GENOTYPE BY ENVIRONMENT INTERACTIONS IN TWO SELECTION LINES OF AFRICAN CATFISH (*CLARIAS GARIEPINUS*) FOR GROWTH AND SURVIVAL TRAITS IN DIFFERENT PRODUCTION SYSTEMS

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ABSTRACT
This study was designed to determine the extent of genotype by environment interaction (GxE) of African Catfish (Clarias gariepinus) for growth and survival traits and to support the decision on the best environment for selection of C. gariepinus for a wide range of farming conditions. We used two lines of C. gariepinus that had been selected for two generations in two production systems. One line was selected in small scale farms (SC) utilizing agricultural by products mixed with complete feed (low line). The other line was selected in semi extensive scale (SE) using flow-through (pond combined with concrete tanks) with good quality feed (moderate line). The heritability for weight gain, specific growth rate and survival were generally higher (0.3), (0.5) and (0.5) respectively. In between pond and small scale farms (SC) (low line), the GxE effect was insignificant, and the genetic correlation between trait expressions between the two environments was (0.9). On the other hand, there as moderate G×E effect between pond and SE (moderate line). The genetic correlations of the same traits between these pair-wise environments were (0.7). It was concluded that the best environment for selection of African Catfish for growth and survival traits on genotype by environment interaction (GxE) is low-input pond environment. A single breeding program on genotype by environment interaction (GxE) to select feed intake under standard pond environment is recommended for African catfish (C. gariepinus).

Key words: Genotype by environment interaction; African Catfish; *Clarias gariepinus*; low input environments

INTRODUCTION
The effect of selection environment on the performance of selected strains over a range of potential production environments is a fundamental breeding question. When genotypes differ in sensitivity to different environmental influences, a genotype by environment interaction (GxE) occurs (Falconer, 1990). In the presence of GxE, the genetic improvement obtained by selection in one environment may not be realized in other environment. Falconer (1990) reviewed a number of experiments and indicated that, in most cases, to increase the mean performance of a genotype over a range of environments, selection should be done upwards in the less favourable environment (antagonistic).

Due to the important role of African Catfish (*Clarias gariepinus)* for aquaculture in Africa, several countries on the continent have shown great interest in developing genetic improvement programs for this species. Regardless of locations or regions, the genetic improvement program for African catfish should start with selection for body weight at harvest. Food security is still an issue in African countries, and fish is priced based on live weight (or size) at local markets (Ponzoni, *et al.,* 2008). The selection environment of our choice is in earthen pond with standard commercial feed and management practices. Pond culture is the prevailing environment (>90%) in a majority of African countries, especially in Nigeria, Ghana, Kenya and Malawi, which are likely to become key players in the development of breeding programs for African catfish. There are also other production systems such as small-scale farms (SC) utilizing agricultural byproducts mixed with complete feed, semi-extensive scale (SE) using flow-through (pond combined with concrete tanks) with good quality feed, or intensive scale (IS) using recirculation systems. It is possible in principle that the genetic gains achieved in the selection environment will not be fully realized in these diverse production systems. In other words, there is a possibility of a genotype by environment interaction (G×E) on performance of African catfish. Three main farming systems are considered: small scale (SC), semi-extensive (SE) and intensive scale (IS).

A number of selective breeding programs to improve the growth of *O. niloticus* have been initiated (Hulata *et al.,* 1986; Eknath *et al.,* 1993; Bensten *et al*., 1998; Eknath *et al.,* 1998). These programmes have typically been carried out in relatively favourable environments where fish receive supplementary feed. However, there are reports that the gains of selection were lost when selected breeds were tested in less favourable environments (Macaranas *et al.,* 1997). This could indicate that growth in different culture conditions is subject to genotype by environment interaction.

This paper presents the result of an experiment. The objective of this study was to compare the growth of selected lines of African Catfish (*Clarias gariepinus)* in different environments, to estimate the level of GxE in each line, to estimate the genetic correlation and heritabilities of the selected lines to support the decision on the best environment for selection growth and survival traits of *Clarias gariepinus* for a wide range of resource poor environments.

MATERIALS AND METHODS

The founder population and production of G_0

The experiment was conducted in fish hatchery of the Department of Biology, Ahmadu Bello University, Zaria, Kaduna State, Nigeria. Fish used for this study were the grandparental population (G_0) produced in 2018, the G_1 generation produced in 2019, and G_2 generation produced in 2020. G_1 and G_2 were the first and second generations of selection respectively.

The founder population (i.e. parents of the G_0 population) was established in a full diallel mating design from four different Nigerian strains namely Eleyele, Oba, Argungu and Yauri (Umar, 2019). Eighty sires and 105 dams, selected at random from among the founder stock, were used to produce the G_0. Each sire was mated to two dams and each dam mated to only one sire, thus generating full and half sib groups. Fry were raised in 2 x 1 x 1 m hapas suspended in concrete tanks and were fed twice daily with 40% protein supplements, initially in the form of powder and later as pellets. Initial feeding rate was 20% of body weight, which was gradually reduced to 5% body weight at tagging size (i.e. mean wet weight of 2g). Fry from each family were individually tagged with Floy® tags and returned to the hapas until all families were tagged. Each family was then divided into two groups. One line was reared in a low-input pond environment and the other in a moderate-input pond environment.

