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Genetic Improvement in Indian Aquaculture: Its Role in Food Security and Sustainability

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Abstract

Recent advancements in genetic improvement programs for commercially important fish species reveal that while many initiatives remain in their early stages, they show promising potential for future development. This article highlights the advancements in genetic improvement programs within Indian aquaculture, driven by the need to enhance the productivity and sustainability of important freshwater cultivable fish species, which is crucial for ensuring food security in the region.

Keywords: Genetic improvement, Jayanti rohu, Amrit catla, GI-scampi, GIFT, Sustainability

Introduction

Aquaculture is recognized as the fastest-growing sector within global food production, currently accounting for nearly half of the world's fish demand. Projections show that production is expected to rise by 40% by 2030 to meet growing consumption demands (Das et al., 2022). Carp, Tilapia, and Shrimp are the most commonly farmed aquatic animals, fulfilling both domestic and international demand for seafood and supporting local and national economies (Miao and Wang, 2020). As aquaculture grows, essential species will face climate change, diseases, and environmental challenges, demanding innovative solutions. Structured breeding programs are crucial for addressing these challenges and advancing the sector.

Breeding programs in the aquaculture industry are designed to improve production efficiency, sustainability, product quality, and profitability while maintaining genetic diversity in the farmed stock (Sonesson et al., 2023). The techniques of induced carp breeding and polyculture in ponds revolutionized the freshwater aquaculture industry. Implementing standardized fish breeding techniques has given rise to applied genetics in aquaculture. Fish breeding is a skill that breeders must master to manipulate th e gene pools of fish through the breeding process.

Genetic improvements can enhance fish production by optimizing traits like growth, carcass quality, and disease resistance (Padhi and Mandal, 2000). Genetic modification, including selective breeding, can be beneficial for sustainable aquaculture production; however, improper practices could harm the industry despite the potential advantages of genetically enhanced fish. Selective breeding is a long-term genetic improvement program involving selecting and breeding individuals or populations with desirable production traits such as growth rate, disease resistance and sex determination over four or more generations (Fig. 1).

