	0.18 - 0.67	0.003 - 0.030	0.010 - 0.088
	2	0.374	0.024	0.007	0.357	0.006	0.029
		0.20 - 0.55	0.003 - 0.082	0.001 - 0.024	0.17 - 0.64	0.001 -0.021	0.004 - 0.079
	3	0.323	0.039	0.003	0.294	0.003	0.023
		0.17 - 0.50	0.004 - 0.113	0.000 - 0.014	0.14 - 0.53	0.000 - 0.011	0.003 - 0.072
	4	0.377	0.030	0.003	0.327	0.002	0.013
		0.19 - 0.58	0.003 - 0.106	0.000 - 0.018	0.16 - 0.54	0.000 - 0.009	0.001 - 0.053
Daily Weight Gain	1	0.335	0.051	0.021	0.370	0.044	0.051
		0.17 - 0.52	0.015 - 0.120	0.005 - 0.056	0.18 - 0.59	0.018 - 0.091	0.018 - 0.101
	2	0.316	0.054	0.012	0.300	0.034	0.092
		0.14 - 0.51	0.012 - 0.134	0.003 - 0.037	0.12 - 0.53	0.013 - 0.076	0.052 - 0.147
	3	0.321	0.038	0.008	0.253	0.019	0.025
		0.13 - 0.51	0.003 - 0.124	0.001 - 0.031	0.10 - 0.46	0.006 - 0.051	0.004 - 0.072
	4	0.346	0.042	0.008	0.268	0.022	0.018
		0.14 - 0.57	0.004 - 0.132	0.001 - 0.035	0.11 - 0.48	0.006 - 0.058	0.003 - 0.059

Table 5. Estimates of hereditability rates (h^2); common environment for larva culture (C^2) and nursery (W^2) for morphometric traits of males and females of Nile tilapia in two-traits analyses in different measurements (MEA) and their respective reliability intervals.

MEA		Males			Females		
		h^2	C^2	W^2	h^2	C^2	W^2
Standard length	1	0.177	0.043	0.013	0.735	0.018	0.021
		0.08 - 0.30	0.011 - 0.098	0.003 - 0.036	0.40 - 0.89	0.005 - 0.049	0.004 - 0.059
	2	0.165	0.064	0.010	0.711	0.016	0.020
		0.07 - 0.28	0.016 - 0.134	0.003 - 0.028	0.29 - 0.90	0.004 - 0.046	0.003 - 0.062
	3	0.125	0.068	0.022	0.533	0.018	0.049
		0.05 - 0.23	0.016 - 0.140	0.006 - 0.055	0.17 - 0.86	0.005 - 0.050	0.019 - 0.098
	4	0.130	0.083	0.006	0.654	0.013	0.011
		0.05 - 0.24	0.026 - 0.158	0.001 - 0.019	0.21 - 0.93	0.003 - 0.040	0.002 - 0.039
Height	1	0.137	0.034	0.016	0.390	0.025	0.036
		0.06 - 0.24	0.008 - 0.086	0.004 - 0.045	0.12 - 0.71	0.009 - 0.059	0.009 - 0.087
	2	0.097	0.045	0.022	0.456	0.027	0.058
		0.04 - 0.17	0.013 - 0.099	0.008 - 0.051	0.15 - 0.80	0.009 - 0.067	0.019 - 0.117
	3	0.122	0.043	0.009	0.397	0.014	0.013
		0.05 - 0.22	0.007 - 0.103	0.002 - 0.035	0.14 - 0.76	0.004 - 0.041	0.002 - 0.042
	4	0.139	0.044	0.010	0.355	0.008	0.022
		0.06 - 0.25	0.003 - 0.114	0.002 - 0.041	0.13 - 0.70	0.002 - 0.026	0.003 - 0.069
Width	1	0.174	0.028	0.013	0.480	0.018	0.018
		0.08 - 0.30	0.006 - 0.076	0.002 - 0.042	0.18 - 0.79	0.005 - 0.047	0.003 - 0.057
	2	0.199	0.017	0.004	0.205	0.011	0.007
		0.09 - 0.33	0.002 - 0.063	0.001 - 0.013	0.08 - 0.40	0.003 - 0.033	0.001 - 0.028
	3	0.100	0.011	0.011	0.245	0.013	0.009
		0.04 -0.19	0.002 - 0.036	0.001 - 0.046	0.09 - 0.47	0.004 - 0.039	0.002 - 0.031
	4	0.123	0.051	0.025	0.464	0.022	0.030
		0.05 - 0.23	0.013 - 0.114	0.001 - 0.028	0.14 - 0.88	0.007 - 0.056	0.008 - 0.060

High rates of additive genetic variances ratio and high rates of hereditability for morphometric traits in females demonstrate decrease in the participation of environmental effects within total variation. The above showed that the animals´ phenotype is a good indicator of animas' genotype.

