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Review Article

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A Review of Growth-Based Strain Selection Methods in Nile Tilapia Aquaculture

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Abstract

Nile tilapia is one of the suitable fish species for aquaculture development. Fish strain selection for aquaculture development involves various approaches such as selective breeding; (based on phenotypes of individuals), within family selection (*i.e.,* improvement of genetic makeup of individuals by cross breeding between individuals from different families) or combination of these. Species in the genus *Oreochromis* are candidates for aquaculture and selected based on their ability to adapt to salty water environment, feeding habit and growth performance. In this paper strain selection for Nile tilapia based on their growth performance has been reviewed.

Keywords: Nile tilapia; Strain; Selection; Aquaculture; Salty water; Environment; Feeding habit

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Introduction

Fish strain selection is the process of choosing particular group (strain) of the same species having desirable growth performance and tolerant to harsh environmental conditions (such as temperature, salinity and pH) to be used in aquaculture. Aquaculture is predicted to play a major and ever-increasing role in meeting human needs for animal source food. Tilapias are one of the most important fish species for aquaculture all over the world and represent the species of choice due to their high growth rate, significant tolerance to environmental stress and for their market demand [1]. For selecting best performing strain different selection approaches are used. Those are selective breeding in which individuals selected based on their phenotypes without finding information from relatives, within family selection in which individual from each family selected and tested under the same environment (food, water temperature and others requirements) [2]. This is also used in order to improve the genetic makeup of particular strain within family by making cross breeding, Combined selection is individual selection based on individual information and its relatives which increases the accuracy of selection [3]. This all approaches are used in selection of best strain used in aquaculture.

Different species in the genus *Oreochromis*, such as Nile tilapia and red tilapia are used in aquaculture in different environmental conditions. These are often selected based on their salty water tolerance, spawning and nursery performance and growth performance (weight and length). The strain having better performance increases the production and becomes consumers preference. In 2010, the world production of farmed tilapias reached 3.2 million metric tons of which about 35% was produced in China [4]. The Chinese tilapia production increased very rapidly during a 20-year period until 2005 when the annual production reached about one million metric tons [5]. In recent years, however, the tilapia production has stagnated in China due to problems related to unstable climatic conditions (*i.e.,* cold winter temperatures, drought *etc.*) and disease outbreaks. In the past, most of the farmed tilapias in China (60%-70%) were hybrids produced by crossing Nile tilapia (*Oreochromis niloticus*) females and blue tilapia (*O. aureus*) males [5]. These hybrids were preferred due to a high male percentage and better survival at low water temperatures [6,7]. In recent years, China has received several imports of genetically improved Nile tilapia, (all originating from the GIFT project in the Philippines, of which some materials have been further

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adapted to the Chinese production systems by mass selection [5,8]. As a result, an increasing number of Chinese farmers are currently producing genetically improved Nile tilapia due to their faster growth. Selective breeding programs with several tilapia species (*i.e.,* Nile tilapia, blue tilapia and red tilapia) have been established during the recent years to develop genetically improved seed for different production systems in China. All species are selected to improve their growth performances in different freshwater environments. Nile tilapia has also been selected to improve its fillet yield, while blue tilapia and red tilapia are being selected to improve their tolerance to cold water and high salinity water, respectively.

In aquaculture, fish size and production determine the price of fish, which in turn depends on the growth. Subsequently, control of size and production are two important tasks to meet the market demands. Due to the increasing importance of the tilapias in global fish farming, the intensity and diversity of efforts to improve the genetic baseline of these species have intensified over the last few decades. Ponzoni et al. showed that genetic improvement is one of the most powerful and least expensive means of increasing the efficiency of aquaculture [9]. Both traditional animal breeding and science-based quantitative genetic approaches have been used to improve tilapia phenotypes [10]. One common traditional approach to genetic improvement is the practice of individual selection or selective breeding, which is based on the underlying principle that some significant portion of the variation in observable performance is due to individual genotypes and that a component of these genotypic influences is directly heritable from parent to offspring [10]. According to Ponzoni et al. selective breeding has a number of advantages over other genetic approaches; continuous genetic gain is possible, genetic gains can be handed down from one generation to the next and gains in a nucleus can be multiplied and expressed in millions of individuals in the production sector [9]. The Genetic Improvement of Farmed Tilapia (GIFT) project, one of the most significant recent innovations in tilapia culture, succeeded in part because it was based upon using selective breeding of a highly diverse synthetic base population [11].

