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Research Article

Genetic Evaluation of Growth Performance, Shooter Frequency and Survival Rates of *Clarias gariepinus* (Burchell, 1822) Haplogroup from River Benue, Nigeria

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ABSTRACT
This study was conducted at the hatchery complex of Kazuh Integrated farms Gidin waya, Ibi L.G.A. Taraba State to evaluated the genetic basis of growth performance, shooter frequency, and survival rates among inbred and crossbred haplotypes of *Clarias gariepinus* (Burchell, 1822) from River Benue, Nigeria. Conducted over an eight-week period (February–March 2021), the research aimed to assess the reproductive potential and performance variations among molecularly characterized haplogroups. A total of thirty (30) broodstock samples were subjected to standard molecular sequencing protocols for haplotype identification. Fry obtained from inbred (Hap1♀B × Hap1♂B; Hap3♀B × Hap3♂B) and crossbred (Hap1♀B × Hap3♂B; Hap1♂B × Hap3♀B) parental combinations were monitored under controlled hatchery conditions for growth metrics, frequency of shooters, and survival rates. At the end of the trial, the crossbred group Hap1♂B × Hap3♀B recorded the highest mean final weight (23.29 ± 2.93 g), as well as superior length gain, specific growth rate, shooter frequency, and survival percentage compared to the inbred groups. These results indicate that crossbreeding among distinct haplotypes enhances growth performance and survival ability in *C. gariepinus*. The findings also underscore the value of molecular characterization and haplotype-based breeding strategies for optimizing genetic resource management and improving aquaculture productivity in Nigeria.

Keywords: Aquaculture Improvement; Broodstock Management; Genetic Diversity; Phenotypic Traits; Reproductive Efficiency; Selective Breeding

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INTRODUCTION

Aquaculture has become an increasingly vital component of global food security, with *Clarias gariepinus* (Burchell, 1822), commonly known as the African catfish, emerging as one of the most widely cultured freshwater fish species in sub-Saharan Africa due to its fast growth rate, hardiness, and tolerance to varying environmental conditions (Olufeagba *et al*., 2020; Okomoda *et al*., 2021; FAO, 2022). In Nigeria, *C. gariepinus* contributes significantly to national fish production and rural livelihoods, especially in riparian communities along major rivers such as the Benue and Niger (Ayinla, 2007; Ugwumba and Nnabuife, 2008). However, despite its aquaculture potential, growth variability, incidence of shooters (individuals that outgrow their cohorts significantly), and differential survival rates remain persistent challenges affecting production efficiency and genetic improvement programs in hatcheries (de Verdal *et al*., 2014; Omasaki *et al*., 2017). Shooter frequency, in particular, is associated with cannibalism and social dominance, leading to skewed size distribution, reduced overall growth performance, and increased mortality during early developmental stages (Baras and Jobling, 2002). These challenges underscore the importance of genetic evaluation and selective breeding strategies aimed at improving growth uniformity, minimizing the occurrence of shooters, and enhancing survival rates.

Genetic variation within and among local populations of *C. gariepinus* provides the raw material for selection and long-term genetic improvement. Studies have revealed considerable intra-species diversity among wild and cultured populations of *C. gariepinus* across Nigerian water bodies, including the River Benue (Olufeagba *et al*., 2015; Anene *et al*., 2020). The application of molecular tools and quantitative genetic analyses has further enabled the identification of superior genotypes or haplogroups that possess desirable traits such as fast growth and resilience to stress (Okey *et al*., 2022). Evaluating the growth performance and survival rates of genetically distinct haplogroups offers a reliable approach for optimizing broodstock selection and developing genetically improved strains for aquaculture.

