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Genotype by production environment interaction in the GIFT strain of Nile tilapia (*Oreochromis niloticus*)

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ABSTRACT

Three discrete generations of GIFT fish (Nile tilapia strain, *Oreochromis niloticus*; a total of 10,065 fish with pedigree and phenotypic information) were tested in pond and cage culture environments to determine genotype by production environment interaction between both environments in Malaysia. Live weight (selected trait), standard length, body depth and width were recorded. A bivariate animal model was used to estimate variance and covariance components, whereby the homologous body traits in pond and cage environments were treated as genetically distinct traits. The heritabilities estimated for these body traits ranged from 0.19 to 0.40 in the pond environment, and from 0.23 to 0.34 in the cage environment. Across all traits the maternal common environmental effects ranged from 0.14 to 0.26 and were greater for the pond than for the cage environment. The genetic correlations between the pond and cage environments were 0.73 ± 0.09 for live weight, 0.81 ± 0.09 for standard length, 0.78 ± 0.10 for body depth, and 0.85 ± 0.13 for body width. Coupled with the total selection responses for live weight after two generations of selection, being 35% for the pond environment and 45% for the cage environment, we concluded that genotype by environment interaction for GIFT strain between pond and cage environments was not important. Hence, it would not be necessary to have two separate selective breeding programs for the GIFT strain in Malaysia.

1. Introduction

Tilapia farming has become one of the most important aquaculture industries in Malaysia. In 2008, Nile tilapia (*Oreochromis niloticus*) accounted for 24% of the total tilapia production in Malaysia, the other 76% fell under the category of incompletely identified tilapia species, tilapia *nei* (FAO, 2010). The Department of Fisheries Malaysia estimates that out of this 24% of Nile tilapia production, 10% belonged to the GIFT (Genetically Improved Farmed Tilapia) strain (Hamzah, 2010, Personal Communication).

The GIFT strain is well known worldwide for its high growth performance and hardiness. In 1989 the GIFT selective breeding project started in Philippines in collaboration with institutes and universities from various countries. The project ended in 1998 after five generations of selection (Bolivar, 1998; Eknath and Acosta, 1998; Eknath et al., 1993; Tayamen, 2004). As one of the partners in the GIFT project, the WorldFish Center received representatives from the GIFT families to continue the work in Malaysia, where its headquarters are located. In Malaysia, the breeding program continued the selection for live weight at harvest time to improve the growth rate of the strain (Ponzoni et al., 2005). The GIFT fish in Malaysia are under the care of the WorldFish Center in collaboration with the Department of Fisheries Malaysia. The fish are being disseminated to government and private hatcheries within Malaysia, and also to other Asian and Latin American countries.

In aquaculture breeding programs, selection takes place in a nucleus, which is usually kept in a well controlled environment, whereas a wide range of commercial production environments usually exist (e.g. cages, canals, reservoirs, lakes, and mining ponds). This diversity of production environments may result in genotype by environment ($G \times E$) interaction. In the context of animal breeding, $G \times E$ interaction describes the situation where different genotypes do not respond in the same way to different environments, so that the genetic and environmental effects are not additive. Falconer (1952) suggested that the same phenotype expressed in two different environments can be treated as two genetically different traits, so that the degree of $G \times E$ interaction can be quantified from the genetic correlation between the trait expressions in both environments. In aquatic animals genotype by environment interactions were considered as an issue in farmed fish as early as the 1970s (Moav et al., 1975). Working with the common carp, these authors recognized their importance and identified their presence.

In Malaysia, tilapia farming is mainly conducted in two production systems, namely, cage and pond culture systems (Hanafi and Chua,

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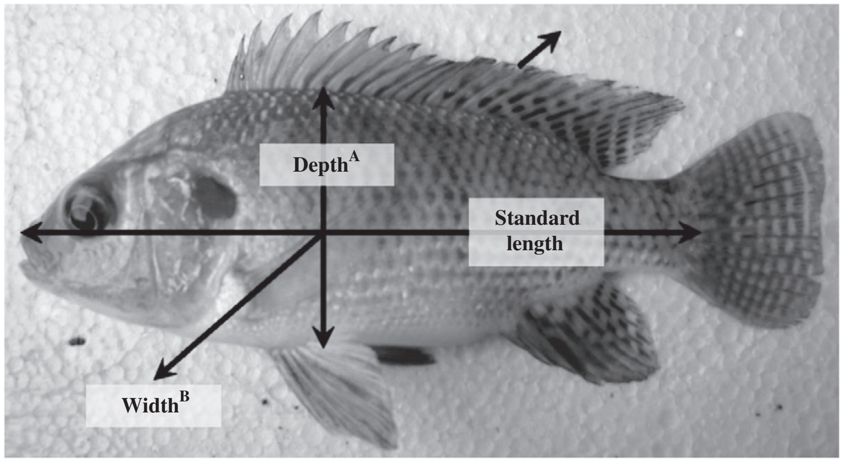

Fig. 1. The definition of the fish body measurements ([A]Body depth is measured from dorsal to ventral locations at the mid-side of the fish; [B]Body width is measured from left to right lateral across the mid-side of the fish).

