www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 16: 123-133 (2016) DOI: 10.4194/1303-2712-v16_1_13

RESEARCH PAPER

Assessment of Reproductive Performance, Growth and Survival of Hybrids of African Catfish (*Clariasgariepinus*) and Indian Catfish (*Clariasbatrachus*) Compared to Their Parental Lines Crosses

Gashaw Tilahun[1,*], Kiran Dube[2], C.S. Chtruvedi[3], Bindhi Kumar[2]

[1] Bahir Dar University, College of Agriculture and Environmental Science, Department of Fishery, Wetland and Wildlife Management, Bahir Dar, Ethiopia.
[2] ICAR-Central Institute of Fisheries Education Deemed University, Department of Aquaculture, Mumbai, India.
[3] ICAR-Central Institute of Fisheries Education Deemed University, Department of Genetics and Biotechnology, Mumbai, India.

* Corresponding Author: Tel.: +251912046846; Fax: 0582202025;
E-mail: gashawtilahun35@yahoo.com

Received 11 December 2015
Accepted 04 March 2016

Abstract

Hybridization was conducted to compare performance of hybrids to their parental line of the pure Clarias gariepinus and Clarias batrachus crosses as a control in triplicates for a period of 60 days, with fortnightly sampling. The hybrid crosses showed intermediate characters between the control crosses in mean weight gain (MWG), specific growth rate (SGR) mean final length (MFL) and survival of fingerlings (SF). However, the hybrids revealed lower characters compared to the progeny of control groups in fertilization rate, hatching and survival of larvae. On the other hand, fertilization and hatching rate among the hybrids and the control batrachus species were statistically insignificant (P>0.05). Similarly, no significant difference (P>0.05) was observed between the two inter-specific hybrids. Though the crosses of C. gariepinus displayed significantly higher value in MWG, SGR, SL and FML than other groups, fingerling survival was found to be lowest. The growth parameters like MWG, SGR and FML of the hybrids were found to be higher than C. batrachus crosses, while survival of hybrid fingerlings were higher than C. gariepinus. Therefore, this is considered as heterosis vigor for the hybrids for that they have achieved better traits either one of the control groups.

Keywords: Clarias batrachus, Clarias gariepinus, hybrid, reproductive performance, growth, survival, heterosis.

Introduction

Hybridization, one of the successful techniques availed to achieve improved traits by crossing two different species or strains. Hybridization through cross and selective breeding methods holds promise in boosting aquaculture production in the coming years (Omeji *et. al*., 2013). Though, interspecific hybridization between endemic species and introduced species or between wild and cultured populations is appearing to be a topic of great concern (Hershberger, 2006; Elo *et al*., 1997; Jansson and Oest, 1997).

Hybrids play a significant role in aquaculture to increase the production of several species of freshwater and marine fishes. GIFT (genetically improved farmed tilapia) and GIFT-derived strains accounted about 68 per cent of tilapia seed production in the Philippines in 2003 (ADB, 2005), in Thailand large scale hatcheries accounted more than 60% of the total sales volume of tilapia seeds using GIFT and GIFT derived strains (DFID World Fish Center, 2010). Hybrids account nearly 80% of the total catfish produced in Thailand (Bartley *et al*., 1997), while, the production of *Clarias* hybrid increased from 390 tonnes to 15234 tonnes over the last decade in Nigeria (Anetekhai, 2013). The expansion of aquaculture sector and the increased number of species being bred and farmed for example hybrid striped bass in the USA, hybrid tilapia in Israel and hybrid characids in Venezuela resulted for the hybrids to account for substantial proportion of national aquaculture production and other hybrid may emerge through further development (Aminur *et al*., 2013).

Hybridization has been successful in improving growth rate like daily weight gain, specific growth rate (El-Zaeem and Salam, 2013), sex ratio, cold tolerance, body size and salinity tolerance (Kuo, 1969; Hu and Yu, 1977) such as in tilapia and other species. Hybridization between some species of tilapia resulted in the production of predominantly male offspring and reduces unwanted natural reproduction in grow out ponds (Rosenstein and Hulata, 1994).

In recent years, hybrids of major carps are being successfully produced and are available for farming due to high resistances against unfavourable ecological conditions (Reddy, 2000; Um-E-Kalsoom

© Published by Central Fisheries Research Institute (CFRI) Trabzon, Turkey
in cooperation with Japan International Cooperation Agency (JICA), Japan

et al., 2009). Feng carp a hybrid of Xingguo red carp and scatted mirror carp, exhibits better growth rate over maternal fish, while Heyuan carp produced by cross breeding of purse red carp and Xiangjiang carp has 50-100% more growth rate than that of the paternal fish (Dong and Yuan 2002). Rainbow trout also achieved better growth rate (heterosis) through hybridization over the parents (Dunham *et al*., 1983; Dunham, 1996b).

Inter-specific ictalurid hybrid has shown heterosis for culture traits when channel catfish female hybridized with a blue catfish male (Dupree *et al*., 1969; Dunham and Smitherman, 1981; Dunham *et al*., 2000). Similarly, crossbreeding between female *Pangasianodon hypophthalmus* and male *Pangasius nasutus* showed better breeding performance (Hassen *et al*., 2011). The hybrid between the female native *C. macrocephalus* and the male *C. gariepinus* is a culture due to its superior growth over the native *Clarias* species in Thailand (Na-Nakorn, 1999).

High growth rate and disease resistance makes African catfish a regular species for homestead fish culture in different areas of the world (Oguguah *et al*., 2011). In Africa, this fish have very good commercial price in markets (Ezenwaji, 1986; Oladosu *et al*., 1993). African catfish is the major fish species cultured in Sub-Saharan Africa followed by tilapia and is distributed elsewhere as exotic species (FAO, 2012). On the other hand, *C. batrachus* is one of the most economically important indigenous freshwater fishes in Asia because of its attractiveness for its good taste, rugged, medicinal value (Debnath, 2011), excellent nutritional profile and high market value (Argungu *et al*., 2012). However, *C. batrachus* shows less resistance to wide fluctuations in temperature and oxygen, lower in growth rate, fecundity and less in disease resistance as compared to that of *C. gariepinus* and provides less productivity per unit area. Hence, the fish farmers have not much benefited in culturing and less interested in this fish farming. Moreover, Hossain *et al*. (2006) described recently, the species has become scarce because of many adverse changes in their natural breeding and growing habitats for that the fry is very rare in nature. Khedkar (2009) also stated that this species lacks genetic diversity which may be one of the reasons to decline in different parts of India. On the other hand, the African catfish from the time it was introduced to India has been distributed to various regions shortly and occupied different water bodies of the country. Its spread and fast growth might have been drawn attention for fish farmers to hybridize with the native fish *Clarias batrachus*. Hence the exploitation of native cultured species with introduced exotic species could be used as means for diversification in aquaculture to increase production even though the protection of native biodiversity would pose a limitation to this technology. De Silva *et al.* (2009) stated that 16% of the global aquaculture production is contributed by alien species. Therefore this study was conducted to assess the reproductive performance, growth and survival of the hybrids of Indian catfish, *C. batrachus* with *C. gariepinus* in comparison with its parental lines as a control.