Previous studies on catfish breeding in Nigeria have shown that crossbred progenies tend to exhibit superior performance compared to inbred lines, particularly in growth and survival traits under culture conditions (Olaniyi and Omitogun, 2017; Solomon *et al*., 2021). Ataguba *et al*. (2010) observed that hybrids of *Clarias gariepinus* and *Heterobranchus longifilis* (Cl♀ × Ht♂ and Ht♀ × Cl♂) often show lower specific growth rates (SGR) compared to their purebred counterparts. These results suggest possible negative heterosis due to genetic incompatibility between species. Also, Ayinla *et al*. (2023) revealed that the crosses between *Clarias gariepinus* and *Heterobranchus bidorsalis* have shown improved growth and survival rates. He also stated that survival rate was also significantly higher in the hybrid group. Okomoda *et al*. (2023) also observed that hybrids *C. gariepinus* and *C. macromystax* demonstrated enhanced growth and survival, especially in semi-arid conditions. Fertilization, hatching, and larval survival exceeded 80%, and the hybrid growth performance was comparable or superior to pure *C. gariepinus*. The performance of these hybrids varies based on the genetic compatibility of the parent species (Uruku and Abur, 2023).

In this context, the River Benue, being one of Nigeria's major inland water systems, harbors genetically diverse populations of *C. gariepinus* that are yet to be fully characterized for aquaculture traits. There is a need for systematic genetic evaluation of these local haplogroups, particularly focusing on traits of economic importance such as growth rate, shooter frequency, and survival. This study, therefore, aims to assess the genetic basis of variation in growth performance, shooter frequency, and survival rates among haplogroups of *C. gariepinus* from the River Benue. Findings from this research will provide insights into the potential of local genetic resources for selective breeding and the development of robust strains suited to Nigerian aquaculture systems.

MATERIALS AND METHODS

Description of the Experimental Site

Kahzuh integrated farm which is a leading modern Technological driven farm which lies on latitude 8º5' 2.472" N and longitude 9º47'34.008" E in Gindin Waya, Ibi LGA, Taraba State Nigeria. It is bounded in the south by Benue state, North by Gassol LGA, East by Wukari LGA and West by Ibi LGA. Gindin Waya agro-ecological zone is the southern guinea savanna and it characterized by tropical hot/wet with distinct rainy and dry seasons.

Fish for Experimentation

The eight hundred (800) fish specimens were obtained from brooders of *Clarias gariepinus* from river Benue after genetic diagnosis and separation to haplotypes and the were used to produce inbred and crossbred fry that were used for this study.

Experimental crosses

The following generic combinations were carried out:

Table 1. Design for the Reproductive characterization

Haplotypes River Benue	**Location**
Haplotype 1	Equal number, equal size, equal sex ratio across the two locations
Haplotype 2	2
Haplotype 3	Equal number, size, sex ratio across the two locations as in Haplotype 1

Table 2. 2x2x2 Factorial Design for Breeding

Location	Generic Groups			
	Inbred hap 1- Gen1	Inbred hap3-Gen 2	Crossbred hap1xHap3- Gen3	Recip Crossbred hap1xHap3-gen-4
Benue	Hap1 FB X Hap1MB	Hap3 FB X hap3MB	Hap1 FB X Hap3MB	Hap1MB X hap3FB

Hap= haplotype; Gen = Generic group; Recip = Reciprocal; MB = Male of Benue; FB = Female of Benue

Determination of Shooters Frequency, Growth Performance, Survival and Feeding of Fry

The incubation tanks were clean and restocked with 72 hours post hatchlings after complete yolk sac absorption per treatment and reared for 21 days. Each of the fry hatched in all the treatment were weighed. Feeding of fry's commenced at 72 hours after hatching. The fry was fed with Artemia for 21 days and later fed with 0.2mm of starter feed (commercially prepared). Each of the replicates were fed at 10% of the body weight three (3) times daily.

A water flow through system was maintained throughout the rearing period (70 days) and water quality of the rearing environment was maintained at a pH of 7.9, temperature at 26.5 – 29^{0}C and dissolved oxygen at 4.5 – 5.2 mg/L. At the expiration of the rearing period (70 days), the fry's in each treatment were sorted into different size categories designated as: as described by Nwadukwe and Nana (2000). Number of fry and the weight of individuals in each size group were determined. Weights were measured using digital weight balance. Percentage of shooters was calculated following Nwadukwe and Nana (2000).

$$\textbf{Shooters} = \frac{Number\ of\ shooters}{Number\ of\ stocked\ fry} \times 100 \quad (1)$$

1 Setting the out-door experiment and feeding of fry

The four crosses were replicated and stocked in twenty-four hapas at 200 fry per hapas. The fry were fed with Coppen's feed of 0.2 - 0.3 mm for 1 week and 0.3 - 0.5 mm for another 4 weeks. Hatchlings were fed twice daily (morning and evening). Sampling for pooled weight and length were taken weekly for 8weeks.

