From drawing board to dining table: The success story of the GIFT project

M.V. Gupta and B.O. Acosta

As compared to crops and livestock, the genetic enhancement of fish is in its infancy. While significant progress has been achieved in the genetic improvement of temperate fish such as salmonids, no efforts were made until the late 1980s for the genetic improvement of tropical finfish, which account for about 90 percent of global aquaculture production.

This paper traces the history of the Genetic Improvement of Farmed Tilapia (GIFT) project initiated in 1988 by the WorldFish Center and its partners for the development of methods for genetic enhancement of tropical finfish using Nile tilapia (*Oreochromis niloticus*) as a test species. It also describes the impacts of the project on the adoption of these methods for other species and the dissemination of improved breeds in several countries in Asia and the Pacific.

Introduction

The demand for fish has increased worldwide as populations have grown, incomes have increased and the nutritional benefits of fish have become better known. However, it is also well documented that most wild fish stocks have been overexploited or have reached their maximum sustainable yield due to overfishing, habitat degradation and pollution. It is estimated that by 2050, when world population is projected to be over 9 billion, Africa will have had to increase food production by 300 percent, Latin America by 80 percent and Asia by 70 percent to provide minimally adequate diets for the projected population of 2 billion, 810 million and 5.4 billion people, respectively (Anon. 1997). It is estimated that as against a production of 93.2 million tonnes of food fish in 1997, the demand for fish and fish products will increase to 130.1 million tonnes by 2020, an increase of 37 million tonnes (Delgado et al. 2003). Aquaculture is expected to contribute 41 percent to the total production of fish (up from 31 percent in 1997), indicating its importance in meeting the growing demand for fish.

While there is room for increasing aquaculture production through better farm management, the increases in production needed to meet the demand will have to come from the use of genetically improved breeds/strains, as has been the case in crops and livestock (Gupta and Acosta 2001a). Genetic research and the application of breeding programs have been responsible for increased production efficiency and improved productivity in crops and livestock. The Green Revolution of the 1960s and 1970s, with its package of genetically improved seed, farm technology and better farm inputs, has been responsible for enormous increases in crop yields in many developing countries (FAO 2001). In India, for example, wheat yields increased by 50 percent and rice yields by 25 percent (The Corner House 2001). In the livestock industry, the success of genetic applications is most apparent in dairy cattle, poultry, beef cattle and swine. At least 30 percent of the increases in the production of protein have resulted from genetic research and comprehensive breeding programs (Anon. 1988). The success of genetic improvement programs for salmon and trout in Norway is proving to be very similar to that achieved with livestock and poultry (Anon. 1988; Gjoen and Bentsen 1997). The research undertaken by the Norwegian breeding program for salmonid fishes in the 1970s had shown the possibility of increasing growth through selective breeding. At present, over 80 percent of the salmon produced in Norway, the world's major producer of Atlantic salmon, is from genetically improved stocks.

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A harvest of Nile tilapia (GIFT strain) from a pond owned by a private farmer in Bangladesh.

While significant progress has been made in the genetic enhancement of crops and livestock and recently of salmonids, no efforts were made until the 1980s for the genetic improvement of tropical finfish. In many cases, the cultured stocks were worse than the wild populations due to inbreeding (Pullin and Capili 1988). No attempts were made to assess whether the genetic gains obtained in crops, livestock and temperate fish could also be obtained in the case of tropical finfish, which contribute about 90 percent of the global aquaculture production.

The WorldFish Center and its national research partners from the Philippines and Norway took up the challenge in the late 1980s to develop methods for the genetic enhancement of tropical finfish using Nile tilapia (*Oreochromis niloticus*) as a test species (Pullin et al. 1991). This paper describes how this research progressed from the drawing board (planning) in the late 1980s to a global program for genetic improvement of tropical finfish.

Tilapia stocks in Asia

While *O. niloticus* is native to Africa, the species has been introduced to 87 countries (Froese and Pauly 2004). *O. niloticus* was introduced into many Asian countries in the1970s for small-scale aquaculture. The expansion and intensification of tilapia farming resulted in problems such as inadequate seed supply and deteriorating growth performance in many aquaculture production systems (Acosta and Williams 2001). Studies undertaken in the early 1980s by the WorldFish Center and its national research partners from the Philippines confirmed the poor growth of fish as one of the major constraints in tilapia aquaculture (Pullin 1980; Kuo and Neal 1982; Smith et al. 1985; Pullin 1985). The poor genetic status of farmed Asian tilapia stocks was largely due to poor broodstock management, resulting in inbreeding and widespread introgression of genes from undesirable feral *O. mossambicus* (Macaranas et al. 1984; Macaranas et al. 1986; Taniguchi et al. 1985; Eknath et al. 1991). A review of the history of introductions and subsequent transfers of *O. niloticus* revealed that aquaculture stocks in Asia were descendants of a few introductions consisting of very few fish and were probably suffering from genetic bottlenecks (Pullin and Capili 1988).