Production of experimental fish

Fish used for the genotype by environment interaction experiment were produced from the second-generation animals (G_2) of both lines. The experimental fish were obtained from the best 37 sires and 40 dams from the moderate line, and 32 sires and 58 dams from the low line. Fry from each line were reared in their respective nursing conditions until tagging (from 35 days old). After tagging, each full-sib family, represented by at least 75 fries, was divided into five groups of 15 fries each and assigned to the five different test environments i.e. five fries per family per replicate pond. All ponds were stocked at the same stocking density of 1 fish/ m^2. Due to tag mortalities, not all fish survived to stocking. Equal stocking densities at the start of the experiment were maintained by stocking some untagged fish from the same families. Temperature, dissolved oxygen and pH were measured twice a week in all ponds. Measurements were taken in the morning (6.00-7.00 h) and afternoon (15.00-16.00 h) with a portable DO meter (WTW® model multi 340i meter). After 4 months of growth (August to November), the fish were harvested by seine netting and the body weight of each fish measured.

Estimation of heritability

The narrow sense heritability which is calculated directly from selection experiments is called "realized heritability". The realized heritability relates the mean of the original random-bred population, the mean of the individuals selected to be the parents, and the mean of the next generation.

$$\text{The realized heritability } (h^2) = \frac{\text{Selection Response (SR)}}{\text{Selection Differential (SD)}}$$

Where selection differential for a given trait is the difference between the mean for the population and the individuals selected to be parents of the next generation (i.e. selected animals –original population) for that trait and selection response is the difference between the offspring mean and the original population mean or the amount by which the population mean shifted due to selection (i.e. next generation – original population).

$$\text{Selection intensity I} = \frac{\text{Selection Differential (SD)}}{\text{Phenotypic standard deviation } (\sigma_p)}$$

$$\text{Standardised Selection Response} = h^2 \times I \times \sigma_p$$

Correlated response (CR) = I x r_g x h_a x h_bx square root of σ^2
Where
CRx = Correlated response in a trait x
I = Selection intensity for a trait x
h_a = heritability of a trait x in environment a
h_b = heritability of a trait x in environment b
r_g = genetic correlation of trait x between environment a and b
σ^2 = genetic variance for trait x.

RESULTS

Genetic parameters

Genetic parameters for weight gain and survival traits of African catfish (*C. gariepinus*) used shown in Table 1. The heritability for weight gain, specific growth rate and survival were higher. The genetic gain for weight gain, specific growth rate and survival was 0.650, 0.547 and 6.365, respectively.

Table 1: Genetic parameters for weight gain (WG), specific growth rate (SGR) and survival traits in African catfish (*C. gariepinus)* reared

	Weight Gain (g)	Specific Growth Rate (SGR)	Survival (%)
Mean	4.151	9.735	92.693
σ_p	1.960	1.070	12.100
S.D.	2.165	1.094	12.735
I	1.105	1.022	1.052
h^2	0.300	0.500	0.500
Δ_G	0.650	0.547	6.365

Legend: σ_p, phenotypic standard deviation, SD, selection differential, I, selection intensity, h^2 realised heritability, Δ_G, genetic gain

From this study, Since the SC system is close to the pond environment, the G×E effect was not significant, the genetic correlation between trait expressions between the two environments was 0.9. On the other hand, there as moderate G×E effect between pond and semi-extensive system. The genetic correlations of the same traits between these pair-wise environments were 0.7 (Table 2).

Table 2: Genotype by environment interaction (GxE), Genetic gain (Δ_G) for each trait between the two environments

Genotype by environment interaction (GxE)	Direct responses			Correlated responses		
	Weight Gain (g)	Specific Growth Rate (SGR)	Survival (%)	Weight Gain (g)	Specific Growth Rate (SGR)	Survival (%)
R_g = 0.9	0.650	0.547	6.365	6.731	0.011	1.670
R_g = 0.7	0.650	0.547	6.365	6.731	0.011	1.670

Legend: SGR, specific growth rate, R_g, genetic correlation between trait expressions between the two environments

DISCUSSION

The main objectives of the present study were to compare the growth and survival traits of two selected lines of African Catfish across a range of environments and to test their sensitivity to environmental changes. To this end, a common gene pool was first formed and divided in two groups which were then selected simultaneously for two generations in fertilized or pellet-fed ponds.

To detect GxE, environments can be classified into groups and a genotype by environment interaction term included in the traditional quantitative genetic model, or the expression of the trait in different environments may be defined as separate traits. A high genetic correlation indicates that the traits are controlled by the same set of genes (Falconer and Mackay, 1996) and that there is no GxE. When phenotypes change gradually and continuously over an environmental gradient, GxE may be described by a reaction norm model (de Jong, 1995). The reaction norm model describes the

phenotype expressed by a genotype as a function of the environment. The decision on the best environment depends upon the genetic correlation and heritabilities of the trait in the two environments (Mathur, 2002). Our data allowed for direct estimation of the heritability or the genetic correlation between test environments.
From this study, Since the SC system is close to the pond environment, the G×E effect was not significant. The genetic correlation between trait expressions between the two environments was 0.9. On the other hand, there as moderate G×E effect between pond and semi-extensive system. The genetic correlations of the same traits between these pair-wise environments was 0.7

CONCLUSION AND RECOMMENDATION

It was concluded that the best environment for selection of African Catfish for growth and survival traits on genotype by environment interaction (GxE) is low-input pond environment. A single breeding program on genotype by environment interaction (GxE) to select feed intake under standard pond environment is recommended for African catfish (*C. gariepinus)*. The decision on the best environment depends upon the genetic correlation and heritabilities of the trait in the two environments. It is clear from this study that, the best selected environment the best performance in growth and survival traits of African Catfish (*C. gariepinus)* strains. With the high heritability for body weight and survival in low-input ponds. It is- from a genetic point of view- efficient to select in low input conditions.

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