2 Determination of growth performance

Data of weight and length collected during the experimental period was analyzed subsequently for the determination of growth rate among the haplotypes. The growth performance of the larvae, fry and fingerlings were determined in terms of mean weight gain (MWG), specific growth rate (SGR) and mean length gain (MLG) parameters. The mean final weight (MFW) and mean final length (MFL) were taken at all the developmental stage (larva, fry and fingerling) of the experiment in order to ascertained the growth rate achieved by each group of the haplotypes. Weekly measurements were carried out for weight (to the nearest g) with a weighing balance and total length (to the nearest mm) with a measuring scale for larvae, fry and fingerlings from each treatment (breed). Length gain, weight gain and specific growth rate (SGR) were determined by formula adopted from Tilahun *et al*., (2016):

Weight gain = Mean final body weight (MFW) – mean initial body weight (MIW);

Length gain (MLG) = Mean final length (MFL) – mean initial length MIL);

SGR = {(In W_2 final weight–In W_1 initial weight)/culture period} × 100

Where;

W_1 is the initial fish weight (g) at time T_1 (day) and W_2 is the final fish weight at time T_2 (day). **3 Survival performance**

The rate of survival in each stage (two weeks for larvae and two weeks for fry and one month for fingerlings) among the haplotypes was determined by counting and recording the mortality at the beginning and end of the culture period. It was calculated by the formula adopted by Ataguba *et al*., (2010).

$$\textbf{\%Survival Rate}\ (SR) = \frac{Ni}{No} \times 100 \quad (2)$$

Where:

Ni is total number of fry at the end of the experiment

No is total number of fry at the beginning of the experiment.

Physicochemical Parameters

The water quality of the system of culture (hatchery unit) was monitored daily for: Temperature, pH, Dissolved oxygen, Ammonia (NH_3) and Electric Conductivity and they were determined following the methods described by APHA

Statistical analysis

Data on production and reproductive potential was analysed using Minitab 14 software for descriptive statistics and GenStat Discovery edition 4 for analysis of variance (ANOVA) with respect to inbreed and their reciprocal crosses. Post hoc test was carried out using Duncan Multiple Range Test (DMRT) to determine the differences between the means (P=0.05) using SPSS version 20.0.

RESULTS

Fishes produced from all the breeding trials increased in Length during the rearing period of

Eight (8) weeks. The corresponding growth curve that illustrates in terms of length increase (cm) for each cross for river Benue strain is presented in Figure 1. The cross bred showed intermediate values between the two parental line crosses for length parameters. The maximum values for mean final length (MFL) (6.47±0.47 cm) and mean length gain (MLG) (6.07±0.47 cm) were recorded in cross bred Hap1 ♂B x Hap3 ♀B - Haplotype 1 male crossed with Haplotype 3 female. whereas the minimum size for MFL (5.37±0.74 cm) and MLG (5.07±0.64 cm) were observed in inbred (Hap1 ♀B x Hap1 ♂B) (Figure 10). The cross bred of Haplotype 1 male crossed with Haplotype 3 female (Hap1 ♂B x Hap3 ♀B) and Haplotype 1 female crossed with Haplotype 3 male (Hap1 ♀B x Hap3 ♂B) recorded greater values for both MFL and MLG compared to that of inbreed of Haplotype 1 female crossed with Haplotype 1 male (Hap1 ♀B x Hap1 ♂B) and Haplotype 3 female crossed with Haplotype 3 male (Hap3 ♀B x Hap3 ♂B).