Materials and methods

Experimental Design and Hormone Administration

A total of 24 brooders were randomly distributed into 4 crosses marked as Cb ♀ x Cb ♂, Cg ♀ x Cg ♂ Cb ♀ x Cg ♂ and Cg ♀ x Cb♂ groups in triplicates each with two brooders (n=6 brooders/group) in a plastic tray following a completely randomized design (CRD): Six male *C. gariepinus* with an average weight of 375.67 ± 34.17g and six female *C. gariepinus* with an average weight of 325.83 ± 23.18g and six female *C. batrachus* with an average weight of 134.8.33 ± 9.33g, six male *C. batrachus* with an average weight of 169.50 ± 16.39g.

Milt was collected from the males by sacrificing them. Testes were removed after dissection and cleaned with tissues paper to get rid of blood. The tests then cut into pieces and crushed for releasing milts using the enamel mortar cup and pestle. The milt samples were kept inside a Petri dish diluted with physiological saline (0.9% NaCl) solution for insemination. On the other hand, the females were removed from the basin head covered with a hand towel to restrain it and injected with synthetic ovatide hormone. After injection, the brooders were returned into tanks containing clean water with appropriate temperature (28°C) for ovulation and maturation of gonads. The females then selected for free flowing eggs and then stripped. The eggs were collected into clean and dry plastic trays/bowls.

Fertilization of Eggs

The milts collected from the two different species were used in fertilizing the eggs in four separate combination crosses inside trays using a clean dry feather to avoid contamination of eggs. Further, the fertilized eggs were washed with clean water repeatedly to remove the excess milt and were placed under a continuous water flow setup from tap water and incubated at a temperature range 27 ^{0}C-30 ^{0}C with a pH of 7.1. The rate of fertilization was calculated as follows.

$$\text{Fertilization Rate} = \frac{\text{Number of fertilized eggs}}{\text{Total number of eggs counted}} * 100$$

Incubation and Hatching

Thin fibrous polythene materials were placed at the bottom of incubated rectangular trays as a substratum for fertilized eggs to prevent clumping among the eggs particularly for eggs of *C. gariepinus* due to its adhesive nature. Hatching rate was calculated as follows;

$$\text{Hatching Rate} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs in a batch}} * 100.$$

Rearing in the Hatchery

The experiment was set up in triplicate groups inside the hatchery. The life cycle of the development begins with the fertilized egg to the fingerling stages at which the rearing period ends. The larvae are considered after hatching of 24 hours up to day 15 (Two weeks). The fry is considered from day 16-30 and the fingerling is considered from day 31^{st} – day 60^{th}. Hatchlings of 20-25 numbers (samples) were taken and measured together for their length and weight from each cross to calculate mean initial length and mean initial weight after 24 hours of hatching. The larvae after yolk sac absorption i.e. on 4^{th} day post hatch were fed with boiled egg before supplying the live feed as a starter. Larvae fry and fingerlings were fed to ad-libitum thrice daily (0.8:00, 13:00 and 18:00 hours) with live feed (Moina and Daphnia) laboratory prepared pelleted feed as supplementary food (35-40% CP) was provided from 15^{th} day post hatching. Water exchange was done regularly to remove uneaten feeds and other metabolite and to prevent fouling. About 25% of the culture water was always replaced every morning in order to eliminate shock and enhance survival of cultural organisms (Peter, 1987). The water quality parameters were recorded every day.

Growth Performance

Data of weight and length collected during the experimental period was analysed subsequently for the determination of growth rate. 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 each developmental stage (larva, fry and fingerling) of the experiment in order to distinguish the growth rate achieved by each group of the progenies.

Fortnight measurements were carried out for weight (to the nearest g) with an electric 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 Adebayo (2006):

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 W2 final weight–In W1 initial weight)/culture period} × 100

Where W1is the initial fish weight (g) at time T1 (day) and W2 is the final fish weight at time T2 (day).

Survival Performance

The rate of survival in each stage (two weeks for larvae and two weeks for fry and one month for fingerlings) was determined by counting and recording the mortality at the beginning and end of each stage. It was calculated by the formula adopted by Adebayo (2006) as follows:

$$\text{Survival Rate} = \frac{\text{No. of final alive at each stage}}{\text{Total No. counted at each stage}} * 100$$

Heterosis

Heterosis is here referred to the performance both in terms of growth or survival of the hybrids relative to that of their parental offspring expressed in percentage. The mean weight, specific growth rate and survival of the interspecific hybrids and the parental species were used to estimate heterosis adopted by Akinwand *et al*. (2011) and Nguenga, *et al*. (2000).

$$\text{Heterosis \%} = \frac{[(C1+C2)/2) - (P1+P2/2)]}{(P1 + P2)/2} \times 100$$

Where C1 and C2 = The mean weight, specific growth rate or survival of hybrids

P1 and P2 = The mean weight, specific growth rate or survival of parent

Statistical Analyses**:** All the parameters were analysed using one-way ANOVA with respect to pure line crosses and hybrids. Post hoc test was carried out using Duncan's multiple comparison procedures to check whether or not they were significantly different. All the statistical analyses were performed by using SPSS 16.0 for windows.

Results

Water Quality Parameters

Water temperature, dissolved oxygen, nitrate, and nitrite were checked every week to maintain the quality of water. Water temperatures ranged between 26-30 ^{0}C, dissolved oxygen 6.3-7.6 mgL^{-1}, pH 6.8-7.5, nitrate 0.002-0.038 mgL^{-1} and nitrite 0.001-0.002 mgL^{-1} throughout the experimental period from larval to fingerling stages and the values were within the recommended range for rearing catfishes (Ayokanmi, 1999; Madu *et al*, 1984)

Latency and Incubation

The latency period of *C. batrachus* was 14-18 hours and the incubation period was between 24-28 hours at the water temperature of 27 to 30 ^{0}C, whereas in *C. gariepinus* the latency period was 8-10 hours and the incubation time was 20-22 hours in a similar water temperature.