The most important criterion determining the number of strains to be developed by the GIFT project was relative performance (growth, maturation and fecundity and hardness) in different target environments or the Genotype x Environment interaction (GxE) [8]. A high GxE effect, on the other hand implies that special strains would have to be developed for specific environments. The GxE interaction effect is found to be low, *i.e.,* overall growth performance is found not to differ significantly with environment, in terms of farming relevance. Hence, it would not be necessary to develop different strains for the different farming systems. The principal breeding objective of the GIFT program is growth rate, while monitoring other traits, such as survival, occurrence of disease and maturation rate [8].

In Ethiopia, fish culture is a very recent practice, which has started at small scale level in farmers' ponds by stocking wild fish species, mostly Nile tilapia (*O. niloticus*), collected from lakes. However, tilapias from different lakes of the Ethiopian Rift valley have different growth performances under pond culture [12]. Consequently, these fish farms stocked with wild fish are operating below sub optimally and below capacity because of fish adaptation problem, lack of expertise in technical support, management and reasons like lack of supplementary feed. The excessive reproduction caused by mixed-sex culture which results in stunted fish growth because of the feed and space competition among the over populated fish has been the major problem observed in the ponds. A tilapia strain that is fast growing in one location can be slower in others due to different external factors. The main objective of this paper is to review the way economically important strain of fish selected based on their growth performance after several generation for aquaculture in different aquaculture setting area.

Techniques of Strain Selection

Individual or mass selection

The terms 'individual selection' and 'mass selection' are often used interchangeably and they refer to selection solely based on the individual's phenotype. It has been a common strategy with fish because of its simplicity. It does not require individual identification or the maintenance of pedigree records; hence, it may be considered the least costly method. In principle, it can produce rapid improvement if the heritability of the trait(s) under selection is high. Hulata et al. carried out two generations of mass selection for growth rate with Nile tilapia (*Oreochromis niloticus*) and observed no improvement over the original base population [13]. They attributed the lack of response to selection to a number of possible factors, including inbreeding and genetic drift. They concluded that mass selection was not a promising method unless measures could be taken to control inbreeding. World Fish Center, records indicate that the experience with Silver Barb *(Barbonymus gonionotus)* in Bangladesh and Thailand and Common Carp *(Cyprinuscarpio)* in Vietnam has been of satisfactory response to the selection in early generations up to the fourth or fifth, declining sharply thereafter.

Overall, the evidence suggests that simple, unstructured, mass selection will result in problems unless the number of parents is large and even so, chance could have a negative effect [14,15]. Some form of structuring to control the parental contribution to the next generation appears necessary. Inbreeding rates can be kept as low as one percent per generation if a minimum of 50 pairs is mated and the number of progenies tested from each pair

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is standardized to 30-50 progeny [16]. The guidelines provided by Bentsen and Olesen can be very valuable if they can be put into practice [16]. However, we have found that in some developing countries, the conduct of a large number of pair matings, the subsequent containment of the full-sib groups and the sampling of a standard number of progenies to contribute to the next generation is a task beyond the available resources.

Within-family selection

The method requires identification of the families. This may be achieved by maintaining them in separate tanks, cages, hapas or any other means of containment, without necessarily tagging the fish. The criterion of selection is the deviation of each individual from the mean of the family to which it belongs. Within-family selection is especially advantageous when there is a large component of environmental variance common to members of the same family. Full-sib groups reared in unreplicated hapas or any other form of containment fall into this category. Under such circumstances selection between families would be misleading from a genetic viewpoint because of the confounding between genetic merit and common environmental effects. If replacements are chosen so that every family contributes the same number of individuals to the next generation (*e.g.,* choose one female and one male from each family), the effective population size is twice the actual [17].

The use of within-family selection was recommended for SE Asian countries by Uraiwan and Doyle [2]. It was successfully applied in the selection program that resulted in an improved Tilapia strain developed in the Philippines by the Freshwater Aquaculture Center (FAC) of Central Luzon State University. The selection program and the strain's performance have been described by Abella et al., Bolivar et al., Bolivar and Newkirk and Camacho et al. [18-21]. The selection line started from a base population combining four strains of tilapia. Nineteen full-sib groups were established and the basis of selection was body weight at 16 weeks of age. The heaviest male from a given family is mated to the two heaviest females of another family to avoid inbreeding. After 12 generations of selection, the genetic gain in body weight has been estimated at 12.4% per generation. The selection program is conducted (from spawning to selection) in outdoor concrete tanks, but the strain also performed well in hapas and ponds. Camacho et al. comment that within-family selection was easy to manage and that taking care of inbreeding by means of a rotational mating posed no difficulties [21]. The method reduces the need for tagging large numbers of individuals. They estimate that the implementation of a selection method that entailed the individual identification of large numbers of fish and a period of communal rearing would be more expensive and difficult to implement.