2008). Farmers are increasingly shifting away from pond culture, because cage culture is more economical in terms of land use, only a minimum infrastructure is required, and cages are easier to manage (Hanafi and Chua, 2008). However, in Asia, most of the selective breeding programs for Nile tilapia have been conducted under pond culture systems, including the GIFT breeding program (Bolivar, 1998; Eknath and Acosta, 1998; Eknath et al., 1993; Tayamen, 2004; Zimmermann and Natividad, 2004). Thus, it is very important to examine the G×E interaction between cage and pond culture systems, to investigate whether the genetic gain achieved in a pond environment will be realized in a cage environment. Several studies have investigated G×E interaction in Nile tilapia, but the degree of G×E interaction between pond and cage production systems in Malaysia has not been investigated to date for the GIFT strain (see review by Ponzoni et al., 2011). The estimated genetic correlations for live weight vary among studies and very much depend on the degree of differences between the tested environments (Eknath et al., 2007; Khaw et al., 2009; Luan et al., 2008).

The objectives of this study were *i*) to estimate the genetic parameters for body measurements expressed in cage and pond environments, *ii*) to evaluate the response to selection in both environments, and *iii*) to determine whether there was G×E interaction between both environments. For this purpose, we treated the body measurements at harvest in cage and pond systems as genetically distinct traits. Body measurements of interest were live weight, standard length, body depth, and body width (Fig. 1).

2. Materials and methods

2.1. The environment

The GIFT breeding program in Malaysia is being conducted at the Aquaculture Extension Center, Department of Fisheries, Jitra, Kedah State, Malaysia. Details about the environment are provided by Ponzoni et al. (2005) and Nguyen et al. (2007).

2.2. The fish and data structure

The foundation stock of GIFT in Malaysia consisted of 63 full-sib groups (63 males, each mated to a different female) from the sixth generation of GIFT provided by the GIFT Foundation International Inc., Philippines (Ponzoni et al., 2011). These groups of fish were transferred in batches to Malaysia between the end of year 2000 and the beginning of year 2001. In the spawning season 2002, those fish were mated and produced the base population in Malaysia. No artificial selection took place among the fish producing the base population.

With the progeny produced in the spawning season 2002, two lines were created: the selection line that was selected for high live weight, and the control line that was selected for average live weight. All the tested fish were individually identified with Floy® tags at the size of about 10 g before sending them for communal rearing. The data set consisted of a total of 10,065 observations from three spawning seasons (2002, 2003, 2004, Table 1). Each male was mated either to one (control line) or two females (selection line) resulting in the number of sires and dams reported in Table 1. Progeny of all the sires and dams were represented in both cage and pond environments, except for a few of the families in the selection line that were not represented in the cage environment for spawning seasons 2003 and 2004, and one family in the control line in 2004 (Table 1). This was mainly due to tag losses, mortality and predation during the grow-out period in the cage environment. In the spawning season 2003, 69% of the parents were from the cage environment and the complement (31%) was from the pond environment. By contrast, in 2004, the situation was almost the mirror image of that in 2003 with 30 and 70% coming from the cage and pond environment, respectively. The reproduction and management schedules are shown in Table 2. Note that the data set analyzed in the present study come from the same source (the GIFT selection program, Ponzoni et al., 2011) as the data sets used by Ponzoni et al. (2005) and by Nguyen et al. (2007). In this particular instance we analyzed them from a different angle, with a different purpose, hence generating different information. In the earlier work there was no attempt at estimating genotype by production environment interaction, whereas this latter issue is the main focus of the current paper.

Table 1
Number of sires, dams and progeny, by spawning season, line and environment.

Spawning season	Line	Environment	Sires	Dams	Progeny
2002	Base population	Cage	52	54	978
		Pond	52	54	706
2003	Selection	Cage	34	61	1524
		Pond	35	65	1036
	Control	Cage	19	19	695
		Pond	19	19	455
2004	Selection	Cage	53	83	1468
		Pond	54	84	2246
	Control	Cage	17	21	421
		Pond	17	22	536
Total			177	244	10065