Fertilization and Hatching Rate

The percentages of fertilization in the hybrids were the lowest (77.10 % for Cb ♀ x Cg ♂ and 74.85 % for Cg ♀ x Cb ♂**)** compared to the parental lines (79.95 % for Cb ♀ x Cb ♂ and 91.25 % for Cg ♀ x Cg ♂) as indicated in Table 1. The values of *C. gariepinus* (Cg ♀ x Cg ♂) were significantly different (P<0.05) from all the other crosses. On the other hand, there was no statistical significance (P>0.05) among the hybrids and pure batrachus crosses. Hatching rate was also recorded high (71.05 %) in *C. gariepinus* (Cg ♀ x Cg ♂) followed by pure batrachus (53.05 %) as shown in Table 1. The values in the hybrids (42.60 %) for Cb ♀ x Cg ♂ and (40.30 %) for Cg ♀ x Cb ♂) were the lowest. The result for *C. gariepinus* for both fertilization and hatching rate was significantly different (P<0.05) from the others (Table 1).

Growth Rate

Fishes produced from all the breeding trails increased in length during the rearing period. The corresponding growth curve that illustrates in terms of length increase (mm) for each cross is presented in Figure 1. The hybrids showed intermediate values between the two parental line crosses for length parameters. The maximum values for mean final length (MFL) (74±40 mm) and mean length gain (MLG) (71.620±1.150 mm) were recorded in *C. gariepinus* (Cg ♀ x Cg ♂), whereas the minimum size for MFL (53.803±2.707 mm) and MLG (48.943±0.665mm) were observed in *C. batrachus (*Cb ♀ x Cb ♂) (Figure 1). The statistical analysis showed significant difference (P<0.05) among the crosses. The hybrids of female batrachus (Cb ♀ x Cg ♂) recorded greater values for both MFL and MLG compared to that of its reciprocal hybrids of female gariepinus fingerlings (Cg ♀ x Cb ♂).

The results of mean final weight (MFW), mean weight gain (MWG), and specific growth rate (SGR) of the parental lines of *C. batrachus*, C. *Gariepinus* and their hybrids reared for 60 days inside the hatchery is presented in Table 2. The MWG was 3.233 ± 0.368 g for the hybrids of female batrachus (Cb ♀ x Cg ♂) and 2.934 ± 0.213 g for female gariepinus (Cg ♀ x Cb ♂) were higher than pure *C. batrachus* (1.532 ± 0.287 g) but lower than pure *C. gariepinus* (3.731± 0.452 g). Likewise, the value recorded in both hybrids for MFW was between the two parental line crosses but the statistical analysis did not show significant difference (P>0.05) between the hybrids and the pure *C. gariepinus* indicating that weight increase of the hybrids was similar to that of

Table 1. Percentage of Fertilization and Hatching in pure parental line of *C. batrachus* (Cb x Cb) and *C. gariepinus* (cg x Cg) and their hybrids of female batrachus eggs (Cb x Cg) and female gariepinus eggs (Cg x Cb)

Combination of Crosses	Fertilization (%)	Hatching (%)
Cb x Cb	79.95±0.35[a]	53.05±0.15[a]
Cg x Cg	91.25±1.55[b]	71.05±3.55[b]
Cb x Cg	77.10± .70[a]	42.60±2.80[a]
Cg x Cb	74.85±3.65[a]	40.30±4.40[a]

Values represent mean ± SE;
Mean values in a column under each parameter bearing different superscripts (a, b,) differ significantly (P<0.05);
N.B In any combination of crosses the first set is for females and the second is for males throughout the text.

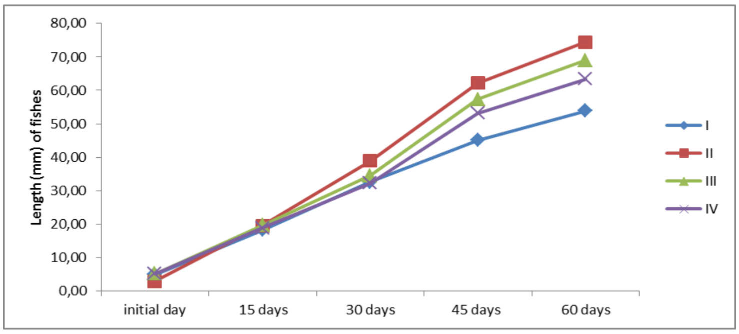

Figure 1. Growth curve showing length increase (mm) for a rearing period of 60 days in the year 2012. (I- Cb x Cb; II-Cg x Cg; III-Cb X Cg and IV-Cg x Cb).

the fast growing pure *C. gariepinus* fingerlings.

The mean specific growth rate (SGR) was also high (10.138±.593 g) in *C. gariepinus* (Cg ♀ x Cg ♂) followed (9.575±0.631 g) by the hybrids of female batrachus (Cb ♀ x Cg ♂) fingerlings. The lowest value (6.742±0.293 g) was recorded in the pure *C. batrachus* (Cb ♀ x Cb ♂) showing significant difference compared to the other crosses ($P<0.05$). It is clear from the result that the hybrids of female batrachus performed better than its reciprocal hybrids of female gariepinus fingerlings (Table 2).

Survival

Survival rate for all combinations of crosses of Cb ♀ x Cb ♂, Cg ♀ x Cg ♂, Cb ♀ x Cg ♂ and Cg ♀ x Cb ♂ from larval to fingerling stages are given in Table 3. Hybrids at their larval stage of development recorded the lowest survival and showed significant difference ($P<0.05$) from the parental crosses. During this period the highest survival was in *C. gariepinus* followed by *C. batrachus* (Table 3). Hybrids at fry stage had higher survival when compared to their larval phase and the statistical analysis did not reveal significant difference to that of the parental groups. There was a higher achievement in the performance of survival of the hybrid fry in the progress development over the pure breed of *C. gariepinus* crosses indicating that the pure breed of *C. gariepinus* had shown a decline trend compared to its own earlier stage as well to the other fry crosses. Although attainment of survival of hybrid fry was higher, it recorded lower than pure strain fry of *Clarias batrachus.* But in the subsequent developmental phase of the fingerlings, survival performance was much achieved and exceeded over all the control groups significantly ($P<0.05$). In this stage the highest (63.5 ± 4.5%) was observed in hybrids of female batrachus crosses (Cb ♀ x Cg ♂) followed (61.75 ± 4.35%) by hybrids of female gariepinus (Cg x Cb) (Table 3). Moreover, in both the hybrids there was no significant difference ($P>0.05$)

Heterosis

In the case of heterosis in terms of weight gain (-6.8%) and survival performance (-68.56%) for larvae was negative for interspecific hybrids compared with parental crosses while for growth in terms of weight gain (17.1%), SGR (6.87%) and performance of survival in fingerlings (23.14%) at the end of the rearing period of 60 days was positive for interspecific hybrids as shown in Table 4. In addition, hybrids of the fry showed superior performance of survival over *C. gariepinus* and grew faster than *C. batrachus* (Tables 2 and 3) indicating that the acquiring of hybrid vigor for such traits appears to exist better in advanced (later) development stage rather than in earlier stage (larvae).