Realizing that the problems in tilapia rearing and general husbandry were also associated with an inadequate base of knowledge on the biology of this group of species (Pullin 1981), a meeting of leading international tilapia specialists convened by the WorldFish Center in cooperation with the Rockefeller Foundation in 1980, identified genetics research as a high priority (Pullin and Lowe-McConnel 1982). Smith and Pullin (1984) predicted that the future success of the tilapia industry in the Philippines and elsewhere and the degree of participation by small-scale producers depended to a great extent upon improved efficiency of culture methods and the performance of cultured stocks.

Surveys and socio-economic studies undertaken by the WorldFish Center in collaboration with national partner institutions in the Philippines and Taiwan during the early 1980s (Kuo 1984; Smith et al. 1985) and the international Workshop convened in Thailand in 1987 to review the global status of tilapia genetic resources, all

Table 1. Prior research efforts on tilapias by the WorldFish Center and collaborators leading to the project on the Genetic Improvement of Farmed Tilapias (GIFT).

Year (s)	Project/activity	Research partners	Donor	Main results
1980	Bellagio Conference on the Biology and Culture of Tilapias		RF	Recommended research on tilapia genetics, especially conservation of genetic resources
1980-82	Mass production of tilapia fry	FAC-CLSU	RF, ARO[1]	Showed differences in culture performance between different tilapia species and hybrids
1982-85	Cooperative tilapia research project	CAPD, NSYSU	CAPD	Defined genetic and non-genetic approaches to saltwater tilapia culture
1982-85	Intensive mariculture of tilapia	KISR	KISR	Compared species and methods for saltwater tilapia culture
1983-84	Genetic characteristics of foodfishes	UPMSI	WorldFish Center	Showed poor status of Asian *Oreochromis niloticus* stocks and introgressive hybridization with *O. mossambicus*
1984-88	Evaluation of farmed tilapia stocks	UPMSI, UHCL, FAC-CLSU	USAID,[2] IDRC[3]	Confirmed poor status of Philippine *O. niloticus* stocks and that breeders and farmers want better fish; improved electrophoretic methods
1986-90	Tilapia genetic resources for aquaculture	ARO, HU, IAB	BMZ	Documentation of tilapia genetic resources; training and staff exchanges

Source: Pullin et al. 1991.

[1]Supplied a founder stock of Israeli *O. niloticus* (ex-Ghana).
[2]Financed supply of founder stocks of tilapias from Taiwan.
[3]Gave financial support for one year (1984-1985).

Acronyms: ARO – Agricultural Research Organization, Israel; BMZ – Bundersministerium für Wirtschaftliche Zusammenarbeit, Federal Republic of Germany; CAPD – Council for Agricultural Planning and Development, Taiwan; FAC/CLSU – Freshwater Aquaculture Center of Central Luzon State University, Philippines; HU – Zoologisches Institut und Zoologisches Museum, Universität Hamburg; IAB- Institute of Aquatic Biology, Ghana; IDRC – International Development Research Centre, Canada; KISR – Kuwait Institute for Scientific Research; NSYSU – National Sun Yat Sen University, Taiwan; RF – Rockefeller Foundation; UHCL – University of Houston at Clear Lake; UPMSI – Marine Science Institute of the University of the Philippines; USAID – United States Agency for International Development.

confirmed the poor genetic quality and limited genetic diversity of tilapia stocks being used for aquaculture in Asia (Pullin 1988).

Birth of the GIFT project

These findings (Table 1) led to the birth of the Genetic Improvement of Farmed Tilapia (GIFT) project in 1988. The project was funded by the United Nations Development Program (UNDP) and the Asian Development Bank (ADB). It was undertaken in partnership between the WorldFish Center (at that time ICLARM), the Norwegian Institute of Aquaculture Research (AKVAFORSK) and the national fisheries institutions in the Philippines (Bureau of Fisheries and Aquatic Resources, BFAR; Freshwater Aquaculture Center of the Central Luzon State University, FAC-CLSU; and the Marine Science Institute of the University of the Philippines, UPMSI). The objective was to develop methods for the genetic enhancement of tropical finfish, using *O. niloticus* as a test species (Eknath 1992).

Selection of Nile tilapia as the test species

O. niloticus was chosen because of its relatively short generation time of about six months and its suitability for investigation of the application of genetics in aquaculture, from conservation of genetic resources to breeding programs (Eknath and Velasco 1993). It is also an important species for many developing countries because of its many desirable traits, such as hardiness (ability to tolerate shallow and turbid waters), comparatively high resistance to disease and parasites, and suitability for culture in a wide range of farming systems (from simple small-scale waste-fed fishponds to intensive culture systems) (Pullin 1983; Pullin 1985; Eknath 1995; Gupta and Acosta 2001a).

