BREAKTHROUGH IN GENETIC IMPROVEMENT OF TROPICAL FINFISH THROUGH PARTNERSHIP BETWEEN ICLARM, ASI AND DEVELOPING COUNTRY NARS

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A. SUMMARY

ICLARM (an IARC) in partnership with the Institute of Aquaculture Research, Norway (an ASI), Central Luzon State University and Bureau of Fisheries and Aquatic Resources, Philippines (NARS) undertook genetic improvement of Nile tilapia and demonstrated for the first time that performance of tropical finfish could be improved through simple selective breeding methods. NARS from Egypt, Ghana, Kenya and Senegal collaborated in this effort by supplying wild germplasm from their countries. The 6th generation of improved tilapia developed, popularly known as GIFT tilapia, is showing 30-65% higher growth as compared to local species in a number of Asian countries where it has been tested. The methods developed through this collaborative work are being extended to carp species, which contribute some 60% of global aquaculture production. This partnership has also led to capacity building in developing country NARS institutions and linkages between developing country institutions and eleven ASIs through networking.

1. Projects involved: Genetic Improvement of Farmed Tilapia (GIFT)
   Dissemination and Evaluation of Genetically Improved Tilapia in Asia (DEGITA)
   Genetic Improvement of Carp Species in Asia
   International Network on Genetics in Aquaculture (INGA)


3. INTRODUCTION

Great strides have been made in the last three decades in increasing the production of crops, livestock and poultry through the application of genetics and breeding techniques. However, fish, a commodity on which about a billion people, mostly in developing countries, depend as their primary source of animal protein, have not benefited from the application of genetics and most of the presently cultured species are similar to wild, undomesticated stocks. The world is looking to aquaculture to bridge the gap between projected global supply and demand for fish of some 30 million tons (about 30% of 1995 world food fish production) by the year 2010. This would not be possible unless better breeds/strains are developed along with improved farm management practices. The research undertaken by the Norwegian breeding programs in the 1970s for salmonid fishes had shown the possibility of increasing growth by 3-4% per generation through selective breeding. However, it was not sure whether these genetic gains could be obtained in the case of tropical finfish, which contribute about 90% of the global aquaculture production. Some studies undertaken earlier for genetic improvement of one tropical finfish species in Israel failed, throwing further doubts on the utility of genetic improvement programs. This had thrown the challenge to ICLARM to come up with methods/techniques for the genetic improvement of tropical finfish species used in aquaculture. ICLARM fully realized the need for collaborative efforts in an activity that could bring a revolution in tropical aquaculture production and contribute to the food security of people in the developing world.
4. ACTIVITIES

ICLARM in collaboration with Philippine institutions (Bureau of Fisheries and Aquatic Resources, the Central Luzon State University and the University of the Philippines) and the Norwegian Institute of Aquaculture Research (AKVAFORSK) implemented the GIFT Project from 1988 to 1997 to develop effective ways of producing improved breeds of Nile tilapia (O. niloticus) for low-cost sustainable aquaculture, and to provide the improved breeds to national and regional programs for dissemination to farmers. The activities included: (a) assembling tilapia germplasm from their wild habitats in Africa (Egypt, Ghana, Kenya and Senegal) and ‘domesticated’ aquaculture stocks in the Philippines; (b) estimation of genotype x environment interactions in diverse Asian farming systems; (c) a complete diallel crossing experiment to determine the magnitude of heterosis; (d) establishment of a synthetic base population from the wild stocks; and (e) initiation of simple selection techniques to improve growth performance and other economic traits. Superior performance in terms of growth and survival under on-station and on-farm conditions has been obtained after one generation of selection. The 6th generation of improved strain (GIFT strain) is showing 77% higher growth and 60% higher survival as compared to local strains in the Philippines (Eknath et al 1992; Eknath et al 1998).

Before disseminating the improved tilapia breed for commercial production, ICLARM and its different research partners during 1994 to 1996 undertook detailed evaluation of the genetic and socio-economic performance and environmental impacts of the improved strain in Bangladesh, People’s Republic of China, Philippines, Thailand and Vietnam (ICLARM 1998). Even the 2nd generation improved strain has indicated 30-70% higher growth as compared to local strains in these countries.

Subsequently, ICLARM and its national research partners established the GIFT Foundation International Inc. as an independent non-stock, non-profit organization primarily to continue the selective breeding research on Nile tilapia initiated by the GIFT Project and to undertake commercialization of the GIFT strain through partnerships with the private sector (Eknath and Acosta 1998).

Encouraged by the potential benefits of selective breeding and prompted by the urgent need to genetically improve the cultured stocks of carps with sustainable productivity, Bangladesh, People’s Republic of China, India, Indonesia, Thailand and Vietnam, which are the major carp producers in Asia, have initiated in 1997 a GIFT-type research program for genetic improvement of 5 species of carps (Gupta et al 1998).