Discussion

Many authors were successful in producing all male or all female population of fishes of different species or strains (El-Zaeem and Salam 2013; Rosenstein and Hulata, 1994) while others also focused on improving the reproductive performances, growth and survival of fishes (Reddy, 2000; Um-E-

Table 2. Growth performance of fingerlings of the four crosses in terms of weight for a rearing period of 60 days (from mid-June to mid-August)

	Combination of crosses			
Growth parameters	Cb x Cb	Cg x Cg	Cb x Cg	Cg x Cb
MIW(g)	0.038 ± 0.000^{b}	0.026 ± 0.002^{a}	0.044 ± 0.001^{c}	0.026 ± 0.002^{a}
MFW(g)	1.572 ± 0.288^{a}	3.758 ± 0.453^{b}	3.275 ± 0.369^{b}	2.956 ± 0.214^{b}
MWG(g)	1.532 ± 0.287^{a}	3.731 ± 0.452^{b}	3.233 ± 0.368^{b}	2.934 ± 0.213^{b}
SGR (g)	6.742 ± 0.293^{a}	$10.138\pm.593^{c}$	9.575 ± 0.631^{b}	8.470 ± 1.230^{ab}

Values represent mean ± SE; Mean values in a row under each parameter bearing different superscripts differ significantly ($P<0.05$).

Table 3. Percentage of Survival of *C. batrachus*, *C. gariepinus*, hybrids of female batrachus and hybrids of female gariepinus from larval to fingerling stage

	Survival %			
Culture stage	Cb x Cb	Cg x Cg	Cb x Cg	Cg x Cb
Larvae	51.70 ± 2.90^{b}	54.55 ± 3.45^{b}	17.95 ± 2.65^{a}	15.45 ± 3.15^{a}
Fry	55.05 ± 2.55^{a}	47.40 ± 3.80^{a}	51.00 ± 2.70^{a}	49.35 ± 2.45^{a}
Fingerling	58.85 ± 5.35^{ab}	44.70 ± 2.90^{a}	63.5 ± 4.5^{b}	61.75 ± 4.35^{b}

Values represent mean ± SE;
Mean values in a row under each parameter bearing different superscripts differ significantly ($P<0.05$)

Table 4. Estimation of heterosis of F_1 hybrids (Cb x Cg, Cg x Cb) of larval survival at the age of two weeks and fingerlings at the end of culture period of 60 days

Parameters	Heterosis (%)
Weight gain (g)	17.1
SGR (%)	6.87
Survival of larvae (%)	-68.56
Survival of fingerlings (%)	23.14

Kalsoom *et al*., 2009). In our study we were able to investigate the achievements on the reproductive performances (Hassen *et al*. 2011), growth (Na-Nakorn, 1999; Dunham, 1996b) and survival of the hybrids over the control groups. Although the experiment of hybridization may succeed or fail, the success of the interspecific hybridization between *C. batrachus* and *C. gariepinus* was demonstrated in this study. It was also evident earlier in the same species by the reports of Sahoo *et al*. (2003) in India, Khan *et al*. (2000) in Bangladesh and in other different countries as well. Asian catfish project described the failure in the same species in Indonesia but succeeded in other countries. Nam *et al*. (2001) reported the embryonic development of hybrid of female catfish, *Silurus asotus* with male mud loach, *Misgurnus mizolepis* which proceeded only until late gastrula stage but did not hatch at all.

Sahoo *et al*. (2007) reported a latency period of 14-17 hours for *C. batrachus* using ovatide as well as HCG inducing hormones. Likewise, Yadav *et al.* (2011) and Chaturvedi *et al*. (2013) also reported a latency period of 14-16 hours for the same species in different regions in India. The observation made on latency period during the present study is in agreement with the previous authors. The latency period was14-18 hours whereas the incubation period was between 24-28 hours at water temperature of 27 to 30 ^{0}C using ovatide hormone. Further, this observation agrees with the earlier reports of Rao *et al*. (1994) and Sahoo *et al*. (2003) in the same species.

For *C. gariepinus* latency period and incubation time was noted 8-10 hours and 20-22 hours respectively, which is in agreement with Viveen *et al*., (1986). In a similar way, Raman *et al.* (1995) reported the same latency period of 8-10 hours for *C. gariepinus* and 20-22 hours for *C. batrachus*. Bruton (1979) also reported early embryonic development for *C. gariepinus* between 21-26 hours. Incubation time of the hybrids followed the maternal parents and hatching time of them (hybrids) were similar to that of the pure crosses that agree with the report of Sahoo *et al.* (2003).

Fertilization and hatching rates in the hybrids of batrachus eggs (Cb ♀ x Cg ♂) were found better compared to its reciprocal hybrids of gariepinus eggs (Cg ♀ x Cb ♂), with lower mortality and deformity, though insignificant to each other (P>0.05). Further, in this observation, embryonic mortality appeared immediately after certain hours of incubation and following hatching the deformed larvae started to die with high rate of mortality. Each batrachus brood eggs weighed more than the gariepinus brood eggs at its initial weight measurement (Table 1) and this might have been in turn contributed to the better performance when two interspecific hybrids were compared to each other (the hybrid of female batrachus progeny with its reciprocal hybrids progeny of female gariepinus eggs). This was favourably agreed to the result obtained by other authors (Dunham *et al*., 1987; Rahman *et al*. 1995; Sahoo *et al*., 2003) which described better performance in the hybrids over its reciprocal hybrids. In addition, Legendere *et al*. (1992) reported that differences in hatching rates were greater between both parental species and between pure species and hybrids obtained from the same eggs showing that hatching rates were determined mostly by species or egg quality.

Although fertilization rate achieved in the hybrids was high (77.10± 0.70% and 74.85±3.65%) for Cb ♀ x Cg ♂ and Cg ♀ x Cb ♂ respectively, it was lower than the parental crosses. The hatching rate also followed the same trend as fertilization rate and recorded the least in the hybrids (Table 1). Similar variation between fertilization and hatching rates in hybrids and pure parental crosses were also made by various authors (Chaudhuri, 1961; Alikunhi and Chaudhuri, 1959; Tarnchalanukit, 1985; Adebayo, 2006; Morni, 2003). Apart from the genetic factors, the non-genetic factors like the culture system and condition like water temperature, salinity, pH and alkalinity also plays a major role in the success of hybridization (Rahman *et al*. 2012). Similar suggestion was given by Ndimele and Owodeinde (2012), who described that the pure breeds tolerate more stress than the hybrids.

When reproductive performances of the two species were evaluated, the eggs of *C. gariepinus* had higher rate of fertilization and hatching over the eggs of *C. batrachus* in both its control and hybrid groups that might be related to the high fecundity of the *C. gariepinus* species (Table 1) agrees with authors (Ndimele and Owodeinde, 2012; Hassen *et al*., 2011; Richter, 1995; Mollah and Tan, 1983)

Though fertilization and hatching in pure batrachus (Cb x Cb) strain was lower as compared to pure gariepinus (Cg x Cg) strain, the results obtained in this study is also comparable with earlier authors who achieved higher performance in the same species (Chaturvedi and Pandy, 2012; Srivastava *et al*., 2012; Goswami, 2007; Mahabatra, 2004).