In their study on longitudinal genetic analysis of Nile tilapias, Rutten et al. (2005a) reported genetic and phenotypic variance rates for body weight with a behavior opposite to the ratio of variances for males and females in current assay. In other words, additive genetic variance rates in females are increasingly greater than those in males as from the second biometry, providing a ratio between increasing variances. Family and residual phenotypic variance due to the great and continuous growth in males may be one of the motives by which additive genetic variance was lower in the assay by the above authors.

Although Bentsen et al. (2012) and Nguyen et al. (2007) reported hereditability of the same greatness between males and females of Nile tilapias, Rutten et al. (2005a) reported higher hereditability estimates for females when compared to males in five measurements for live weight during the culture period. Dupont-Nivet, Chevassus, Mauger, Haffray and Vandeputte (2010) reported higher hereditability rates for live weight in the still sexually immature male rainbow trout (*Oncorhynchus mykiss*). It may be surmised that this condition may be the cause of variation for the characteristic weight. The same authors registered that physiological changes during the phase may impair the growth of the animals and weight before and after sexual maturation should be considered as distinct traits.

The effect of common environment of larva culture in males and females and the common environment of nursery in females featured the greatest relevance in all the traits under analysis. There was a decrease in estimates as measurements progressed in spite of idle rates mainly in intermediate measurements (Tables 4 and 5). Closeness to nursing period and the start of the reproduction activity have great importance in females since they reduce growth at an early stage and redirect their energy towards reproduction.

Charo-Karisa et al. (2006) and Rutten et al. (2005a) suggest that the common family environment decreases over time due to the distancing of the effect with regard to the measurement of the characteristic analyzed. Consequently, reliability interval rates close or equal to zero, as reported in males for the nursery effect in the third and fourth biometry for live weight and in females for the larva culture effect, indicate that these effects may be discarded in the model without affected the preciseness of the selection.

Only the effect of common environment is usually employed in genetic enhancement programs for aquiculture species. It is related to the period in which groups of siblings remain together up to identification, which is different from that reported in current assay in which two common environments are taken into consideration due to the absence of artificial incubation. In fact, Charo-Karisa et al. (2007); Ponzoni, Hamzah, Tan and Kamaruzzaman (2005); Rutten, Bovenhuis and Komen (2005b) registered the effect of a common environment for the traits weight and body shape, varying between 0.00 and 0.15.

Genetic correlations rates between males and females varied between 0.58 and 0.85. Moreover, rates lower than 0.32 were reported for phenotypic correlations (Table 6). Reduction behavior of phenotypic correlations and phenotypic ratios owing to the aging of the animals indicate that the prolongation of the culture period enhances phenotypic differences between males and females, with an underscoring of sexual dimorphism as previously reported by Bhatta et al. (2013); Oliveira et al. (2013), Lind et al. (2015).

Table 6. Estimates of genetic and phenotypic correlation rates (r_p) between males and females for performance and morphometric traits in different measurements (MEA).

MEA	WEIGHT	DWG	SL	H	W
	Genetic correlation				
1	0.853 0.63 - 0.96	0.771 0.45 - 0.93	0.829 0.58 - 0.95	0.769 0.40 - 0.94	0.838 0.57 - 0.96
2	0.862 0.64 -0.97	0.739 0.33 - 0.93	0.802 0.50 - 0.94	0.585 0.25 - 0.57	0.746 0.35 - 0.95
3	0.766 0.454- 0.93	0.747 0.35 - 0.94	0.826 0.48 - 0.97	0.680 0.21 - 0.92	0.713 0.26 - 0.94
4	0.724 0.40 - 0.92	0.734 0.33 - 0.94	0.760 0.38 - 0.94	0.739 0.34 - 0.94	0.681 0.22 - 0.92
	Phenotypic correlation				
1	0.327 0.16 - 0.52	0.272 0.10 - 0.45	0.299 0.13 - 0.45	0.179 0.05 - 0.34	0.242 0.09 - 0.41
2	0.313 0.15 - 0.50	0.230 0.06 - 0.41	0.275 0.10 - 0.43	0.136 0.01 - 0.26	0.149 0.05 - 0.28
3	0.234 0.10 - 0.39	0.213 0.06 - 0.39	0.214 0.06 - 0.38	0.151 0.03 - 0.31	0.111 0.03 - 0.22
4	0.253 0.10 - 0.43	0.223 0.06 - 0.40	0.295 0.06 - 0.39	0.165 0.04 - 0.32	0.165 0.03 - 0.36