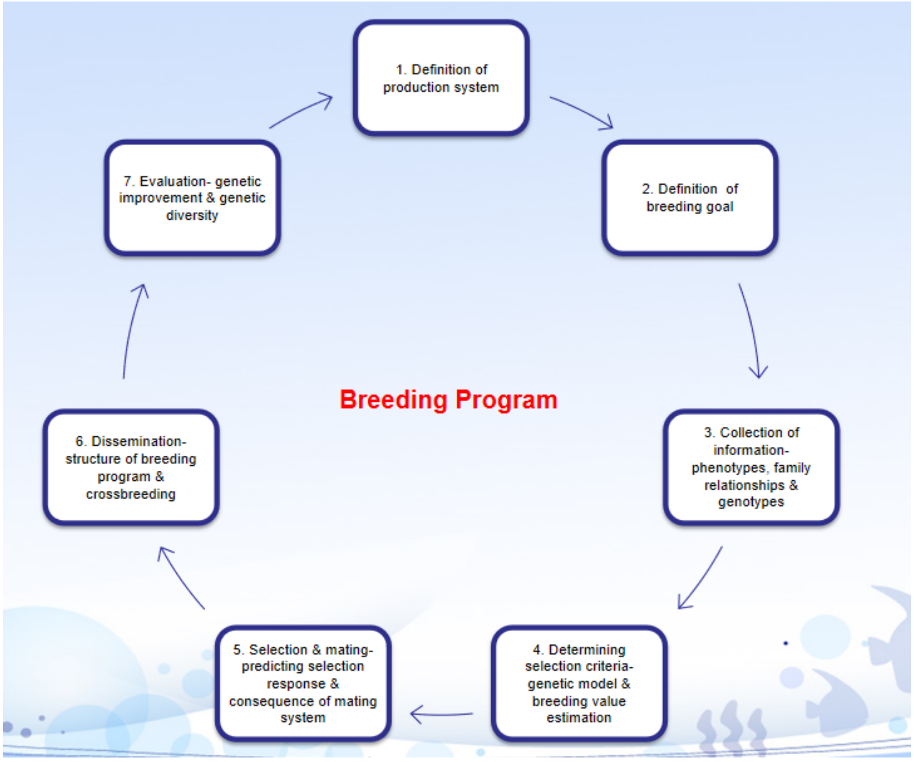

Fig. 1. A cyclic diagram illustrating the selective breeding program in fish

Genetically improved fishes

1. Jayanti Rohu (CIFA IMPROVED ROHU)

In 1992, India launched its first selective breeding program for rohu (*Labeo rohita*) at the Central Institute of Freshwater Aquaculture (ICAR-CIFA), Bhubaneswar in collaboration with the Norwegian institution Nofima. This program aimed to enhance genetic growth traits within the species (Fig. 2-i). Rohu was selected due to its considerable consumer preference and comparatively slower growth rates in multispecies carp culture systems than other Indian Major carps. The base populations for this selective breeding program were sourced from five distinct riverine sources: the Ganga, Yamuna, Brahmaputra, Sutlej, and Gomati rivers, with an additional sixth source from the fish farm of ICAR-CIFA. The main goal of the selection process was to enhance the growth rate. The program has implemented a combined selective breeding methodology, completing 12 generations to date, which has achieved an impressive genetic gain of 18% per generation. Each generation comprises 50 to 60 families within each year class (Mahapatra et al., 2017). In addition, the selection process has also aimed to incorporate a disease-resistance trait against the aerobic pathogen *Aeromonas hydrophila* (see Table 1).

The production costs for an improved variety of rohu remain low, as it can be cultivated using locally produced plant-based feeds that contain 25% protein, thus negating the necessity for high-protein feed alternatives. As a result, this strain reaches market size approximately two months earlier than conventional rohu and can command a premium market price due to its appealing colouration. Importantly, Jayanti rohu is not classified as a genetically modified organism (GMO) and does not pose a risk to aquatic biodiversity. This strain has garnered widespread acceptance among hatchery operators and fish farmers throughout various regions in India, with over 20 million spawns being disseminated annually to different states from the breeding nucleus located at ICAR-CIFA.

Species	Name of GI product	Year	Selected trait/s	Genetic gain/ generation (%)	No. of generations	Reference
Rohu	Jayanti rohu	1992	Body weight at harvest & disease resistance against *Aeromonas hydrophila*	18	9	Mahapatra et al., 2017
Catla	Amrit catla	2010	Body weight at harvest	15	4	Mahapatra et al., 2018
Giant river prawn	GI scampi	2007	Body weight at harvest	7	9	Pillai *et* al., 2017
Nile tilapia	GIFT	1988	Body weight at harvest	17	5	Pulin *et* al., 1991

Table 1. Overview of genetic improvement programs of commercially important species

2. Amrit Catla

Catla is considered second most important fish species in Indian aquaculture due to its fast growth rate, large size, and high market demand, making it a key component of carp polyculture systems. However, its production is hampered by a large head size, which reduces the edible meat yield, leading to genetically improve the species through selective breeding programs to address this drawback and enhance its overall productivity. ICAR-CIFA launched a selective breeding program in 2010 to improve the harvest weight of Catla and meet the demand for high-quality fish seed. The program collected nine strains of *L. catla,* including two riverine strains (Ganga and Subernarekha) from different geographical regions (West Bengal, Bihar, Odisha, Andhra Pradesh, and Uttar Pradesh), to serve as the base population for the selective breeding program using the combined family selection method, incorporating phenotypic information and microsatellite markers (Mahapatra et al., 2018).

Superior animals were selected for breeding based on their breeding value, resulting in significant genetic improvements. Genetic gain reached 35% in the third generation. Field trials in Odisha, West Bengal, Assam, and Maharashtra demonstrated that the improved Catla strain can achieve an average weight of 1.8 kg in polyculture systems, compared to 1.2 kg for local strains within a year. It was recently officially renamed to 'CIFA-Amrit Catla' (Fig. 2-ii). The genetically improved variety was distributed to the National Freshwater Fish Brood Bank (NFFBB) of the National Fisheries Development Board (NFDB). This initiative will allow more farmers to access this improved breed, positively affecting the aquaculture industry. It is part of the efforts by ICAR-CIFA to improve fish seed quality and support the expanding fish farming community in India.

3. Genetically Improved Scampi (CIFA GI SCAMPI)

Giant freshwater prawn (*Macrobrachium rosenbergii*), popularly known by its trade name 'scampi,' is a native species of India that resides in rivers, canals, estuaries, and coastal waters. It is one of the most important cultivable species in freshwater systems due to its high price, large size, faster growth, good taste and high export demand. India was a major producer of this species until the early 2000s, but smaller harvests and low survival rates in ponds have led to reduced returns and a decline in production.