Crossbreeding is used to achieve improved traits (heterosis), minimize inbreeding and obtain better hybrids (Mires, 1982; Bartley *et al*., 1997; Dong and Yuan, 2002; Anita, 2004; Jothilakshmanan and Karal Marx, 2013). The results of growth in both hybrids for MWG, SGR and MLG were intermediate between the two parental line groups and showed superiority over *C. batrachus* crosses. This was similar with earlier studies which reported an intermediate growth performance of the parents for F1 hybrids and its reciprocal crosses. Jothilakshmanan and Karal Marx (2013) reported intermediate growth for hybrids of *Hetropneustes longifilis* and *Clarias batrachus*. Rahman *et al.* (1995) also reported hybrid vigor of fast growth in catfish was produced through cross breeding between *C. batrachus* ♀ and *C. gariepinus* ♂. In addtion Nwadukwe (1995) described an intermidiate growth performance between the parents for F1 hybrids and its reciprocal hybrid from the crossbred of *Clarias gariepinus* and *Hetrobranchus longifilis.* Moreover, growth rates of different strains of Nile tilapia and their crosses showed that the crosses were superior to pure Senegal strains to one of the parents (Circa *et al.,* 1994). In this study the values of heterosis for growth and in terms of weight gain was positive (17.1%) for the interspecific hybrids as shown in Table 4. Heterosis for SGR was also recorded positive (6.87). Similarly, Akinwande *et al.* (2011) reported positive heterosis for the interspecific hybrids of *Clarias gariepinus* and *Clarias angularis*. On the other hand, Ataguba *et al*. (2010) reported negative heterosis for growth (-42%) in the hybrids of *C. gariepinus* and *Herobranchus longifilus* after 56 days of larval to fingerling rearing. In our observation, the values for pure *C. gariepinus* (Cg ♀ x Cg ♂) were significantly ($P<0.05$) higher than the other crosses and this result was in agreement with other studies (Hulata, 2001; Adewolu *et al*., 2008; Ataguba *et al*., 2009, 2010; Ndimele and Owodeinde, 2011). Moreover, Sahoo *et al*. (2003) in the same species reported that both the hybrids grew faster than the parental crosses explaining the case due to maternal heterosis effects and indicated that the hybrids have good potential for aquaculture.

In the current study, survival was achieved in both hybrids during fingerling stages over the parental groups (with a significant difference ($P<0.05$) which could be attributed to improved hybrid vigour Table 3. This is in agreement with the findings of earlier reports which indicated that hybrids in most cases were superior to the parental strains (Bakos, 1982; Jensen *et. al.,* 1983; Madu and Ita, 1990 and Salami *et. al*., 1993). In the present study, heterosis for survival of fingerlings in the hybrids was positive (23.14%). On the other hand, survival of larvae recorded was low in both the hybrid crosses and was varied significantly ($P<0.05$) due to the appearance of deformed larvae which started to die immediately after hatching until about ten days of age. The effect of hybridization to lower performance of survival is also claimed by the report of other researchers (Rahman *et al*., 1995; Legendere *et al*., 1992; Sahoo *et al*., 2003; Ndimeleand Owodeinde, 2012). Similarly, Jothilakshmanan and Karal Marx (2013) in the hybrids of *Hetropneustes longifilis* and *Clarias batrachus* reported reduced survival (0.8 and 0.9%) due to high rate of mortality of the hatchlings when the transition from endogenous to exogenous feeding took place. Mukhopadhyay (1999) also made a similar study and reported the survival of hybrids of female *C. Batrachus* and male *H. Fossilis* were very poor and most of the embryos died during embryogenesis or after hatching. Legendre *et al.* (1992) concluded that the survival of hybrids *H. Longifilis* x *C. gariepinus* (6±2.8%) was very low and was strongly influenced by the maternal parent.

On the other hand, during fry stage in the current observation the survival of hybrids had no significant difference (Table 3). This indicates that fry improved in their survival much better than the parental crosses as they progressed from the stage of larvae towards fry. Further, at the end of the rearing period of the fingerling stage (60^{th} day) the values for the hybrids was documented significantly higher than the parental lines. Moreover, values of heterosis for survival of hybrids at fingerling stage confirmed positive (23.14%) indicating that hybrids improved well in survival over the parental groups. Similarly, Ataguba *et al*. (2010) reported that hybrids of *C. gariepinus* and *Hetrobranchus longifilus* showed a positive heterosis (29.4%) after 56 days of rearing and also explained that poor larval and fry development of negative heterosis growth (-42%). The authors further reported the improvement of growth and survival in the later stage as advanced to fingerling stage. Likewise, in the current study heterosis for larval survival were of negative value (-68.567) indicating that the hybrids at their larval stage had poor in survival.

Hatchlings and survival of larvae in *C. gariepinus* were recorded significantly higher than the other groups but the progeny of these crosses exhibited a decline trend in survival when advanced towards fry and fingerlings phases while other group crosses achieved well progress in its subsequent developmental stages. It might be due to its cannibalistic nature of the species. Similarly, de Graaf *et al*. (1995) reported a survival rate of 41.5% in *C. gariepinus* claiming that cannibalism is the cause for lower percentage performance. Moreover, Rahman *et al*. (1992) also reported lower survival in the same species. Size segregation was also recommended to minimize cannibalism in different stages for *C. gariepinus* by other authors (Viveen *et al*., 1983; Legendere *et al*., 1992). According to Janssen *et al*. (1983), sibling cannibalism has been observed earlier among fry of *C. gariepinus* in hatcheries.

During the study period, the pure *C. batrachus* progenies which were poor in survival at initial stages significantly improved and progressed in its survival performance better than *C. gariepinus* and showed similarity to the hybrids without significant variation at the end of the experiment. This might have been related with its improved adaptability and absence of cannibalism. Moreover, cannibalism was not observed in both types of hybrids (Cb♀ x Cg ♂ and Cg ♀ x Cb♂). This is supported by the improved survival percentage recorded as each group of progenies passed through the successive developmental stages. This finding is in agreement with the report of Sahoo *et al*., (2003) for the hybrids of female batrachus (Cb♀ x Cg ♂) that achieved better than the pure batrachus.

Conclusion

The study revealed that the hybrids achieved better than the control batrachus groups in growth and survival except the low survival performance of the larvae recorded with a negative percentage of heterosis. It indicated that the interspecific hybrids combines improved traits in growth and survival at fingerling stages but requires further improvement for the poor survival of the larvae as to produce sufficient seed for grow-out culture to exploit the potential of the hybrids in aquaculture. The success of hybridization in captivity between these two closely related species could be a sign to occur in the wild at the natural water bodies where the African catfish is currently expanded and share together many parts of the Indian catfish habitats.