DWG: Daily weight gain; SL: standard length; H: height; W: width.

Highest rates occurred in genetic and phenotypic correlations in the first biometry, with reduction or oscillation in the following measurements. The above may be due to the need to maintain groups of true siblings in the nursery structure (1 m^3 hapas in

a hatchery) till identification. Therefore, restriction of physical space and different environmental conditions from where the specimens are selected may have contributed for not observing sexual dimorphism in the first biometry. However, transference to the commercial culture system in caged water tanks where the environment is proper for the breeding of animals, with adequate density, better water quality and less temperature variation, may have enhanced males´ performance. It must have provided the best conditions for their genetic capacity and evidenced the differences in the growth of the animals.

According to Oliveira et al. (2013), studies on growth curves of Nile tilapia which were genetically improved within Brazilian conditions of culture, showed that sexual dimorphism may be observed by body weight as from 165 days of life. Since in current assay animals aged between 170 and 285 days were used, the evaluation of animal performance during measurements evidenced differences between the genders.

Only Rutten et al. (2005a) had previously reported experiments on the sexual dimorphism of the Nile tilapia throughout the culture period. Although genetic correlation rates for body weight between males and females close to 1 and the lowest greatness in the last measurements were reported, the authors failed to observe sexual dimorphism.

Further, Nguyen et al. (2007) estimated genetic parameters for males and females and the possibility of applying different selection strategies for the two genders but results disagreed with those in current research. The above-mentioned authors reported that, due to high positive correlations (0.91-0.96) for performance and morphometric traits in males and females, there was no need to deal with the genders as distinct in genetic improvement programs. Their results may be because the authors used information derived from only one biometry and sexual dimorphism may not have manifested itself sufficiently to require differentiated selection programs. Moreover, results may be divergent since estimates of genetic parameters are intrinsic to the population and to the environment in which the animals were assessed (Santos et al., 2011).

In their studies on GIFT strain, Bentsen et al. (2012) registered the genetic correlations for weight between males and females in hatcheries (0.78) and in caged water tanks (0.88), demonstrating a medium interaction between genotype and gender. The authors suggested that growth rate was more influenced in hatcheries due to early sexual maturity and reproduction when compared to animals in caged tanks. The above shows that the verification of the genotype and gender interaction for tilapias in caged tanks had not been performed prior to current assay.

Conclusion

Results demonstrate that the two common environments reveal important differences for males and females. Hereditability rates of genetic and phenotypic correlation reveal that the traits under analysis respond distinctly to selection for the two genders. Specific detection programs for males and females are required as the age of animals increases.

References

Bentsen, H. B., Gjerde, B., Nguyen, N. H., Rye, M., Ponzoni, R. W., Vera, M. S. P., ... Dionisio, E. E. (2012). Genetic improvement of farmed tilapias: Genetic parameters for body weight at harvest in Nile tilapia (*Oreochromis niloticus*) during five generations of testing in multiple environments. *Aquaculture, 338*(1), 56-65.

Bhatta, S., Iwai, T., Miura, T., Higuchi, M., Maugars, G., & Miura, C. (2013). Differences between male and female growth and sexual maturation in tilapia (*Oreochromis mossambicus*). *Kathmandu University Journal of Science, Engineering and Technology, 8*(2), 57-65.

Charo-Karisa, H., Komen, H., Rezk, M. A., Ponzoni, R. W., van Arendonk, J. A., & Bovenhuis, H. (2006). Heritability estimates and response to selection for growth of Nile tilapia (*Oreochromis niloticus*) in low-input earthen ponds. *Aquaculture, 261*(2), 479-486.