Collaborative research and training in fish genetics is important because the field needs strong and more effective research systems, better utilization of scarce resources and matching of complementary skills of national institutions, organizations involved in fish genetics and breeding. Hence, ICLARM and its partner institutions in Asia and Africa established in 1993 the International Network on Genetics in Aquaculture (INGA) as a global forum for collaborative research and training in applied fish breeding and genetics (Seshu et al 1994; Gupta and Acosta, 1999). With a present membership of 13 countries from Asia, Pacific and Africa with ICLARM as member-coordinator and 11 advanced scientific institutions as associate members, the network is undertaking the: (i) development of national breeding programs; (ii) initiating regional research programs for genetic improvement of carps and tilapias; (iii) transfer of germplasm among member countries, following strict quarantine protocols and material transfer agreements; (iv) assistance in formation of national genetics networks; and (v) strengthening of national research capacity.

5. Area: Genetic resource management and biotechnology

6. Region: Asia, Africa and the Pacific
B. STAKEHOLDERS

1. Beneficiaries

- National research institutions (NARS) in 13 countries of Asia-Pacific and Africa (Bangladesh, People’s Republic of China, Côte d’Ivoire, Egypt, Fiji, Ghana, India, Indonesia, Malaysia, Malawi, Philippines, Thailand and Vietnam) who are using the methods developed for genetic improvement of tropical aquaculture species;

- Thousands of small-scale farmers from 7 countries in Asia and the Pacific who received the improved tilapia germplasm and who culture the fish with very low inputs; small scale-farmers from carp producing countries in Asia;

- Poor consumers in urban and rural areas of 13 countries benefiting from low cost production of fish;

- About 54 NARS scientists from 13 countries trained in aquaculture genetics.

2. Research Partners

IARC : ICLARM

NARS :
- Bangladesh: Bangladesh Fisheries Research Institute (BFRI)
- People’s Republic of China: Shanghai Fisheries University; Freshwater Fisheries Research Centre (FFRC), Wuxi
- Côte d’Ivoire: Centre National de Recherche Agronomique (CNRA), Bouake
- Egypt: Central Laboratory for Aquaculture Research (CLAR); Suez Canal University
- Fiji: Ministry of Agriculture, Fisheries and Forestry
- Ghana: Water Research Institute
- India: Central Institute of Freshwater Aquaculture (CIFA); National Bureau of Fish Genetic Resources (NBFRG); University of Agricultural Sciences (UAS), Bangalore
- Indonesia: Research Institute for Freshwater Fisheries (RIFF)
- Kenya: Baobab Farms
- Malawi: University of Malawi
- Malaysia: Universiti Malaya
- Philippines: Bureau of Fisheries and Aquatic Resources (BFAR); Freshwater Aquaculture Center/Central Luzon State University (FAC/CLSU); Marine Science Institute of the University of the Philippines
- Senegal: Department of Fisheries
- Thailand: National Aquaculture Genetics Research Institute (NAGRI)
- Vietnam: Research Institute for Aquaculture (RIA) No. 1; Research Institute for Aquaculture (RIA) No. 2

ASI :
- Australia: Queensland University of Technology (QUT)
- Belgium: Musée Royal de l’Afrique Centrale
- Germany: University of Hamburg

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1 ICLARM collaborators from Africa who provided wild Nile tilapia germplasm
2 main collaborating institutions involved in the GIFT Project
3 ICLARM collaborators who provided assistance in the collection and transfer of Nile tilapia germplasm from Africa to Philippines
Hungary: Fish Culture Research Institute  
Israel: Agricultural Research Organization  
Italy: FAO of the United Nations  
Japan: National Research Institute of Aquaculture  
Netherlands: Wageningen Agricultural University  
Norway: AKVAFORSK (Institute of Aquaculture Research, Ltd.)
Philippines: Southeast Asian Fisheries Development Center, Aquaculture  
UK: University of Wales Swansea  
UK: University of Stirling

Donors: United Nations Development Programme (UNDP)  
Asian Development Bank (ADB)  
International Development Research Centre of Canada (IDRC)  
Ministry of Foreign Affairs (Norway)

C. RESULTS AND IMPACT

1. Accomplishments and impact:

The GIFT project was completed in December 1997. Within this period, selection was undertaken through six successive generations. The improved strain popularly known as the GIFT fish was tested on-station and on-farm under different farming systems (ponds, cages, in integration with rice, etc.) in the Philippines, for growth and survival against the existing strains (ICLARM 1998). In its 6th generation of selection, the GIFT fish has demonstrated 77% faster growth and 60% higher survival as compared to farmed strains in the Philippines. On the average, the genetic gain per generation across five generations of selection was about 12-17% (Eknath and Acosta, 1998).

