Genetic Parameters And Genotype By Environment Interaction For Growth Of Nile Tilapia In Low And Optimal Temperature

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Introduction

Tilapia is an economically important species cultivated mostly in tropical countries. The adaptability and tolerance of this species to diverse environments and systems has resulted in a rapid expansion of tilapia farming. Water temperature is recognized as one of the most important factors influencing growth of tilapia. The optimal temperature for growth of most tilapias range from 26°C to 30°C, while the lethal temperature is 10°C. Activity and feed utilization will decrease when temperature falls below 20°C (Chervinski, 1982). Therefore introduction of Nile tilapia (O. niloticus) to subtropical and temperate regions, will lead to poor growth and massive mortality during over-wintering. Performance and robustness of tilapia in temperate climates may be improved by increasing growth rate and pond survival at low temperatures. This will contribute to increased production of tilapia by either extending the growth season or by increasing the number of crops per year in these environments.

Several estimates of heritability (h²) for harvest body weight of Nile tilapia are reported in the literature, ranging from 0.12 to 0.65 (e.g. Charo-Karisa et al., 2006; Luan et al., 2008; Rutten et al., 2005). However, none of the estimates are based on growth in temperate environment, and the potential for genetic improvement of growth during periods with decreased temperature or in highland areas has neither been explored nor exploited.

Northern Vietnam has a subtropical climate with lower temperature from December to March compared to the summer. Occasionally, water temperature drops to 20°C for a period during the winter. Hence, it is important to ensure farmers in the northern Vietnam access to robust fish material which can perform well in their challenging farm environment. A selective breeding program for tilapia was implemented in northern Vietnam to improve growth in ponds under favorable (optimal) temperature or tropical conditions (Luan et al., 2008). The improved strain has become popular among fish farmers and the fish has been disseminated all over the country. However, the performance at lower temperature such as during the winter and fall also needs to be improved. Hence, the main objective of the present study was to investigate the potential for improving growth under low temperature conditions by estimating genetic parameters for growth traits at different temperature

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regimes of Nile tilapia, and to consider the need for region specific breeding programs by studying the possible degree of genotype by environment interaction (GxE).

Material and methods

Experimental design and test environment. The fish used was from the selective breeding program at Research Institute for Aquaculture No.1 (RIA1) in northern Vietnam (Luan et al., 2008, 2010). A total of 102 family groups were produced and nursed according to the GIFT guidelines (WorldFish Center, 2004). Families were produced in breeding hapas using a hierarchical design, where every sire was stocked with two dams. However, high water temperature often prevented mating of males with the second female, resulting in a much lower number of half-sib families than planned. The first batch consisted of 40 full-sib families produced during autumn 2006 by 38 sires and 40 dams. The second batch consisted of 62 full-sib families produced during spring 2007 by 51 sires and 62 dams. Swim-up fry were collected from each full-sib family in the breeding hapas, and reared separately in rearing hapas until tagging with electronic PIT tags. Initial body weights were recorded before a random sample of 35 or 20 fish from each family were stocked together in the experimental tanks and pond of the first and second experimental batch, respectively.

The first batch of full-sib families (Batch 1) were produced from end of September to end of October, 2006, while the test period for these fish was carried out from February until June 2007 at RIA1 and in the Lao Cai province (Table 1). The rearing period of Batch 1 corresponds to early seed stocking season in the North of Vietnam. The second batch of full-sib families (Batch 2) were produced between May and June, 2007, while the test period for these fish was carried out from October 2007 until early January 2008 (Table 1). The rearing and test period of Batch 2 corresponds to winter time in North Vietnam. The fish was tested in three temperature regimes; in an on-station trial with controlled temperature in four tanks holding 30°C (Optimal = O) and four tanks holding 21°C (Low = L), and in an on-farm trial in the mountain province (Lao Cai) where the fish were kept in an earthen pond without any control of the temperature (Natural pond = N). A total of 8 cement tanks, each with the dimension of 25 m² and water depth of 1.2 m were used for the on-station test with controlled temperature in each batch. Stocking density in each tank was 12.4-14.0 fish per m². In the four tanks with optimal temperature, the temperature was maintained at approximately 30°C by using electric heating. In the remaining tanks, low water temperature was maintained at approximately 21°C by using a cooling system. The on-farm trial was conducted in a natural household pond of 500 m² with water depth of 1.2 m in the mountain province (Lao Cai at >1,200 m.a.s.l.) and stocking density of 2.5-2.8 fish m⁻². Water temperature was measured every morning, and average temperature was 23.5°C with a daily variation from 19.0 to 27.5°C.

Traits included in the analysis. Individual body weight was recorded at tagging (IW) shortly before the fish were transferred to the experimental facilities, and at the end of the test period or harvest (HW). To account for the considerable individual variation in IW at the start of the experiment, the following derived variables related to growth were calculated: body weight gain (WG, g) = HW - IW; relative weight gain (RWG, %) = (WGx100)/IW; and specific growth rate (SGR, g.day⁻¹) = (LnHW– LnIW)/(t₂-t₁) where t₁ and t₂ were the
recording date of IW and HW, respectively, $t_2-t_1$ is number of days from tagging to harvesting.