Evaluation of farmed and wild stocks

In order to establish a wide genetic base before starting a genetic improvement program, especially in view of the poor genetic status of farmed tilapia stocks in Asia, 'wild' *O. niloticus* populations were collected from Africa (Ghana, Egypt, Kenya and Senegal) during 1988-1999 and transferred to the Philippines (Pullin et al. 1991; Eknath 1995). The collections were held in isolation and subjected to quarantine procedures for three to seven months in the Philippines (Eknath et al. 1993). *O. niloticus* populations used by tilapia farmers in Asia (Israel, Singapore, Taiwan and Thailand) were also gathered from the Philippines, bringing together a total of eight African and Asian tilapia populations for the genetic improvement program. Further details on the origins and collections of the strains are in Table 2.

For a thorough understanding of the morphometric and genetic differences, the assembled *O. niloticus* populations were characterized using morphometric, electrophoretic and mitochondrial DNA techniques (Eknath et al. 1991). Truss morphometric characterization, which involves detection of subtle differences in variations of shape, revealed very little morphometric differences among the eight strains (Velasco et al. 1996). Results of isozyme electrophoresis showed a

Table 2. Details on the origins and collections of Nile tilapia germplasm

Strain	Origin/collection sites	Date	Numbers collected
Egypt	Egypt- first collection: - Lake Manzallah - Creeks along desert road to Port Said - Lakes around Alexandria Egypt- second collection: - Abbassa - Ismailia	May 1988 August 1989	30 breeders 25 breeders 70 breeders 60 breeders 90 breeders
Ghana	Ghana: Volta river system	October 1988	220 fingerlings
Kenya	Kenya: First generation progeny from a founder stock collected in August 1988	August 1989	800 fingerlings
Senegal	Senegal: - Dagana - Dakar-Bangos - Mbane	October 1988	120 breeders 40 breeders 40 fingerlings
Israel	Derived from founder stocks of Ghanaian origin kept in Israel. The original founder stock (1974) was 9 females and 2 males. Fry from 100-200 single pair mating were shipped to the Philippines in 1979		
Singapore	Descended from a founder stock of Ghanaian origin shipped to Singapore from Israel and from there to the Philippines in 1979		
Thailand	Egyptian origin. Introduced to the Philippines from Thailand in 1987. The Thailand founder stock was introduced from Japan in 1965 (50 fish formed the founder stock; however, the number that actually survived to breed is not clear)		
Taiwan	Descended from founder stocks introduced to the Philippines from Taiwan in 1983-84; previous history not certain but most likely of Ghanaian origin		

Source: Modified from Eknath et al. 1993.

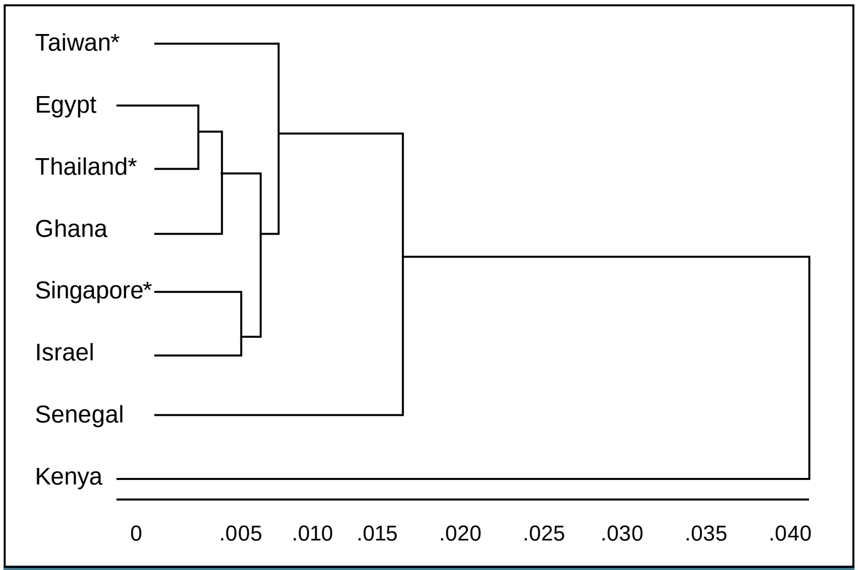

Figure 1. Dendogram constructed from genetic distance values shows separate groups amongst the eight tested populations of *O. niloticus* – a cluster of Philippine farmed strains (marked with asterisks; showing countries of origin of stocks used in the Philippines) with the Egypt, Ghana, Senegal and Kenya strains.
Source: Eknath et al. 1991.

clustering of Philippine strains with those from Egypt and Ghana, suggesting the close identity of these populations; a slight separation of the Senegal strain and a larger separation of the Kenya strain (Eknath et al. 1991; Macaranas et al. 1995) (Figure 1). The wider separation of the Kenya strain probably supports Trewavas' (1983) claim that the Kenya population belongs to the subspecies *O. niloticus vulcani*, while the other African strains (Egypt, Ghana and Senegal) belong to the subspecies *O. niloticus niloticus* (Eknath et al. 1991). The Philippine domesticated populations were genetically more diverse than the strain from Egypt, probably due to introgression with *O. mossambicus* (Eknath 1995). Based on genetic distances between strains, it was assumed that the combinations most likely to increase the genetic variability would be crosses involving the Kenya and/or Senegal strains (Macaranas et al. 1995).