The second generation of GIFT fish was subsequently tested in four other countries of Asia (Bangladesh, People’s Republic of China, Thailand and Vietnam) which collectively produce about 60% of cultured tilapia worldwide, to assess its performance in different agroecological conditions and farming systems. The study found that the second generation of GIFT strain has a higher growth rate than local strains, the difference ranging from 18% in China to 66% in Bangladesh. This combined with better survival rate, indicated that yield potential for a given farm is between 54 to 97% higher depending on local conditions. Further, the production cost was lowered by 20% to 30%. In the Philippines, it was estimated that a 40% increase in productivity due to adoption of improved strain developed would increase profitability to the producer by 84% (ICLARM 1998).

Analysis of the overall potential impact of the improved fish breed in 5 Asian countries (Bangladesh, People’s Republic of China, Philippines, Thailand and Vietnam) indicates that the adoption of the improved strain will increase tilapia production and consequently the total fish production in a country, enhance profitability of fish farming, decrease tilapia price, increase consumption of tilapia and other fish for non-fish producing consumers and GIFT adopting farmers and increase the welfare of the country’s economy as a whole (Dey, in press).

The research and cooperation between different partners did not end with the GIFT project, but led to the establishment of GIFT Foundation for the continuation of the genetics research and dissemination of the improved strain. Probably, this is the first initiative in establishment of a non-profit foundation to continue research initiated by an IARC and NARS. All the partners of the project are on the Board of the Foundation.
The simple selection techniques developed for the genetic improvement of Nile tilapia is now being extended to five species of carps in six Asian countries (Bangladesh, People’s Republic of China, India, Indonesia, Thailand and Vietnam).

The sustainability of the GIFT project results is evident from demand for the improved germplasm from other countries and also the use of methods by developing country NARS who are not originally part of the project. For instance in Indonesia, the GIFT strain introduced from the Philippines by the Research Institute for Freshwater Fisheries (RIFF) as part of the INGA program, has saved the freshwater aquaculture industry. The superiority of GIFT strain has attracted the attention of both small and large-scale farmers and the culture of this fish has spread widely in freshwater ponds, brackishwater ponds, and floating net cages in areas of West Java, Central Java and East Java (Imron, Hardjamulia and Rukyani 2000).

Using the selection methods developed through GIFT Project, the developing country NARS in Asia, Pacific and Africa have initiated through INGA the national breeding programs for genetic improvement of their indigenous cultured species. INGA has been playing an important role in national, regional and international genetics research aimed at improving production from aquaculture operations and conservation of aquatic genetic resources and biodiversity. Moreover, it has assisted in the collection and transfer of fish germplasm for direct use in aquaculture or utilization in breeding programs. Protocols and quarantine procedures for the transfer of germplasm, based on international codes of practice and material transfer agreements formulated by INGA are used as guidelines. So far, a total of 30 shipments of tilapia and carp have taken place through the network. At present, the network is linking the work of 11 advanced scientific institutions (ASIs), which are Associate Members of INGA, with developing country institutions for synergy. This development is important for the advancement in science of fish breeding and genetics as a whole.

The research partnership has also ensured continuous capacity building in NARS institutions through training programs, workshops and exchange visits of scientists. Intensive training programs on ‘Quantitative Genetics and its Application in Aquaculture’ organized in 1995 for aquaculture geneticists from 13 Asian and African countries are being continued under INGA. A total of 54 NARS scientists have been trained in this program.

The collaborative research for genetic improvement is a landmark achievement in the history of tropical aquaculture and a pioneering effort linking biodiversity research and the development of fish breeding programs. In summary, the collaborative efforts of partners has resulted in:

- developing a simple and environmentally friendly method for genetic improvement of tropical finfish;
- an improved strain of Nile tilapia with over 70% faster growth and survival;
- a regional effort for genetic improvement of five species of carps;
- capacity building of national staff in aquaculture genetics research;
- graduation of 20 students through work on the project;
- establishment of national breeding programs for Nile tilapia in Bangladesh, People’s Republic of China, Indonesia, Philippines, Thailand and Vietnam;
- establishment of a non-profit Foundation for the continuation of research and dissemination of improved strains in the Philippines.
- establishment of the International Network on Genetics in Aquaculture;
- contributions to the science of aquaculture genetics.
- training of 54 scientists from 13 countries in aquaculture genetics and its application in aquaculture.
• thousands of farmers in Asia who are using the genetically improved finfish.

2. Dissemination of the results

The main products of GIFT research are the improved fish breed and the genetic improvement methods developed for adoption by member countries interested in establishing national fish breeding programs.