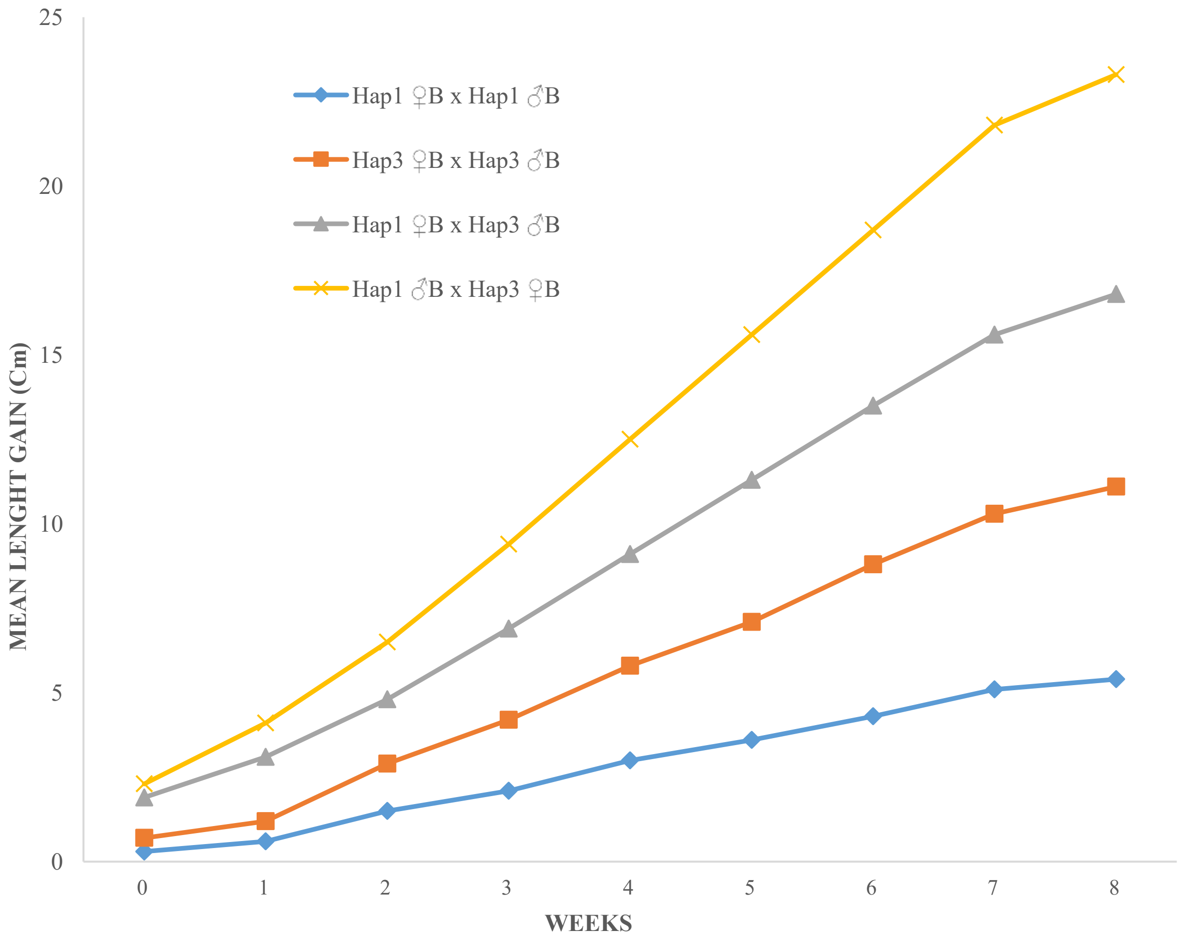

Figure 1: Weekly length gain of inbred and crossbred haplotype of river Benue

Fishes produced from all the breeding trails increased in Weight during the rearing period of Eight (8) weeks. The corresponding growth curve that illustrates in terms of weight increase (g) for each cross for Benue Haplotype is presented in Figure 2. The crossbred showed intermediate values between the two parental line crosses for weight parameters. The maximum values for mean final weight (MFW) (23.29±2.93 g) and mean weight gain (MWG) (22.02±2.72 g) were recorded in crossbred Hap1 ♂B x Hap3 ♀B - Haplotype 1 male crossed with Haplotype 3 female. Whereas the minimum size for MFW (16.42±1.6 g) and MWG (15.38±1.34 g) were observed in inbred (Hap3 ♀B x Hap3 ♂B). The cross bred of Haplotype 1 male crossed with Haplotype 3 female (Hap1 ♂B x Hap3 ♀B) and Haplotype 1 female crossed with Haplotype 3 male (Hap1 ♀B x Hap3 ♂B) recorded greater values for both MFW and MWG compared to that of inbreed of Haplotype 1 female crossed with Haplotype 1 male (Hap1 ♀B x Hap1 ♂B) and Haplotype 3 female crossed with Haplotype 3 male (Hap3 ♀B x Hap3 ♂B).