In order to revive the farming of scampi, in 2007, the Indian Council of Agricultural Research -Central Institute of Freshwater Aquaculture (ICAR-CIFA) initiated the selective breeding of scampi in collaboration with WorldFish in Penang, Malaysia. To rejuvenate scampi farming, ICAR-CIFA began selective breeding program for improving the growth rate of scampi in collaboration with WorldFish in Penang, Malaysia, in 2007. The genetically diverse base population for selective breeding was formed by collecting scampi from three regions of India: Gujarat, Kerala, and Odisha. An average genetic gain of 7 % per generation has been obtained after eleven generations of selection (Fig. 2-iii). This newly developed fast-growing scampi are also found to be performing better in farmers' fields in Odisha and Andhra Pradesh. These improved seeds are disseminated to farmers through commercial hatcheries under a Memorandum of Understanding (MoU), which aims to enhance brood development and seed production. Moreover, there has been a significant push to create awareness about the benefits of GI Scampi.

(i) Jayanti Rohu

(ii) Amrit Catla

(iii) CIFA GI Scampi

(iv) GIFT tilapia

Fig. 2. Genetically improved fishes for commercial farming in India

4. Genetically Improved Farm Tilapia (GIFT)

The "Genetic Improvement of Farmed Tilapias (GIFT)" project was a ten-year collaborative research initiative from 1988 to 1997. Its main objective was to develop a genetically improved strain of Nile tilapia through selective breeding. The project was led by WorldFish Center (formerly known as the International Center for Living Aquatic Resources Management) in collaboration with AKVAFORSK (Institute of Aquaculture Research, Norway), and several Philippine research institutions including the National Freshwater Fisheries Technology Research Center, Freshwater Aquaculture Center of Central Luzon State University, and Marine Science Institute of the University of the Philippines to improve growth rates, disease resistance, and overall productivity of tilapia.

Starting with a base population of 40 full-sib families from 8 strains of Nile tilapia, the program achieved significant genetic gains. The eight strains of Nile tilapia (*Oreochromis niloticus*) used in the Genetically Improved Farmed Tilapia (GIFT) program came from Africa and Asia: Four strains collected from the wild in Egypt, Ghana, Kenya, and Senegal between 1988 and 1989, whereas four strains introduced to the Philippines from Israel, Singapore, Taiwan, and Thailand between 1979 and 1984. The GIFT project demonstrated the potential of using selective breeding to enhance the genetic production performance of Nile Tilapia. After five generations of selection, the growth performance of the GIFT strain was improved by more than 80 per cent compared with the base population (Fig. 2-iv).

The GIFT strain is hardier, faster-growing, and more resistant to disease than other tilapia varieties. The GIFT project successfully developed a significantly improved tilapia strain, widely distributed across various Asian countries, significantly boosting tilapia production in the region. In 2008, the Rajiv Gandhi Centre for Aquaculture (RGCA) in Andhra Pradesh collaborated with WorldFish in Malaysia to develop the 8th generation of GIFT in India as part of the GIFT Tilapia project. In India, the Government of Odisha has played a pivotal role in promoting GIFT Tilapia in collaboration with WorldFish. Farmers' adoption of this genetically improved strain has been steadily increasing, as evidenced by the establishment of the GIFT Multiplication Center and hatchery at a government fish farm. The scheme's success in 2021 led to the preparation of new plans aimed at expanding uptake within the private sector.

Future Directions

The focus should be on using genetic tools to enhance precision in breeding, thereby enabling the development of climate-resilient and disease-resistant fish varieties. Additionally, efforts must be directed towards improving the nutritional content of these fish and emphasizing value-addition processes. It is also crucial to strengthen intellectual property rights alongside regulatory frameworks to foster innovation and protect developments in this field. Furthermore, promoting public-private partnerships and fostering international collaboration will be essential to achieve these goals effectively and sustainably.

Challenges and Opportunities

The contemporary aquaculture faces challenges and opportunities, notably in combating genetic erosion while enhancing biodiversity. Addressing the critical issues of disease outbreaks and antibiotic resistance is imperative to ensure sustainable farming practices. Furthermore, promoting environmental sustainability and social responsibility within agricultural frameworks is essential. Expanding aquaculture in both inland and coastal regions presents a strategic opportunity for growth while prioritizing the enhancement of skills and knowledge among farmers and stakeholders will foster resilience and innovation in the sector. Enhance skills and knowledge among farmers and stakeholders.

Conclusion

Selective breeding in aquaculture enhances production efficiency and resource utilization by fostering faster growth, improved disease resistance, and better feed efficiency, making it crucial for modern aquaculture. As environmental challenges increase, selectively bred species exhibit greater adaptability, helping to secure a stable fish supply. This strategy not only boosts productivity and profitability but also fosters economic growth, food security, sustainability, and job creation.

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