Charo-Karisa, H., Bovenhuis, H., Rezk, M. A., Ponzoni, R. W., van Arendonk, J. A., & Komen, H. (2007). Phenotypic and genetic parameters for body measurements, reproductive traits and gut length of Nile tilapia (*Oreochromis niloticus*) selected for growth in low-input earthen ponds. *Aquaculture, 273*(1), 15-23.

Cowles, M., Best, N., & Vines, K. (1995). *Convergence diagnostics and output analysis* (Vol. 1). London, UK.

Dupont-Nivet, M., Chevassus, B., Mauger, S., Haffray, P., & Vandeputte, M. (2010). Side effects of sexual maturation on heritability estimates in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research, 41*(11), 878-880.

Kause, A., Ritola, O., Paananen, T., Mäntysaari, E., & Eskelinen, U. (2003). Selection against early maturity in large rainbow trout *Oncorhynchus mykiss*: the quantitative genetics of sexual dimorphism and genotype-by-environment interactions. *Aquaculture, 228*(1), 53-68.

Lind, C. E., Safari, A., Agyakwah, S. K., Attipoe, F. Y. K., El-Naggar, G. O., Hamzah, A., ... Ponzoni, R. W. (2015). Differences in sexual size dimorphism among farmed tilapia species and strains undergoing genetic improvement for body weight. *Aquaculture Reports*, *1*(1), 20-27.

Lozano, C. A., Gjerde, B., Ødegård, J., Rye, M., & Luan, T. D. (2014). Heritability estimates for male

proportion in hybrids between Nile tilapia females (Oreochromis niloticus) and blue tilapia males (Oreochromis aureus). *Aquaculture*, *430*(1), 66-73.

Nguyen, N. H., Khaw, H. L., Ponzoni, R. W., Hamzah, A., & Kamaruzzaman, N. (2007). Can sexual dimorphism and body shape be altered in Nile tilapia (*Oreochromis niloticus*) by genetic means? *Aquaculture, 272*(1), S38-S46.

Oliveira, A. M. S., Oliveira, C. A. L., Matsubara, B. J. A., Oliveira, S. N., Kunita, N. M., Yoshida, G. M., & Ribeiro, R. P. (2013). Padrões de crescimento de machos e fêmeas de tilápias do Nilo (*Oreochromis niloticus*) da variedade GIFT. *Semina: Ciências Agrárias, 34*(4), 1891-1900.

Ponzoni, R. W., Hamzah, A., Tan, S., & Kamaruzzaman, N. (2005). Genetic parameters and response to selection for live weight in the GIFT strain of Nile tilapia (*Oreochromis niloticus*). *Aquaculture, 247*(1), 203-210.

Rutten, M. J., Komen, H., & Bovenhuis, H. (2005a). Longitudinal genetic analysis of Nile tilapia (*Oreochromis niloticus* L.) body weight using a random regression model. *Aquaculture, 246*(1), 101-113.

Rutten, M. J., Bovenhuis, H., & Komen, H. (2005b). Genetic parameters for fillet traits and body measurements in Nile tilapia (*Oreochromis niloticus* L.). *Aquaculture, 246*(1), 125-132.

Santos, A. I., Ribeiro, R. P., Vargas, L., Mora, F., Alexandre Filho, L., Fornari, D. C., & Oliveira, S. N. (2011). Bayesian genetic parameters for body weight and survival of Nile tilapia farmed in Brazil. *Pesquisa Agropecuária Brasileira, 46*(1), 33-43.

Toguyeni, A., Fauconneau, B. t., Fostier, A., Abucay, J., Mair, G., & Baroiller, J.-F. (2002). Influence of sexual phenotype and genotype, and sex ratio on growth performances in tilapia, *Oreochromis niloticus*. *Aquaculture, 207*(3), 249-261.

Van Tassell, C., & Van Vleck, L. (1995). *A manual for use of MTGSAM. A set of fortran programs to apply gibbs sampling to animal models for variance component estimation*. US Department of Agriculture, Agricultural Research Service, (86). USA.

Yoshida, G. M., Oliveira, C. A. L., Oliveira, S. N., Kunita, N. M., Resende, E. K., Alexandre Filho, L., & Ribeiro, R. P. (2013). Associação entre características de desempenho de tilápia-do-nilo ao longo do período de cultivo. *Pesquisa Agropecuária Brasileira, 48*(8), 816-824.

Received on December 8, 2014.
Accepted on June 29, 2015.