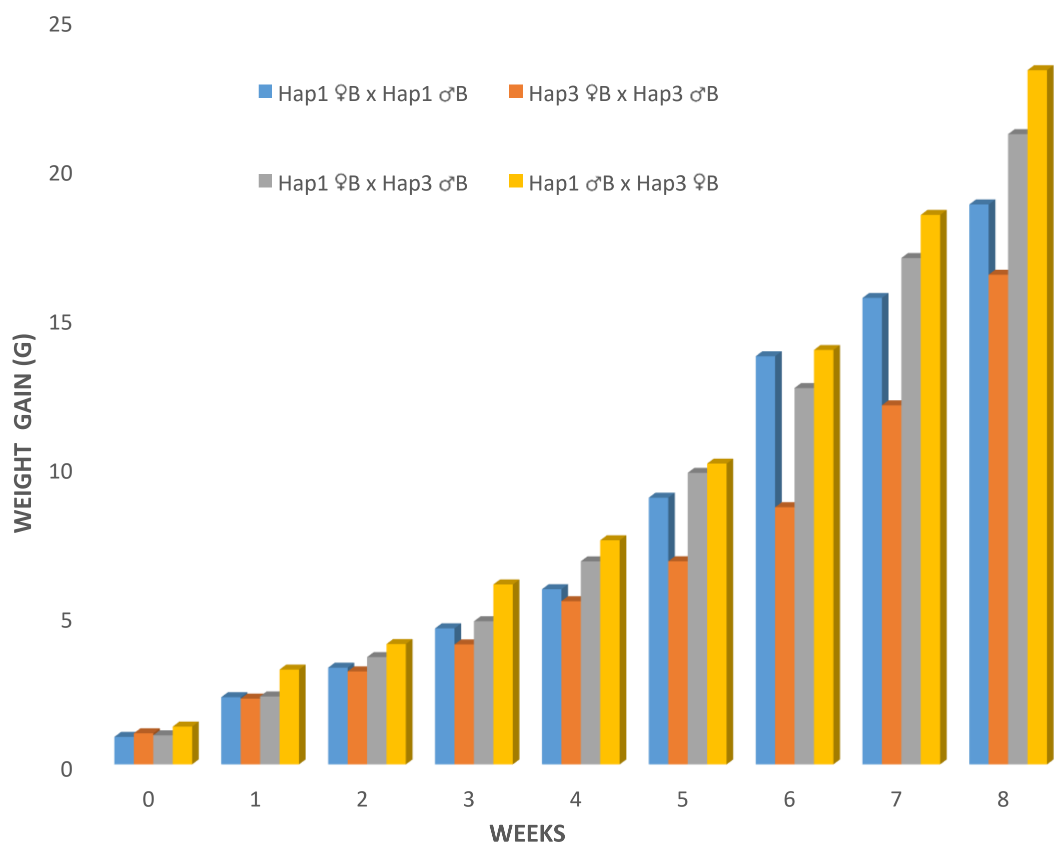

Figure 2: Weekly weight gain of inbred and crossbred haplotype of river Benue population