Combined selection

We use the term 'combined selection' in a broad sense, meaning selection that is based on individual information as well as on information coming from relatives (*e.g.,* full and half sibs, progeny). In this case, all of the additive genetic variance is available for selection and the use of information from relatives increases the accuracy of the estimation of breeding values. Earlier work with fish, used selection index theory to combine individual, full-sib and half-sib information [3]. Three documented examples of the successful application of combined selection to the improvement of fish in developing countries will be cited here (in all cases growth rate was the main focus of selection): The GIFT project in Philippines, which reported genetic gains of 12%-17% per generation in Nile Tilapia, over five generations; the JayantiRohu *(Labeo rohita)* selective breeding project in India, which reported a genetic gain of 17% per generation over five generations (personal communication) and the selection project of a Malawian indigenous Tilapia *Oreochromis* shiranus, where the accumulated gain over two generations was 13% [3,22,23]. GIFT and Jayanti Rohu have been tested extensively on farm and proven to outperform other strains used by farmers. We earlier mentioned that the GIFT and Fast strains have very similar growth performance, but GIFT has shown greater survival rate, possibly due to the broader genetic basis in the population originally assembled and to the greater effective population size relative to Fast.

Comparison and selection of species in the genus *Oreochromis*

Tilapia farmers often have problems deciding if Nile tilapia or red tilapia is the proper choice for culture. Nile tilapia is the most widely farmed tilapia world-wide but interest in red tilapia culture is growing rapidly. Nile tilapia is more dependable spawner that produces more consistent quantities of fry than red tilapia. Survival of eggs, fry and juveniles is higher for Nile tilapia and Nile tilapia are more tolerant of low water temperatures than most strains of red tilapia. Red tilapia often has higher market value, are more appropriate for culture in salinities above 10 g/l and are easier to seine harvest from earthen ponds and transport live than Nile tilapia. Red tilapia needs continual selection to retain their red color and pass the red color from generation to generation. Farmers should evaluate environmental conditions, culture system and markets before selecting either Nile tilapia or red tilapia for culture.

Salt water tolerance

Some strains of red tilapia are salt water tolerant. *Oreochromis mossambicus* is known to tolerate full strength seawater and red tilapia with Mozambique tilapia heritage can be cultured in full strength seawater [24]. The Florida and Taiwanese strains of red tilapia both grow

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equal to or better in seawater than in freshwater [25,26]. Florida red tilapia can reproduce in salinities up to 36 g/l, however, egg fertilization, egg hatch and survival of larvae is highest at 12 g/l and drops markedly after 18 g/l [26]. Nile tilapia is not as salinity tolerant as red tilapia hybrids with a genetic component from Mozambique tilapia. Nile tilapia can be adapted to 25 to 30 g/l saltwater but growth is inhibited in salinities above 15 g/l [27,28]. Nile tilapia is reported to spawn in salinities above 20 g/l but egg hatch is reduced in salinities above 10 g/l compared with hatch rates in freshwater and 5 g/l salinity [29].

Spawning and nursery performance

Techniques for spawning red tilapia are the same as those used for other tilapias in the genus *Oreochromis*. Methods of reproducing *Oreochromis sp.* are well documented [30,31]. Major disadvantages of red tilapia culture are the difficulty spawning some strains of red tilapia and the low viability of red tilapia eggs and fry. Hulata et al. compared the reproductive success of red *O. niloticus* from Egypt and red *O. niloticus* from the Philippines crossed with either pure *O. aureus* or *O. niloticus* and *O. aureus* x *O. niloticus* hybrids in earthen ponds [32]. The red Egypt *O. niloticus* x *O. aureus* yielded only a small number of off-spring but all the off-spring are males. No differences are noted for the number of off-spring produced among the other red and wild-type hybrid crosses tested. Survival of all-red tilapia hybrids is lower than survival of *O. aureus*x *O. niloticus* hybrids during the nursery phase. The reason for the poor reproductive performance of the red Egypt *O. niloticus* x *O. aureus* is thought to be caused by behavioral differences during courtship that limited spawning. Low survival of juvenile red tilapia hybrids compared with wild-colored hybrids is because of bird predation on the easily seen red fish.