Genotype-environment interaction

The highest performing genetic stock under one set of environmental conditions might not necessarily have the same performance under a different set of environmental conditions. When the relative performances of various genotypes change significantly under different environmental (agroclimatic) conditions, a genotype–environment interaction is evident (Anon. 1988). To assess whether this interaction was of importance in the eight *O. niloticus* strains and whether or not it was necessary to develop specialized strains for each environment, their growth performance was evaluated in test environments covering a wide range of tilapia farming systems in the Philippines: fertilized ponds (with and without supplementary feeding); ponds fertilized with ipil-ipil leaves and vines of sweet potato; rice-fish systems; cages; and three different agro-climatic conditions (Eknath et al. 1993; Pullin et al. 1991). The genotype x environment interactions were estimated by communal rearing of 11 400 individually tagged fingerlings of 8 strains for 90 days over two consecutive generations. The study revealed that, except for the Ghana strain, the other three African strains performed as well as or better than the domesticated strains in the Philippines. The growth performance of the strains was relatively consistent across the test environments, indicating low genotype x environment interaction (Eknath et al. 1993; Eknath 1995). These findings led to a decision to develop a single strain for different farming systems.

As part of the pure strain comparisons, Palada de Vera and Eknath (1993) determined the effects of size at stocking on body weight of *O. niloticus* strains (Egypt, Ghana, Senegal, Israel, Singapore, Taiwan and Thailand) at harvest. Groups of tilapia fry differing in mean size at stocking from 2.9 to 8.3 g did not differ significantly in body weight at harvest after three months of communal stocking. The study concluded that the growth performance of *O. niloticus* appears to be unaffected by initial size differences within this size range (Palada de Vera and Eknath 1993; Bentsen et al. 1998).

Cross-breeding and heterosis

The growth performance and magnitude of heterosis of crossbred and pure bred combinations of eight strains in a complete 8 x 8 diallel crossing experiment, carried out for 90 days in eight different test environments, indicated that only seven out of the 22 crosses that expressed significant heterosis were better performing than the best pure strain (Kenya strain) and the largest gain was 11 percent (Bentsen et al. 1998; Eknath 1995). The least squares mean heterosis within the test environments ranged from 0 to 9.6 percent, indicating that the gain in growth and survival from crossbreeding was marginal and of low significance in terms of a breeding program (Bentsen et al. 1998). In view of this, a selective breeding program based on additive genetic variance was identified as the appropriate breeding strategy.

Establishment of base population

Based on the performance of the pure bred and crossbred groups, the 25 best performing groups were selected to form a genetically mixed base population (synthetic population) and the selection program was initiated (Eknath 1994; Eknath 1995; Eknath and Acosta 1998).

Progenies from the base population breeders (150 full-sib groups within 50 half-sib groups) were evaluated for growth performance, and genetic parameters were estimated by individually tagging fingerlings of the base population and communally rearing them for 90 days in seven different test environments, along with fingerlings of the most commonly used commercial strain in the Philippines (Israel strain) for comparison (Eknath 1995). In on-station trials, the synthetic (base) population was about 60 percent heavier at harvest than the most widely cultured Israel strain (Eknath 1995; Eknath and Acosta 1998).

Selective breeding

Before a selection program is initiated, it is necessary to identify the breeding goal and the traits of economic importance. Traits may be genetically correlated to one another, either positively or negatively. If a primary trait responds to a selection, secondary traits will respond depending on the nature of genetic correlation between the primary and secondary traits (Anon. 1988).

As a deteriorating growth performance was one of the problems in the culture of *O. niloticus*, selection for growth was identified as the primary trait for the genetic improvement program. However, one trait that has a major effect on tilapia growth, especially among the slow-growing tilapia species, is the tendency of females to mature and reproduce early and at small sizes. Investigations on the reproductive activity of individual females of different strains of *O. niloticus* under communal stocking revealed that reproductive activity starts much earlier and at lower mean body weights in slow growing strains than in the faster growing strains (Eknath et al. 1996). In another study, the growth performance of late spawning and virgin female *O. niloticus* was found to be nearly equal to the male growth performance in some of the strains tested. This suggested that if reproduction is delayed in the females, average growth rates comparable to those of an all-male population can be achieved (Bolivar et al. 1993). In view of this, a method for recording the occurrence of early maturing females at a fixed time after stocking was investigated (Longalong and Eknath 1995; Eknath et al. 1996) and a response to bi-directional selection for this trait and correlated response in growth performance was estimated (Longalong et al. 1999). The study revealed that the age-corrected least squares mean of body weight was higher in the progeny of breeders from full-sib families with a high frequency of early maturity in the females, suggesting a negative genetic association between the two traits and the need to carry out combined selection for body weight and frequency of early maturing females in applied breeding programs for *O. niloticus*.