The results of mean weight gain (MWG), mean length gain, specific growth rate (SGR), frequency of shooters and percentage survival of the parental lines of *C. gariepinus* of river Benue haplotype reared for Eight weeks is presented in Table 1. The MWG was 21.83g for the crossbred (Hap1 ♂B x Hap3 ♀B) and 20.16g for the crossbred (Hap1 ♀B x Hap3 ♂B) were higher than inbred of Hap1 ♀B x Hap1 ♂B (17.81) and Hap3 ♀B x Hap3 ♂B (15.38). The mean specific growth rate (SGR) was also high (2.22g) in crossbred (Hap1 ♀B x Hap3 ♂B) followed (2.14g) by the inbreed of Hap1 ♀B x Hap1 ♂B parental line. While the lowest value (1.99g) was recorded in the inbred Hap3 ♀B x Hap3 ♂B. The highest percentage survival (75.50%) was recorded in crossbreed Hap1 ♂B x Hap3 ♀B followed by (71.00%) crossbred Hap1 ♀B x Hap3 ♂B while the lowest (53.50%) was recorded in inbred Hap1 ♀B x Hap1 ♂B. Crossbred of Hap1 ♀B x Hap3 ♂B and Hap1 ♂B x Hap3 ♀B performed better than the inbred (Table 1).

Table 1: Weight Gain, Length Gain, Specific Growth Rate, Frequency of Shooters and % Survival After Week 8 of Culture of River Benue *Clarias gariepinus* Haplotype

	Hap1 ♀B x Hap1 ♂B	**Hap3 ♀B x Hap3 ♂B**	**Hap1 ♀B x Hap3 ♂B**	**Hap1 ♂B x Hap3 ♀B**
Weight gain (g)	17.8	15.38	20.16	21.83
Length gain (cm)	5.10	5.30	5.30	6.10
SGR	2.14	1.99	2.22	2.00
Shooters Frequency	14.00	25.00	39.00	42.00
%Survival	53.50	62.50	71.00	75.50

Inbreed = (Hap1 ♀B x Hap1 ♂B - Haplotype 1 female crossed with Haplotype 1 male and Hap3 ♀B x Hap3 ♂B - Haplotype 3 female crossed with Haplotype 3 male)

Crossbreed = (Hap1 ♀B x Hap3 ♂B - Haplotype 1 female crossed with Haplotype 3 male and Hap1 ♂B x Hap3 ♀B - Haplotype 1 male crossed with Haplotype 3 female)

Table 4 shows that among the assessed water quality parameters, temperature exhibited a negative correlation with the number of fertilized eggs, number of hatchlings, percentage fertilization, and survival during eight weeks of rearing, with correlation coefficients (r) of -0.53, -0.53, -0.53, and -0.52, respectively. pH demonstrated a strong positive correlation with percentage hatchability (r = 0.53), but negatively correlated with the number of fertilized eggs and percentage survival (r = -0.31 and -0.28, respectively). Dissolved oxygen showed positive correlations with the number of hatchlings, percentage hatchability, and Day 3 survival (r = 0.27, 0.46, and 0.17, respectively), while weak negative correlations were observed with the number of fertilized eggs, percentage fertilization, and percentage survival (r = -0.04, -0.04, and -0.15, respectively). Ammonia was positively correlated with the number of fertilized eggs, number of hatchlings, percentage fertilization, percentage hatchability, and Day 3 survival (r = 0.14, 0.27, 0.14, 0.32, and 0.11, respectively), but negatively correlated with percentage survival (r = -0.42). Electrical conductivity showed positive correlations with the number of hatchlings and percentage hatchability (r = 0.07 and 0.31, respectively), and negative correlations with the number of fertilized eggs, percentage fertilization, Day 3 survival, and percentage survival (r = -0.17, -0.17, -0.01, and -0.17, respectively).

Table 4: Correlations (r Values) of Water Quality Parameters and Reproduction Indices of River Benue Studied *Clarias gariepinus* Haplotypes Population

	Tempt. (^{O}C)	pH	DO (mg/L)	NH_3 (mg/L)	E. C.
No. of fertilized egg	-0.53	0.06	-0.04	0.14	-0.17
No. of hatchlings	-0.52	-0.31	0.27	0.27	0.07
% Fertilization	-0.53	0.06	-0.04	0.14	-0.17
% Hatchability	-0.06	0.53	0.46	0.32	0.31
Survival at Day 3	-0.52	0.18	0.17	0.11	-0.01
% Survival	-0.10	-0.28	-0.15	-0.42	-0.17