The mean HW for the different test environments of Batch 1 ranged from 128g (L) to 208g (O). Corresponding means for Batch 2 ranged from 143g (L) to 221.1g (O). The mean IW ranged from 38.2 g to 43.3 g for the different environments of batch 1, while lower mean IW were observed at stocking for batch 2 (29.6 - 30.7 g).

**Statistical analyses.** Genetic and environmental variances and co-variances were estimated using a linear animal model and Asreml software (Gilmour et al., 2002) with fixed effects of tank/pond, batch, sex and batch by sex interactions, linear and quadratic covariate effects of age nested within test environment and batch and finally random environmental effects common to full-sibs (c). Six generations of pedigree information was included in the analysis. A univariate animal model was used to estimate heritabilities for growth in each test environment. The c² was only successfully included in these univariate analyses. Due to convergence problems caused by limitations in the mating design (relatively few half-sib families produced) and the fact that only one generation with data was included, the common environmental effect could not be included in the multi-trait analysis. A multi-trait animal model was used to obtain (co)variance components for body weight and derived growth variables between different test environments.

**Results and discussion**

Estimates of genetic parameters are shown in table 1. Generally, $h^2$ estimated for HW and growth in optimal temperature and natural environments were higher than in low temperature environments. This is expected as increasing the water temperature to optimal level increase the growth rate of tilapia. Hence the genetic potential of the fish for growth may be expressed better. Also, $h^2$ estimates for WG, SGR and RWG were slightly higher than for HW in the same environment. The estimates of $h^2$ for HW (0.19-0.31) in this study were within the range of estimates published for *O. niloticus* (Luan et al. (2008), Ponzoni et al. (2005); Rutten et al., (2005).

Table 2: Heritabilities ($h^2$) and genetic correlations ($r_g\pm se$) between the pairs of test environments for different growth variables of Nile tilapia

<table>
<thead>
<tr>
<th>Traits</th>
<th>$h^2$</th>
<th>$r_g$ between environments$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O L N</td>
<td>O and L O and N L and N</td>
</tr>
<tr>
<td>HW</td>
<td>0.31±0.08 0.19±0.04 0.26±0.07</td>
<td>0.88±0.19 0.61±0.05 0.78±0.10</td>
</tr>
<tr>
<td>WG</td>
<td>0.29±0.08 0.21±0.04 0.28±0.07</td>
<td>0.90±0.17 0.65±0.05 0.83±0.12</td>
</tr>
<tr>
<td>RWG</td>
<td>0.42±0.07 0.34±0.07 0.34±0.06</td>
<td>0.85±0.17 0.46±0.05 0.61±0.04</td>
</tr>
<tr>
<td>SGR</td>
<td>0.39±0.11 0.27±0.05 0.30±0.06</td>
<td>0.87±0.19 0.62±0.03 0.77±0.09</td>
</tr>
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</table>

$^b$O is optimal; L is low and N is natural temperature regime of the test environments

High genetic correlations were estimated between harvest body weights (HW) in O and L environments (0.88±0.19) and between harvest body weights in L and N environments (0.78±0.10), while a slightly lower genetic correlation (0.61±0.05) was estimated between O and N environments. Similarly, moderate to high genetic correlations were estimated (0.61-
0.90) between test environments for weight gain (WG), specific growth rate (SGR) and relative weight gain RWG) with one exception (r_g=0.46 between O and N environments for RWG). Estimated genetic correlations suggest that there is some GxE for growth traits in controlled optimal temperature and natural subtropical mountain pond environments. However, the genetic correlation for growth between the two environments indicate that a moderate and favorably correlated selection response can be obtained for growth in natural pond environments when selecting and testing in optimal temperature conditions.

Although a certain GxE is documented in the present study, a low tilapia production volume and low ability to invest among small-scale fish farmers in the mountain and highland areas in Vietnam are reasons to question whether investments in a separate highland breeding program can be justified at this relatively low level of G×E. However, the results show that it may be important to continue testing and selection in a natural pond environment with natural temperature variation in order to avoid that a more sensitive and less robust fish is developed.

The estimated genetic correlations between environments for HW, WG, SGR and RGW may be biased upwards because common full-sib effects were not included in the statistical model, and should therefore be treated with care. However, in the univariate analyses the estimates of common environmental effects ($c^2$) were generally less than 10%.

**Conclusion**

The present study indicates a large potential for improving production in cold climates by selecting for growth in low temperatures and in mountain pond environment. Testing and selection in natural tropical ponds to improve growth and robustness of fish is recommended for farming in different commercial environments of Vietnam. Further, additional samples of families may be tested in a subtropical pond in the mountain area to allow for some selection and dissemination of broodstock (or seeds) that are more fit for mountain farming, while continuing selection for performance in tropical pond environment in the nucleus.

**References**