The strategy followed by the GIFT project for selective breeding experiments was a combined between-family and within-family selection. The first to sixth generations of selection focused on growth. A second trait (frequency of spawning females) was included from the fourth generation of selection and was continued during the sixth generation of selection within the resources of the GIFT Foundation (Eknath and Acosta 1998). Six generations of selection (starting from synthetic base population), undertaken during 1993-1997, involved the production of about 200 families by mating 100 selected males with 200 selected females in a nested mating design for each generation of selection. Progenies representing different families were individually tagged and reared in different test environments for 120 days. After the grow-out period, the test fish were ranked based on their breeding value – the additive genetic gain value, estimated by evaluating the performance of the individual itself and its full and half-sibs (De Vera 1998; Eknath and Acosta 1998).

The selectively bred strain was named the GIFT fish (Genetically Improved Farmed Tilapia). The GIFT project ended in 1997 after completing six generations of selection. The genetic gain per generation was about 17 percent across five generations of selection for growth (Eknath and Acosta 1998). The accumulated genetic gain in relation to the base population was 85 percent. The estimated rates of inbreeding for generations 1,2,3,4 and 5 were 0.138, 3.82, 5.34, 7.09 and 7.09, respectively (Eknath et al. 1998; Eknath and Acosta 1998).

Evaluation of the GIFT strain in Asia

The development of the improved GIFT strain of *O. niloticus* was hailed as a significant development in the history of genetic improvement of tropical finfish. However, the WorldFish Center and its research partners recognized that this was only the beginning of the story and the strain developed under Philippine conditions needed to be evaluated for its performance in different agro-ecological conditions/countries before its dissemination was undertaken (Dey and Eknath 1997). As an initial step in this direction, and recognizing the positive and negative lessons learned from plant and livestock breeding and the need to seek advice from international experts on the potential socio-economic and environmental impacts of improved breeds, a meeting on International Concerns in the Use of Aquatic Germplasm was convened in 1992 to discuss strategies/safeguards for the transfer and distribution of GIFT germplasm (Eknath 1995).

Following the recommendations of the meeting, the second to fourth generations of GIFT fish were evaluated in Bangladesh, China, the Philippines, Thailand and Vietnam for their genetic and economic performance (Dey and Eknath 1997; ICLARM 1998; Dey and Gupta 2000).

In these countries, the culture performance of the GIFT strain and the existing 'best' local *O. niloticus* strain (non-GIFT) was evaluated in different farming systems and agro-ecological zones. The GIFT strain performed much better compared to the non-GIFT strains in terms of growth in both pond and cage culture systems (Dey et al. 2000). The performance evaluation of the third generation selected GIFT strain showed, on average, an 18 percent higher body weight at harvest in China and up to 58 percent in Bangladesh (Table 3). This resulted in bringing down the break-even price above variable cost by 7-36 percent (Dey et al. 2000). *Ex-ante* analysis, undertaken in Bangladesh, China, the Philippines, Thailand and Vietnam, indicated that the adoption of the GIFT strain would increase the production of tilapia and, hence, total fish production, lower the price of tilapia and increase consumption, thereby improving the overall nutritional status of the population (ICLARM 1998; Dey 2000).

Table 3. Percentage increase in average weight at harvest and survival when using the GIFT strain as compared to using a non-GIFT strain on average farms: results of on-farm trials.

Country	Culture system	Generation of GIFT strain	Average weight (% increase)	Survival (% increase)
Bangladesh	Pond	3	+57.9***	NS
China	Pond/cage	3	+17.5***	+3.3*
Philippines	Pond	2 3	+22.4 +34.2**	+14.6*** +13.9**
Thailand/Vietnam	Pond	4	+32.3*	NS

Source: Dey et al. 2000.

Note: NS-not statistically significant at 10% level; *** significant at 1% level; ** significant at 5% level; * significant at 10% level. As Thailand and Vietnam used the same strain (Thai strain, probably Chitralada) as control, and as each of the countries had a limited number of trials, the Thailand and Vietnam data sets were combined to increase computational efficiency.

Impacts of the GIFT project

The GIFT project has provided a good example of a multidisciplinary and interactive research initiative with successful partnerships that has progressed into a global program for the genetic improvement of tropical finfish. Figure 2 illustrates the stages of the globalization of methods and outputs from the GIFT project. The impacts of the project are briefly listed below.

Table 4. Yield and variable costs of tilapia farming using GIFT and non-GIFT strains in cages and earthen ponds in on-farm trials.