Note: * Indicates that correlation is significant (P> 0.05); Tempt. = Temperature (O^{C}); E.C = Electrical Conductivity

DISCUSSION

The present study demonstrated the feasibility of hybridization among the haplotypes of *Clarias gariepinus*, including reciprocal crosses, which may be attributed to genetic improvement facilitated by molecular diagnostics (Uruku *et al*., 2021). The hybrids were viable, and their survival was significantly influenced by the maternal parent. Provided that fecundity remains stable, the key factors for the successful and economically viable production of catfish fry and fingerlings are the hatching and larval survival rates (Uruku and Abur, 2023). The high survival rate observed in the crossbred haplotypes of *C. gariepinus* during the eight-week rearing period is likely due to their hardiness and adaptability to environmental conditions. This finding aligns with previous reports by de Graaf *et al*. (1995), Olufeagba and Akomoda (2015), Omeji *et al*. (2013), and Uruku and Abur (2023), who also documented high survival rates of *C. gariepinus* reared under moderate stocking densities for short durations in controlled tank environments. The enhanced adaptability of the crossbred haplotypes to outdoor conditions may explain their superior performance, whereas the lower survival rate observed in inbred haplotypes could be attributed to environmental and climatic stressors.

Crossbreeding is a widely adopted strategy for improving desirable traits (heterosis), reducing inbreeding, and enhancing hybrid performance (Jothilakshmanan and Karal Marx, 2013). Over the 8-week experimental period, the mean weight gain among the genetic groups ranged from 15.38 to 21.83 grams. The crossbred haplotypes recorded the highest final mean weight gain, likely reflecting the benefits of hybridization not only for sex manipulation or sterility but also for enhanced growth rate, flesh quality, and disease resistance (Bartley *et al*., 2001). In contrast, the lower weight gain in inbred haplotypes may result from inbreeding depression, which is prevalent among clariid catfish in Nigeria.

Artificial propagation, supported by molecular diagnostics, holds promise for the development of superior *Clarias* strains. This supports findings by Akankali *et al*. (2011), who emphasized that artificial propagation techniques not only enable the production of high-quality seed but also allow for the improvement of stock through selective breeding, hybridization, and molecular characterization. The high specific growth rates (SGR) recorded in both inbred and crossbred *C. gariepinus* haplotypes are consistent with the findings of Ataguba *et al*. (2012) and de Graaf *et al*. (1995), who reported similar growth trends for *C. gariepinus* in early rearing phases. These results align with the observed mean weight gain and may be attributed to the species' physiological characteristics. River Donga populations offer valuable genetic diversity for breeding. Crossbred catfish typically outperform inbreds, particularly under culture conditions (Olaniyi and Omitogun, 2017).

One of the major challenges in catfish production is growth heterogeneity and the cannibalistic behavior of faster-growing individuals, known as "shooters," which negatively impacts overall yield and profitability in aquaculture (Uka *et al*., 2005). In this study, gamete variation significantly influenced shooter heterogeneity, frequency, and weight. The inbred haplotype population exhibited a lower frequency of shooters, whereas the crossbred group showed higher variability and frequency. The occurrence of "shooters" fast-growing individuals reflects genetic variability and influences production outcomes (Hossain *et al*., 2013).

Although Ataguba *et al*. (2022) reported that increased water hardness adversely affects embryonic development, the mean water quality parameters recorded in this study were within optimal ranges for *C. gariepinus* growth and survival. Temperature, pH, dissolved oxygen (DO), and ammonia levels all correlated positively with reproductive performance during the experimental period (Loyd, 1992; Lawson, 1995).

CONCLUSION

This study indicates that inbred strains of *C. gariepinus* exhibit slower growth rates, frequency of shooters and lower survival rates compared to more genetically diverse crossbred populations. Genetic factors play a pivotal role in the growth rates of *C. gariepinus*. Crossbreed haplotype (Hap1 FB X Hap3MB and Hap1MB X hap3FB) yields superior growth performance in weight and length compared to inbreeding due to the positive effects of heterosis and genetic diversity. Therefore, aquaculture practices should focus on the utilization of crossbreeding strategies to optimize growth rates, health, and sustainability in fish farming systems.

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