Acknowledgement

The author would like to thank Ministry of Education of Ethiopian government for providing sponsorship for this study and Dr W.S. Lakra, the director of Central Institute of Fisheries Education, Mumbai, India for allowing me to use all the necessary facilities to conduct my research work.

References

Asian Development Bank (ADB), 2005.An impact evaluation study on the development of genetically improved farmed tilapia and their dissemination in selected countries, Manila 77.

Adebayo, O.T., 2006. Reproductive performance of African Clariid Catfish *Clarias gariepinus* broodstock on varying maternal stress. *J. Fish. Int*., 1 (1-2): 17-20.

Adewolu, M.A., Ogunsanmi A.O. and Yunusa, A., 2008. Studies on Growth Performance and Feed utilization of two clariid catfish and their hybrid reared under different culture systems. *Eur. J. Sci. Res*., 23 (2): 252-260.

Akinwande, A.A., Fagbenro, O.A., Adebayo, O.T., 2011. Growth and heterosis in reciprocal *Clarias* hybrids between *Clarias gariepinus* and *Clarias angularis*. *J. fish. Int*., 6 (3): 67-70.

Alikunhi, K.H. and Chaudhuri, H., 1959. Preliminary observations on hybridization of the common carp (*Cyprinus carpio*) with Indian carps. *Proc. Indian Sci. Congr.*, 46

Aminur Rah, M., Arshad, A.B., Marimuthu, K., Ara, R., Amin, S.M.N., 2013. Inter-specific Hybridization and Its Potential for Aquaculture of Fin Fishes. *Asian journal of Animal and veterinary Advances*, 8 (2): 139-153. doi:10.3923/ajava.2013.139.153

Anetekhai, Martins Agenuma, 2013. Catfish Aquaculture Industry Assessment in Nigeria. African Union – Inter African Bureau for Animal Resources.

Anita, M. Kelly, 2004. Channel Catfish Broodfish Management. Southern regional center. SRAC No. 1802.

Argungu, L.A., Christianus, M.N., Amin, S.K., Daud, I.S., Siraj, S. Rahman, M., 2012. Asian Catfish *Clarias batrachus* (Linnaeus, 1758) Getting Critically Endangered. *Asian journal of Animal and veterinary Advances*, 8 (2):1683-1699.

Ataguba, G.A, Annune, P.A, Ogbe, F.G., 2010. Growth performance of two African catfishes *Clarias gariepinus* and *Heterobranchus longifilis* and their hybrids in plastic aquaria. Livest. Res. Rural. Dev. 22 (2): 20.

Ataguba, G.A., Annune, P.A., Ogbe, F.G, 2009. Induced breeding and early growth of progeny from crosses between two African clariid fishes, *Clarias gariepinus* (*Burchell*) and *Heterobranchu*s *longifilis* under hatchery conditions. *J. Appl. Biosci.*, 14:755-760.

Ayokanmi, A.D., Chukat T.M., 1999. *Clarias gariepinus* (B), *Clarias anguillaris* (L), *Heterobranchus bidorsalis* (G), *Hreteroclarias*, *Clariabranchu*s and *Chirlas* Hybrids under outdoor nursery management system.

Bakos, C., 1982. Selective breeding and interspecific Hybridization of warm water fishes. *Proceeding of world symposium on Selective, Hybridization and genetic engineering in Aquaculture* (Klaus 'Dew ed.) Berlin. pp.27.

Bartley, D.M., Rana, K., Immink, A.J., 1997. The use of inter-species hybrids in aquaculture and their reporting to FAO. *The FAO Aquaculture newsletter*, 17: 7-14.

Bruton, M.N., 1979. The Breeding Biology and Early Development of *Clarias gariepinus* (Pisces: Claridae) in Lake Sibaya, South Africa with a review of breeding in species of subgenus *Clarias.* London, *Trans. Zool. Soc*., 35: 1-45.

Chatruvedi, C.S., Pandey, A.K., Ram, S., Sharma, A., 2013. Induced spawning in Asian catfish, Hetropneustes fossilis (Bloch, 1794) in captivity at CIFE center Lucknow, Uttar Pradesh. *J. Kalash Sci.*, 1: 105-108

Chatruvedi, C.S. and Pandey A.K., 2012. Successful induced breeding and hatchery development of Asian catfish, *Clarias batrachus* in port Blair. *Biochem. Cell. Arch*., 12: 321-325.

Chaudhuri, H., 1961. Spawning and hybridization of Indian carps. *Proc. Pacif. Sci. Congr.,* Abstract pp 10.

Circa, AV., Eknath, A.E., Taduan, A.G., 1994. Genetic improvement of farmed tilapias: the growth performance of the GIFT strain of Nile tilapia in rice-fish environments. Fifth International Symposium on Genetics in Aquaculture. Halifax, Canada. Pp. 52.

de Graaf, G.J., Galemoni, F. and Banzoussi B., 1995. The Artificial Reproduction and Fingerling Production of the African Catfish, *Clarias gariepinus* (Burchell, 1822) in protected and unprotected ponds. *Aquacult. Res.*, 26: 233-242.

De Silva, S.S., Nguyen Thuy T.T., Turchini G.M., Amarasinghe U.S., Abery N.W., 2009. Alien species in aquaculture and biodiversity: a paradox in food production. *Ambio*., 38: 24–28. doi.org/10.1579/0044-7447-38.1.24

Debnath, S., 2011. *Clarias batrachus*, the medicinal fish: An excellent candidate for aquaculture and employment generation. *Proceedings of International Conference on Asia Agriculture an Animal.* HongKong. Pp. 2-3.

DFID World Fish Center, 2010. Making a GIFT selection: improved tilapia in the Philippines

Dong, Z.J., Yuan, X.H., 2002. The utilizations of heterosis in common carp in China. *Aquaculture Asia*, 7: 2

Dunham, R. 1996b. Results of early pond-based studies of risk assessment regarding aquatic GMOs. 126th Annual Meeting of the American Fisheries Society, Dearborn, MI, August 26-29. *Abstract* No. 381.

Dunham, R.A. and Smitherman R.O., 1981. Growth in response to winter feeding of *Clariasis heriensis* using pituitary extracts from non piscine sources. *J. Appl. Aquacult*., 1 (4): 15-20.

Dunham, R.A., Lambert D.M., Argue B.J., Ligeon C., Yant D.R. and Liu Z., 2000. Comparisons of manual stripping and pen spawning for production of channel catfish X blue catfish hybrids and aquarium spawning of channel catfish. N. *Amer. J. Aquacult*., 62: 260-265.

Dunham, R.A., Smitherman R.O. and Goodman R.K., 1987. Comparison of mass selection, cross breeding, and hybridization for improving growth of channel catfish. *Progressive Fish-Culturist,* 49: 293-296.

Dunham, R.A., Smitherman, 0. and Webber, C., 1983. Relative tolerance of channel X blue hybrid and channel catfish to low oxygen concentrations. Prog. Fish-Cult., 45 (1): 55-57.

Dupree, H. K., Green O. L., and Sneed K. E., 1969. Techniques for the hybridization of catfishes, U.S. Fish Wildlife Service. Southeast Fish Cultural Laboratory. Publ. 221,

Elo, K., Ivanoff, S., Vuorinen, J.A., Piironen, J., 1997. Inheritance of RAPD markers and detection of interspecific hybridizations with brown trout and Atlantic salmon, *Aquaculture,* 152: 55–65.

El-Zaeem S.Y and Salam G.M, 2013. Production of genetically male tilapia through interspecific hybridization between *Oreochromis niloticus* and *O. Aureus.* 12 (4): 802- 812

Ezenwaji, H.M.G., 1986. The problem of Taxonomy of *C. gariepinus*. Pisces: (Clariidae) of Africa and suggestions for the field worker. *J. Sci. Educ.*, 2:22-34.

Falconer, D.S., 1989. Introduction to quantitative genetics. 3rdEdn., Longman, Science and Technology, England, ISBN:9780470211625, p438.

FAO, 2012. Cultured Aquatic Species Information Programme. *Clarias gariepinus*. Text by Pouomogne, V. In: *FAO Fisheries and Aquaculture*.

Goswami, B., 2007. Magur *(Clarias batrachus)* seed production using low Hatcheries. *Aquacult. Asia Mag*., 12: 14-16.

Grant, P.R., Grant, B.R., 1994. Phenotypic and genetic effects of hybridization in Darwins finches. *Evol.,* 48: 297-316. doi: 10.2307/2410094

Hassan, A., Ambak M.A. and Samad A.A., 2011. Crossbreeding of *Pangasianodon hypophthalmus* (Sauvage, 1878) and *Pangasius nasutus* (Bleeker, 1863) and their larval development. *Aquaculture*., 74: 1-10.

Hershberger, W.K., Meyers, J.M., McAuley, W.C., Saxton, A.M., 1990. Genetic changes in growth of coho salmon (Oncorhynchuskisutch) in marine net pens, produced by ten years of selection. *Aquaculture*, 85: 187-197.

Hossain, Q.M. Altaf Hossain, A.H., Parween, S., 2006. Artificial breeding and nursery practices of *Clarias batrachus* (Linnaeus, 1758). *Scientific World*, 4:4.

Hu, S.H. and Yu, T.G., 1977. Hybridization and culture of (in Chinese with English abstract). 629: 81-93.

Hulata, G., 2001. Genetic manipulation in aquaculture: a review of stock improvement by classical and modern technologies. *Genetica,* 111: 155-173.

Jansson, H., and Oest, T., 1997. Hybridization between Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in a restored section of the river Dalaelven, Sweden *Canadian Journal of Fisheries and Aquatic Science,* 54: 2033–2039.

Jessen, J., Durham, R., Flynn, J., 1983. Production of Channel catfish fingerling, Circular ANR-327 Alabama Co-operative Extension Service Auburn University; Alabama, U. S .A. Pp.19 - 21.

Jothilakshmanan, N., Karal Marx, K. 2013. Hybridization between Indian catfish, female *Hetropneustes fossilis* (Bloch) and Asian catfish, male *Clarias batrachus* (Linn). 12 (9): 976-981. doi:10.5897/AJB11.3215

Khan, R., Mollah, A., Ahmed, U., 2000. Mass production of hybrid magur and its culture potential in Bangladesh. *J. Aquacult. Res*., 31: 1-6.

Khedkar, G.D, Reddy, A.C., Mann, P., Ravinder, K., Muzumdar, K., 2009. *C. batrachus* (Linn.1758) population is lacking genetic diversity in India. *Mol. Biol. Rep*. pp.1. doi: 10.1007/s11033-009-9517-3

Kuo, H., 1969. Notes on hybridization of tilapia. blue, channel, white, and hybrid catfishes. *Progressive Fish-Culturist,* 43: 63-66.

Legendre M., Teugels G. G, Cauty C., Jalabert B., 1992. A comparative study on morphology, growth rate and reproduction of *Clarias gariepinus* (Burchell, 1822), *Heterobranchus longifilis* Valenciennes, 1840, and their reciprocal hybrids (Pisces, Clariidae). *J. Fish. Biol*., 40: 59–79. doi: 10.1111/j.1095-8649.1992.tb02554.x

Nwadukwe, F.O., 1995. Hatchery propagation of five hybrid groups by artificial hybridization of *Clarias gariepinus* and *Heterobranchus longifilis* (Clariidae) using dry powdered carp pituitary hormone. J. *Aquacult. Trop*., 10: 1-11.

Madu, C.T., Okoye, F.C., Sado, E.K., Omoruikoba, V.S., Butkole, N.O., Millita, E.O., 1984. A preliminary reporton Induced breeding trials with the mudfish *Clarias angutllaris. Kl. Rl Annual Report.* Pp. 144-145.

Madu, C.T., Ita, E.O., 1990. Comparative growth and survival of hatchlings of *Clarias sp*; Clrias hybrid and *Heterobranchus sp* under indoor hatchery system. AUFF. R. Annual Report. Pp. 47- 50.

Mires, D., 1982. A study of the problems of the mass production of hybrid tilapias fry. In: R.S.V. Pullin and R.H. Lowe~McConnel (eds). *The Biology and culture of tilapias.* Pp 317.

Mohapatra, B.K., 2004. Conservation of the Asiatic catfish, *Clarias batrachus* through artificial propagation and larval rearing technique in India. *Aquaculture*, 9: 8-9.

Mollah, M.F.A., Tan, E.S.P., 1983. HCG induced spawning of the catfish, *Clarias macrocephalus* (Gunther). *Aquaculture*, 35: 239–247. doi:10.1016/0044-8486(83)90094-7

Morni, M.M., 2003. Study on Cross breeding Between Asian and African Catfish (*Clarias macrocephalus* and *Clarias gariepinus*) and Some Aspects of The Hybrid Larvae Development and Rearing. Kolej University of Science and Technology Malaysia, Master of Science Thesis. Pp. 137.

Mukhopadhyay, N. Ray, A., *1999*. Utilization of copra meal in the formulation of compound diets for Rohu *Labeo rohita* fingerlings. *J. Appl. Ichth*., 15: 127-131. doi:10.1046/j.1439-0426.1999.00132.x

Nam Y.K, Cho, HJ Im, J.H, Park I.S, Choi, G.C, Kim, D.S (2001). Production of all-female diploid and triploid far eastern catfish, *Silurus asotus* (Linnaeus): survival and growth performance. Aquacult. Res. 32: 991-997. doi: 10.1046/j.1365-2109.2001.00634.x

Na-Nakorn, U., 1999. Genetic factors in fish production: a case study of the catfish Clarias. In: *Mustafa, S. (Ed.), Genetics in Sustainable Fisheries Management.* Fishing News Books, London, pp.175–187.

Ndimele, P.E., Owodeinde F.G., Kumolu-Johnson C.A., Jimoh A.A., Whenu O.O. and Onyenania O.B., 2011. Growth Performance of the Reciprocal Hybrids of *Clarias gariepinus* (Burchell, 1822) and *Heterobranchus bidorsalis* (Valenciennes, 1840). *J. Biol. Sci*., 3 (1): 137-140.

Ndimele, P.E., Owodeinde, F.G., 2012. Comparative Reproductive and Growth Performance of *Clarias gariepinus* (Burchell, 1822) and Its Hybrid Induced with Synthetic Hormone and Pituitary Gland of *Clarias gariepinus*. Lagos, Nigeria. Turk. *J. Fish. Aquat. Sci*., 12: 619-626. doi: 10.4194/1303-2712-v12_3_09

Oguguah, N.M., Nwadukwe, F., Atama, C.I., Chdobem, J.I., Eyo, J.E., 2011. Growth performance of hybrid catfish (*Hetrobranchus bidorsalis* (♀) x *Clarias gariepinus* (♂) at various stocking densities in varied culture tanks. *Animal Research International*, 8 (3): 1419-1430.

Oladosu, G.A., Ayinla, O.A., Adeyemo, A.A., Yakubu, A.F. Ajani, A.A., 1993. Comparative study of the reproductive capacity of the African catfish species *Hetrobranchus bidorsalis* (Geoffery), *Clarias gariepinus* (Bur.) and their hybrid "Heteroclarias". African Regional Aquaculture Centre Technical Paper (ARAC) Tech. pap. 92: 1-5.

Omeji, S., Obande, R.A. and Oyaje, J., 2013. Intra-specific hybridization of local and exotic *Clarias gariepinus*. IJMBR 1: 35-41

Peter, R.E., 1987. Lesioning studies on the gravid female goldfish: neuroendocrine regulation of ovulation. *Gen. Comp. Endocrinol.*, 35: 391-401.

Rahman, M.A., Arshad A., Marimuthu K., Ara R. and Amin, S.M.N., 2012. Inter-specific Hybridization and its potential for Aquaculture of Fin Fishes. Selangor, Malaysia. *Asian J. Anim. Vet. Adv.*, 8 (2): 139-153

Rahman, M.A., Bhadra, A., Begum, N., Islam, M.S., Hussain, M.G., 1995. Production of hybrid vigor through cross breeding between *Clarias batrachus* Lin. and *Clarias gariepinus* Bur., *Aquaculture*, 138 (1-4): 125-130. doi:10.1016/0044-8486(95)01076-9

Rahman, M.M., Varga, I., Choudhury, S.N., 1992. Manual on African magur (*Clarias gariepinus*) culture in Bangladesh. Dhaka-Bangladesh FAO-UNDP. Pp. 43.

Rao, G.R.M., Tripathi, S.D., Sahu, A.K., 1994. Breeding and seed production of the Asian catfish *Clarias batrachus* (Lin.). *In: Manual Series 3. A publication of CIFA*, Kausalyaganga, India. pp. 5.

Reddy, P.V.G.K, 2000. Genetics resources of Indian major carps. Optimization of feminisation protocol. Aquaculture, 89: 329-339.

Richter, C.J.J., Edarg, E.H. and Verreth, A.J., 1995. African catfish (*Clarias gariepinus*). In: Brood stock management and egg and larval quality (ed. Niall R. Bromage and Ronald J. Roberts). *Blackwell Scientific publication*, Oxford. Pp. 242-276.

Rosenstein S. and Hulata G., 1994. Sex reversal in the genus *Oreochromis*: Optimization of feminization protocol. *Aquaculture and Fisheries Management*, 25: 329–339.

Sahoo, S.K., Giri, S.S., Chandra, S., Sahu, A.K., 2007. Spawning performance and egg quality of Asian catfish *Clarias batrachus* (Linn.) at various doses of Human Chorionic Gonadotropin (HCG) injection and latency periods during spawning induction. *Aquaculture*, 266: 289-292. doi:10.1016/j.aquaculture.2007.02.006

Sahoo, S.K., Giri, S.S., Sahu, A.K., Ayyappan, S., 2003. Experimental Hybridization between Catfish *Clarias batrachus* (Linn.) x *Clarias gariepinus* (Bur.) and Performance of the Offspring in Rearing Operations. *Asian Fish. Sci.* 16: 157-166.

Salami, A.A., Fagbenro, O.A., Sydenham, D.H.J., 1993. The production and growth of hybrids in concrete tanks. *Isr. J. Aquacult. Bamidgeh*. 45 (1): I – 25.

Srivastava, P.P., Raizada, S., Dayal, R., Chowdhary, S., Lakra, W.S., Akhilesh, K.Y., Sharma, P. and Gupta, J., 2012. Breeding and Larval Rearing of Asian Catfish, *Clarias batrachus* (Linnaeus, 1758) on Live and Artificial Feed. *J Aquacult Res. Dev*., 3: 4. http://dx.doi.org/10.4172/2155-9546.1000134.

Tarnchalanukit, W., 1985. Experimental hybridization Between Catfish of the Families Clariidae and Pangasiidae in Thailand. Kasetsart University. *Fish. Res. Bull*., 16: 8-10.

Um-E-Kalsoom, Salim, M., Shahzadi, T. and A. Barlas, 2009. Growth performance and feed conversion ratio (FCR) in hybrid fish (*Catla catla* x Labeo rohita) fed on wheat bran, rice broken and blood meal, *Park. Vet. J*., 29: 55-58.

Viveen, W.A., Richter C.J., Van Oordt, P.G., Janssen, J.A. and Huisman, E.A., 1983. Practical manual for the culture of the African catfish (*Clarias gariepinus*). The Netherlands

Viveen, W.J., Richtor, C.J., Van Ordt, P.G., Janseen, J.A. Huisman, E.A., 1986. Practical manual for culture of the African catfish (*Clarias gariepinus*). Section for research and technology. The Hague, The Netherlands, pp 121.

Yadav, A.K., Mishra, R.K., Singh, S.K., Varshney, P.K, Pandey, A.K., Lakra, W.S., 2011. Induced spawning of Asian catfish, *Clarias batrachus*, with different doses of GnRH-based drugs. *J. Exp. Zool.*, 14:199-202.