Siddiqui and Al-Harbi evaluated pure Nile, blue and Mozambique tilapias, the Taiwanese red tilapia and a Nile x blue tilapia hybrid for freshwater tank culture [33]. Survival from fry to 250 g for hybrid tilapia, Nile tilapia, blue tilapia, Mozambique tilapia and red tilapia is 80%, 74%, 72%, 61% and 7%, respectively. Most red tilapia died during the 112-day rearing period from fry to 30 g and was related to genetic factors. No difference in survival is noted among the pure tilapia species, the tilapia hybrid and the red tilapia during grow out from 30 g-250 g when survival is above 96% for all tilapias tested.

Grow-out performance

Red tilapia is grown to market size using a variety of culture techniques similar to those used to culture pure-line tilapia species. Red tilapia is grown in fresh and saltwater with cages, concrete tanks and earthen ponds using semi-intensive and intensive systems [26,34,35]. Green et al. compared the performance of 10 g sex-reversed fingerlings from a mating of Florida red tilapia x *O. niloticus* with wild-type *O. niloticus* stocked at 2/m^2 in earthen ponds fertilized with chicken manure and chemical fertilizers [36]. Final average weights for red and Nile tilapia are not significantly different but total yield and survival significantly lower for red tilapia. Average survival of Nile tilapia is 91% compared to 51% for red tilapia. Lower average yield of red tilapia (772 kg/ha) compared with Nile tilapia (1,353 kg/ha) is related to lower survival and not slower growth. Poor survival of red tilapia is blamed on increased bird predation in red tilapia ponds.

Pruginin et al. compared the growth of Philippine red tilapia *(O. mossambicus x O. niloticus)*, Singapore red tilapia *(O. mossambicus)* and wild-type *O. niloticus* x *O. aureus* hybrids in 500 m^2 plastic lined earthen ponds stocked with 30 tilapia/m^2 [37]. The 3 tilapia strains were stocked together in the same ponds. Ponds were filled with brackish water and provided with aeration and 1%-10% water exchange per day. Ponds were harvested after 160 days and specific growth rates for Philippine red, Nile x Blue tilapia hybrids and Singapore red tilapias were 3.22, 2.56% and 1.43% per day. The Philippine red tilapia grew from 10 g-240 g while the *O. niloticus* x *O. aureus* hybrid grew from 20 g-190 g. The growth rate of the Singapore red tilapia was slow and further studies with this fish were abandoned.

Hopkins et al. compared the growth of 1 g-3 g sex-reversed *O. spilurus*, *O. aureus* and Taiwanese red tilapia hybrids in 2m^3 circular tanks filled with 38 g/l-40 g/l salinity seawater in Kuwait [38]. Tanks were provided with water exchange and aeration and were stocked with 100 tilapia/m^3. Fish were fed a 40% crude protein diet for 226 days. Average harvest weights of the red tilapia, O. spilurus and *O. aureus*, were 132 g, 80 g and 33 g, respectively. The Taiwanese red tilapia grew fastest of the three tilapia species tested but 38% survival forced the authors to reject the red tilapia as a culture species. Low survival of the red tilapia was caused by stress from 19°C-200°C water during the winter months.

Conclusion

In generally selective breeding and other techniques of increasing genetic makeup of fish species increases their values in aquaculture. The selection approach for all strain is almost based on their growth performance (*i.e.,* the better performing fish is selected and used in aquaculture). Various strain selection project also depends on fishes growth performance because, strain of fish with highest weight and length are preferable by consumers. Nile tilapia is the best candidate of fish species for aquaculture in the world and various Nile tilapias strain selection were carried out to improve their genetic makeup as they increase aquaculture production. The better performing strain of fish selected and used in aquaculture to meet protein need and the least performing strain also tested again and again because there may be various internal and external factor that limit them not to perform to the

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required size and length. Various strain of Nile tilapia should be selected at the World level, based on their tolerance to harsh environmental condition like salty water, cold water and other external factor because when they transported from one country to other the strain should be tolerant to environmental condition in the transported area.

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