Items	Bangladesh	China		Philippines		Thailand	
	Pond	Cage	Pond	Cage	Pond	Cage	Pond
GIFT							
Yield (kg/unit area	1 593	3 893	4 645	236	1 361	2 829	743
Variable cost	463	4 191	3 548	168	1 385	1 510	427
Variable cost of fish/kg	0.29	1.08	0.76	0.71	1.02	0.53	0.58
Non-GIFT							
Yield (kg/unit area)	896	3 111	4 275	153	912	2 044	558
Variable cost	405	4 191	1 523	168	1 375	1 517	411
Variable cost of fish/kg	0.45	1.35	0.82	1.1	1.51	0.74	0.74
Percentage difference (GIFT — non-GIFT/non-GIFT)							
Yield	77.8	25.1	8.7	54.2	49.2	38.4	33.2
Variable cost	14.3	0	0.7	0	0.7	-0.3	3.9
Variable cost of fish/kg	-35.6	-20	-7.3	-35.5	-32.5	-28.4	-21.6

Source: Dey 2002.

Note: Units are in hectare for pond and 100 m^2 for cages.

Table 4 illustrates the GIFT project as an example of how a technological breakthrough can affect an aquaculture production system. It was estimated that the technical change or introduction of improved technology could result in a 10 percent decrease in the market price of tilapia (Dey 2002). Dey and Paraguas (2001) indicated that, with the introduction of the GIFT strain of tilapia in Asian countries, it is expected that both the profitability of tilapia production and the competitiveness of their exports of tilapia will improve.

Establishment of an international network on genetics

The outcome of the GIFT project has created an interest in developing countries in Asia, Pacific and Africa in undertaking genetic research and developing their own fish breeding programs. Realizing this, the WorldFish Center through the support of UNDP, organized technical missions to several countries in Asia and Africa to assess the need for fish genetic research and explore the possibility of networking (Seshu 1993). It was found that several areas of research on both tilapias and carps are of common interest across the countries, warranting the need for networking. This led the WorldFish Center to establish the International Network on Genetics in Aquaculture (INGA) in 1993 (Seshu et al. 1994; Gupta and Acosta 1999).

The network has a membership of 13 countries from the Asia-Pacific region (Bangladesh, China, Fiji, India, Indonesia, Malaysia, Philippines, Thailand and Vietnam) and Africa (Cote d'Ivoire, Egypt, Ghana and Malawi), 11 advanced scientific institutions, four regional/international organizations, and one private sector institution. It facilitates: (i) the development of national

2004 Improved carps and tilapias developed in most INGA member countries in Asia; dissemination of improved fish to public/ private hatcheries initiated; development of tilapia breeding program in Africa in progress

2000 GIFT technology transferred for development of national breeding programs in Asia, Africa and the Pacific; GIFT strain disseminated in 11 countries in the Asia/Pacific region

1999 GIFT Foundation formed alliance with private sector company; further improved strain developed from collaboration distributed to world's commercial market

1997 GIFT Project completed; GIFT Foundation established

1994 GIFT strain disseminated and evaluated in five Asian countries

1993 Selectively bred tilapia developed by selection; INGA was established

1988 WorldFish Center and partners from the Philippines and Norway started GIFT project; first direct transfer of pure stocks from Africa

1987 International workshop in Bangkok confirms the poor genetic status of tilapia genetic resources in Asia and Africa

1982 Genetic characterization studies revealed introgression of genes of *Oreochromis niloticus* (Asian stocks) with *O. mossambicus*

Figure 2. Development of GIFT and globalization of methods and outputs.

breeding programs; (ii) initiation of regional research programs for genetic improvement of carps and tilapias; (iii) the transfer of germplasm among member countries, following strict quarantine protocols and material transfer agreements; (iv) the formation of national genetics networks; and (v) the strengthening of national research capacity (Gupta and Acosta 2001b).

The network has disseminated GIFT germplasm to 11 countries in Asia and the Pacific (Bangladesh, PR China, Fiji, India, Indonesia, Lao PDR, Malaysia, Sri Lanka, Papua New Guinea, Thailand and Vietnam) following the international protocol on fish transfer and safeguard measures (Acosta and Williams 2001; Gupta and Acosta 2001b). Figure 3 illustrates the transfer of GIFT germplasm to developing countries in Asia and the Pacific.

Development of National Breeding Programs for GIFT: Bangladesh, China, Fiji, Malaysia, the Philippines, Thailand and Vietnam, which are recipients of GIFT germplasm, have initiated national breeding programs for further improvement of the GIFT strain and dissemination of improved breeds (Hussain and Mazid 2002; Li 2002; Nandlal 2002; Pongthana 2002; Dan and Thien 2002). For example, it is estimated that over 200 million fry of GIFT fish are produced and disseminated annually by public and private sector hatcheries in Thailand (Pongthana, pers. comm.). In Vietnam, further selection of the GIFT strain for faster growth and better tolerance at low temperatures is in progress. After four generations of selection in Vietnam (from the sixth generation of selection in the Philippines), growth has been further improved by 20 percent (Tran Mai Thien, pers. comm.). Nearly two million improved tilapia seed have been produced at the Research Institute of Aquaculture No.1 and disseminated in the Northern provinces (Dan and Thien 2002). In the Philippines, the Bureau of Fisheries and Aquatic Research crossbred GIFT fish with other local strains and came up with a GIFT derivative, named GET-EXCEL, and is disseminating it among farmers (Tayamen and Abella 2004).

In Fiji, the best performing tilapia strain (Chitralada strain) was evaluated against the GIFT strain and the latter was found to be better performing. The GIFT fish has also been improved further through three generations of selection, and more than half a million GIFT fingerlings have already been distributed to subsistence and semi-commercial farmers throughout the country (Nandlal 2002).

Further improvement of the sixth generation GIFT fish is being undertaken in Malaysia by the WorldFish Center in collaboration with the Malaysian Department of Fisheries. Ponzoni et al. (in press) indicates that, despite having undergone several generations of selection, the GIFT population still has additive genetic variance to enable further improvement. The observed selection response was 10 percent after one round of selective breeding work in Malaysia, despite heavy tag losses during harvest time.

Transfer of GIFT technology to sub-Saharan Africa and Egypt

Africa, the home of the tilapia, has a high potential for tilapia farming, but currently benefits the least from the GIFT strain developed in the Philippines (Dey and Eknath 1997). This is due to concerns that the introduction of GIFT fish might contaminate the wild germplasm and the WorldFish Center policy of not introducing the GIFT fish to countries where it is indigenous.

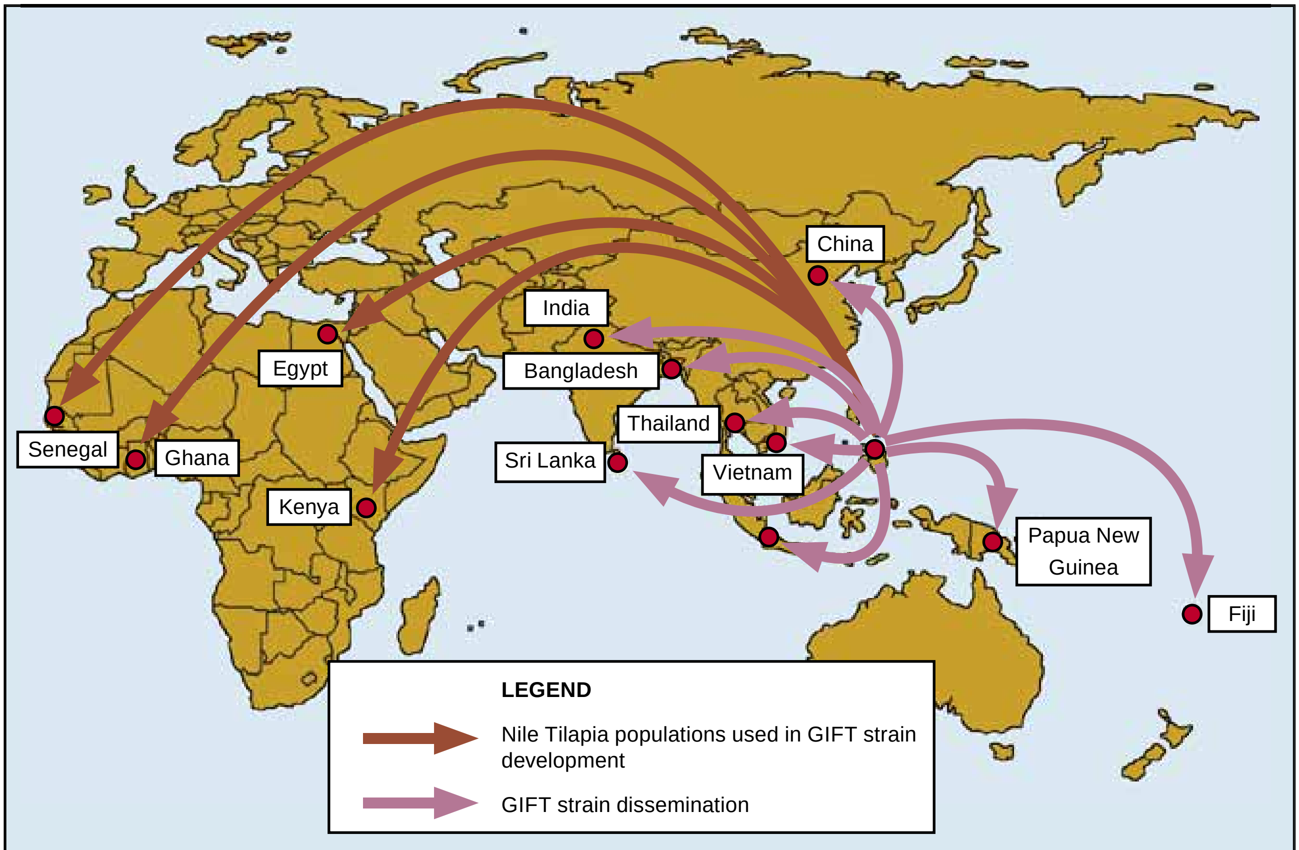

Figure 3. GIFT germplasm transfers to developing countries in Asia and Pacific.

An expert consultation sponsored in 2002 by the WorldFish Center, the Food and Agriculture Organization of the United Nations (FAO), the World Conservation Union (IUCN), United Nations Environment Programme (UNEP) and Technical Center for Agriculture and Rural Cooperation (CTA) cautioned against introduction of the GIFT fish to Africa (Gupta et al. 2004).

To overcome this, the GIFT methodology is being applied to the genetic improvement of indigenous tilapias in Cote d'Ivoire, Egypt, Ghana and Malawi. Research is in progress for the genetic improvement of *O. niloticus* in Cote d'Ivoire, Egypt and Ghana, and *O. shiranus* in Malawi (WorldFish Center 2003).

Establishment of the GIFT Foundation International Inc.

After the completion of the GIFT project in 1997, the WorldFish Center and its Philippine partners established the GIFT Foundation International Inc. The Foundation is an independent non-stock, non-profit organization (Eknath and Acosta 1998) with a mandate to: (i) continue the selective breeding program and maintain the fish collections of the breeding nucleus; (ii) produce the commercial breeders needed by the satellite licensed hatcheries; (iii) provide some coordination in establishing standards that need to be met by the licensed hatcheries; and (iv) provide the GIFT system with brand development and marketing support (Rodriguez 2002).

In the Philippines, where the GIFT strain and the selective breeding technology were disseminated primarily through the GIFT Foundation, the tilapia industry is now reaping the benefits of the improved fish. Rodriguez (2002) reported that the Foundation, through its licensing arrangements with privately owned hatcheries in the country, has increased the distribution of high quality GIFT fingerlings from 50 million in 1998 to over 200 million in 2001. The GIFT Foundation estimated that during 2001 about 200-250 million GIFT fingerlings were produced, fulfilling 20 percent of the total demand for tilapia fingerlings in the Philippines (Rodriguez, pers. comm.).

Private sector involvement

In 1999, the GIFT Foundation entered into an alliance with GenoMar, a private sector company based in Norway with expertise on the use of bioinformatics tools. Through this alliance, GenoMar has received the rights to continue selective breeding and to distribute the further improved GIFT strain internationally. The new strain, developed from Generation 10 (seventh generation of selection) GIFT strain, is now known commercially as GenoMar Supreme Tilapia and is being distributed to local farmers in the Philippines through accredited local hatchery operators and to the world's commercial markets through GeoMar's distribution channels in Asia, Latin America and Africa (GenoMar 2003).

Transfer of GIFT technology to carps

Building upon the success of the GIFT project, six major carp producing countries in Asia (Bangladesh, China, India, Indonesia, Thailand and Vietnam) have initiated research for genetic improvement of rohu (*Labeo rohita*), common carp (*Cyprinus carpio*), silver barb (*Barbonymus gonionotus*) and blunt snout bream (*Megalobrama amblycephala*). The studies have shown that the growth of these carps can be increased by about 10 percent per generation (Gupta et al. 2001c; ICLARM 2001).

Intellectual property rights

The improved GIFT strain is in the public domain and is accessible to any government for research and development. The WorldFish Center continues to provide the GIFT strain on request from governments, following internationally agreed material transfer agreements and quarantine protocols and after assessing the biodiversity and environmental implications.

Future directions

Some of the major problems faced by the developing world today are food insecurity, malnutrition and environmental degradation. To ensure that the improved breeds are available to small-scale farmers, INGA/WorldFish Center continue to provide assistance to member countries for developing national strategies/guidelines for the effective dissemination and maintenance of improved fish breeds. This will also include assessing the involvement of the private sector and facilitating the access of small-scale farmers to the improved strains.

To keep pace with the rapid expansion in fish farming and fish demand, an assessment of other traits for possible inclusion in selective breeding programs needs to be made. The on-going selective breeding work in Malaysia by the WorldFish Center and the Department of Fisheries is focusing on fillet yield and flesh quality in addition to further improvement of growth rates. Other economically important traits will also be investigated in the near future (Ponzoni, pers.comm.).

The option of combining the traditional breeding approach (selective breeding) with other approaches (e.g., sex control) and applying modern biotechnology (e.g., molecular marker-assisted selection) for maximum genetic gain will also be explored (Gupta and Acosta 2001c).

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