*Improved fish breed*. Dissemination of the improved tilapia breed (GIFT) was initiated through the performance evaluation trials conducted on-station and on-farm environments in the 5 countries of Asia (Bangladesh, China, Philippines, Thailand, and Vietnam). Subsequently, the improved germplasm was bred and disseminated to local farmers through the NARS. In the Philippines, the GIFT Foundation International Inc is doing widespread dissemination of the GIFT strain in the country through accreditation of tilapia hatcheries.

The transfer of the improved fish breed to other countries is facilitated through INGA/ICLARM. Protocols and quarantine procedures for the transfer of germplasm based on International Codes of Practice and Material Transfer Agreement are being used as guidelines. A total of 7 countries in Asia and Pacific have so far received the improved tilapia strain.

*Genetic improvement methods*. The genetic improvement methods are disseminated to developing country NARS through intensive training programs in quantitative genetics and its application to aquaculture and preparation and distribution of a Manual of Procedures.

Results have also been distributed through:

- Published materials (Scientific papers, articles, brochure) and papers presented in local and international workshop
- Local and international media coverage (television and radio programs and press releases in newspaper)
- Video tape titled ‘Onee’ (a 7-minute presentation on GIFT)

D. PARTNERSHIP

1. Respective roles of different stakeholders and coordination mechanisms

- **IARC (ICLARM)**: coordinating research efforts, providing intellectual inputs in planning and implementation of the projects through its own multidisciplinary research team; ensuring successful implementation of all Project activities in participating countries; facilitating exchange of information, methodologies and genetic materials among research partners, organizing training programs, workshops, cross country visits of NARS; preparing and distributing research reports; sourcing out of project funds.

- **NARS**: providing the necessary manpower (both technical and support staff), taking the lead role in on-station and on-farm testing of the improved strain and in developing and implementing the national breeding programs for the improved fish breed; providing the facilities such as ponds, tanks, a hatchery and farm inputs and if available, the fish germplasm required for developing the synthetic base population.

- **ASIs**: providing advisory services in planning and implementation of the project, analysis of the data generated and training of national scientists; sharing the technical expertise that can be used to assist the research and training needs of NARS institutions.
• **Donors**: providing financial support to the project and development know-how; participating in various consultation meetings prior to the project initiation and subsequent project reviews, guiding the project as it progressed.

Prior to initiation of the projects, extensive consultations were held between ICLARM, participating institutions in Asia and Africa, representatives of advanced scientific institutions and donor institutions for developing the detailed work plans. For the GIFT Project, an advisory panel consisting of eminent geneticists reviewed the project as it progressed and provided guidance in implementation of the project. A Memorandum of Agreement specifying the responsibilities of each of the partner organization, control and use of improved germplasm and the data generated, was signed. Throughout the duration of the GIFT project, ICLARM as the executing institution, employed a consultative management approach by putting in place a Project Management Committee comprising of representatives of various partner institutions.

2. Added value of partnership

ICLARM realized from the beginning that the success of developing tools that would have benefits globally would require having the knowledge of: (a) the needs of developing country institutions and the private sector; (b) basic and applied research of ASIs; (c) skills in planning and implementation of the multidimensional and multidisciplinary projects.

Having realized this, series of consultations were held with NARS, advanced scientific institutions and donors, which resulted in a research partnership that take advantage of the strengths of each of the participating institutions, as detailed below:

- ICLARM (the IARC) which coordinated the entire project and provided the initial impetus and technical skills;
- Philippine Bureau of Fisheries and Aquatic Resources (BFAR) which provided needed infrastructure facilities and addressed national needs;
- Central Luzon State University, Philippines which provided researchers and research facilities;
- Aquaculture Research Institute, Norway (AKVAFORSK) with a track record in genetics of temperate finfish;
- The United Nations Development Program (UNDP) and the Asian Development Bank (ADB) providing development know-how, project formulation guidance, project review and the needed funding; and
- NARS institutions in Egypt, Ghana, Kenya and Senegal providing wild germplasm of Nile tilapia and the institutes in the Philippines providing secondarily introduced strain of Nile tilapia. The established farm stocks in Asia do not form the best genetic base to begin a genetic improvement program because of small founder populations hence it became necessary for the GIFT team to collect breeders from Africa ((Pullin and Capili 1988; Eknath 1995).

E. CONCLUSION

Partnership in research and commitment of partners (IARC, ASI, and NARS) has led to tangible and sustainable results. There was also little time lost in adoption of methods developed and use of improved germplasm, due to involvement of developing country NARS from the time of conceptualisation of the projects. The partnerships between IARCs/ASIs/ developing country NARS have supported the capacity building among NARS institutions thereby ensuring the sustainability of research initiated.
The success of the landmark project can be attributed to the close collaboration of various partners (IARC, NARS, ARI and the donors). Any one of these organizations working by themselves would not have achieved this success. This is a fine example of partners complementing each other’s strengths and skills.

REFERENCES: