THE ROLE OF THE ASIAN INSTITUTE OF TECHNOLOGY IN THE PROMOTION OF TILAPIA FOR AQUACULTURE

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ABSTRACT

*Fifty Nile tilapia (*Oreochromis niloticus*) fry given as "gift" from the present Emperor of Japan to the King of Thailand in 1965 were the original stock of popularly known Chitralada strain today. Perceiving the potential value of phenomenal self-recruitment as seen in the pond in Chitralada palace where they were maintained, the King gave 10,000 fingerlings to Department of Fisheries (DoF) for distribution to farmers. The DoF distributed the fish to 15 inland fisheries research stations to distribute to the public. Tilapia was the focus of AIT's research since early 1980s and even became a vehicle for trips to reach poor farmers. AIT maintained the stock in hapas-in-pond, conducted series of research trials over a decade, developed practical techniques of fry production and grow-out. Low-cost grow-out technique in green water coupled with nursing of fry in hapas at early stage was transferred through Aqua Outreach program in Asia. Due to the promotional efforts of various organizations, Nile tilapia gained increasing interest among farmers. It became the most widely cultured fish in Thailand overtaking catfish in total production since 90s. However, wide adoption of tilapia farming was still hindered by unavailability of large quantity of quality fry which was realized by researchers at AIT and attempts were made in finding a practical solution to this and its dissemination. A success in producing consistently high quality mono-sex fry on a mass scale using hormonal sex-reversal helped improve consistency of marketable size and improved profitability and encouraged intensification of tilapia farming. The mono-sex production method consists of techniques of maintaining large number of broodfish in hapas, collection and artificial incubation of their eggs, and a practical method of sex-reversal. This combination of techniques developed at AIT was successfully transferred to the private sector in addition to the public sector with contractual arrangements. As a result, now there are over 20 such type of hatcheries in Thailand alone; one of them produces up to 20 million fry per month. This technology has now spread world-wide e.g. Bangladesh, Brazil, Myanmar, Nepal, PR China, the Philippines, Vietnam, and others. This paper describes the approaches and strategies applied by AIT hoping that these should be good to follow by others too.*

Citation:

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1. INTRODUCTION

1.1 Background

Aquaculture program at AIT was launched in 1981 as a separate Field of Study to promote sustainable aquaculture development and management of small-scale inland capture fisheries aiming at achieving food security and poverty reduction. The program was the offshoot from environmental and sanitation engineering. Therefore, initial research was using tilapia in sewage treatment and research on waste-water fed aquaculture. The program also focused on technological development, such as methods of breeding and culture techniques of carps, tilapia, catfish and others. Finally, it expanded to broader perspective taking consideration of social and environmental dimensions. Integrated planning and management of aquatic resources and community based fisheries management (CBFM) became strong research themes. These complemented the traditional strengths in the development and application of sustainable technologies using the fundamental knowledge of fish nutrition, fish breeding and grow-out practices. In order to reflect its wide spectrum of activities the Aquaculture program was renamed as "Aquaculture and Aquatic Resources Management (AARM)" in 1997; by then AARM became a successful field of study of AIT within the School of Environment, Resources and Development (SERD). AARM is playing a leading role in the promotion of sustainable aquaculture in the region including tilapia farming as one of the most sustainable practices, especially suited for rural areas. There is a need to highlight the role, which could be a model for other organizations to follow its in their region/countries. This paper; therefore, describes various approaches and strategies adopted by AIT in promoting tilapia culture and the aquaculture as a whole.

1.2 Why Tilapia?

Although tilapias were originally from Africa, they are not considered aliens in Thailand. One may ask why Nile tilapia (*Oreochromis niloticus*) became a focus species when there were over 200 species available for culture in different parts of the world. There were several underlying reasons. One of them is that it has a special history in Thailand. It was first introduced in 1965 to the Royal Palace as a gift by the Japanese Emperor. After successful breeding in 1966 without the need of hormone injection unlike in other species, HM the King gave 10,000 fingerlings to DoF which distributed the fish to 15 inland fisheries research stations. Common people started to receive tilapia from them since 1967 (Pullin, 1988; Bhujel and Stewart, 2007). Many Thais consider tilapia as precious fish probably because it is thought to be the King's fish. After obtaining the fish, realizing quickly its ease of breeding and culture, it started to develop improved and low cost culture techniques through research. In developing world, simple and low-cost techniques are the ones which have high adoption and success rate. As tilapia survived well in adverse environmental conditions, it became the species of interest among common people as poor-men's fish. Rich farmers grow shrimps, catfish and snakehead. However it started to attract even richer farmers as an alternative when shrimp farming was devastated by diseases. Tilapia was seen since then as potential species to become aquatic chicken which can be grown in culture systems ranging from backyard to intensively managed tanks and ponds (Little, 1998). Various on-station and on-farm research have showed that tilapia can rely on planktons as feed which can be produced simply by fertilizing or manuring of ponds by adding easily available chemical fertilizers used for rice e.g. urea, triple super phosphate, and manures available in their animal barns. People could also add rice bran, oil cakes and others, as fish feed to increase productivity, which are produced in their farms as byproducts. As a results, now, not only in Thailand, but also other countries in the region, for examples, China, Laos, the Philippines, Vietnam, Taiwan, Malaysia and Indonesia, tilapia has gained its popularity and people do not treat tilapia as exotic, but cherish it as a very important species.

1.3 Seed Quantity and Quality: Critical Problem

Precocious breeding behavior of tilapia without any hormone injection in captivity was thought to be the main advantage over other species. This provided an opportunity to the resource poor farmers in having and managing their family-scale fish ponds. There were many hatcheries producing mix-sex fry in Central Thailand before the mono-sex fry production technologies were developed (Little et al., 1994). However, when the tilapia farming became more expanded and specialized, number of tilapia farmers increased so did the demand for good quality fry increased dramatically. It was not possible for the hatcheries to produce and supply large quantity of fry. The number of eggs, an individual female could produce i.e. about 1,000 eggs per spawn, and asynchronous spawning became the constraint. At the same time, because quality indicators such as uniformity, growth potential and survival became questionable. As a result, production of sufficiently large quantity of good quality seed became inevitable but was still a big challenge (Little et al., 1997; Bhujel et al., 2000). Nevertheless, the problem was quickly realized that tilapia culture was not expanded as was expected. This provoked the research program at AIT that aimed at developing mass fry production technique for hatchery operators. Section 2 describes about how the research was carried out.

2. RESEARCH AND DEVELOPMENT: SOLUTION STEP-I

Tilapia received the focus for research and development at AIT due to its potential mainly for serving rural resource poor farmers. AIT procured the first batch of Nile tilapia fry from a commercial hatchery called Lee Meng Huat. They were kept in hapas and continuously bred to produce fry and fingerlings to be used for research trials. Establishment of brood stock started in 1984 though research into low cost tilapia based aquaculture started much earlier i.e. 1979. Initial focus was about developing a system to reuse wastewater and, subsequently septage before then also assessing opportunities for livestock fish (egg duck research), agricultural wastes and by-products (e.g. water hyacinth, etc) and integrated farming more holistically, then started developing mono-sex fry production. The first series of studies was a comparison of breeding in earthen ponds, hapas-in-ponds and tanks within a recirculation system (Little, 1989; Macintosh and Little, 1995). Later they included determining the stocking density, feeding rate, hapa size and so on for maximum seed production improving from simple fry collection method from earthen ponds, hapas and tanks to the development of an artificial incubation system (Little, 1989). One of the major challenges was to explore the best system or method, and container or jar for artificial incubation of eggs that could ensure high hatching rate and survival of eggs and yolk-sac larvae to swim-up fry consistently. Learning from other systems e.g. use of conical vessels and shaking tables (Macintosh and Little, 1995), various containers were tried such as simple coke bottles and white water bottles (Fig. 1). However, semi-transparent fiber-glass jars (Fig. 2: bigger size) locally made was found to be the best. Attempts are still going on to explore possibility of using new containers for the improvement in hatching and survival of eggs/larvae. Recently, simple plastic incubators (Fig. 2: small jar) have also been used mainly because they are easily available in local markets at cheap prices, more transparent so that the hatchery operators can see the egg movement easily, and they are also lighter and easier to handle. However, relatively rough wall of the fiberglass jars facilitate egg hatching accelerating the process of removing egg's hulls.

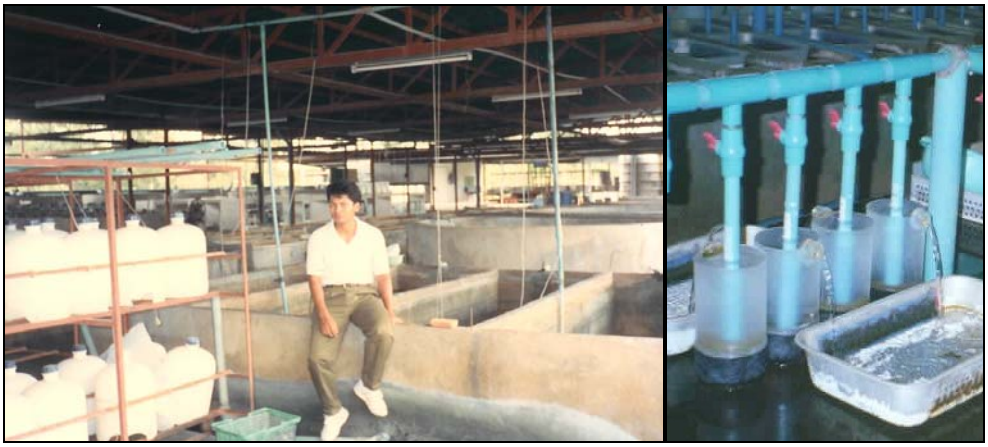

Fig. 1 Developing a tilapia egg incubation system; 20-L white bottles used for drinking water distribution (left) and round-bottomed coke bottles (right).

Fig. 2 Fiber-glass jar (big) and plastic jar (small) for egg incubation and trays for larval rearing.

As tilapia eggs are heavy and remain at the bottom, they needed to be moved gently so that they would not get injured and stay at the bottom without getting adequate oxygen. For this, up- and down-welling water flows into the jars were compared and the downward water flow was found to be better which has been commonly used by the hatchery operators. After hatching, finding a suitable system for post-hatch fry rearing was another challenge. Use of shallow trays for yolk-sac fry was another innovation due to which a large number of fry has been made possible to rear in shallow water oxygenated by its gentle movement. Number of trials to study the effects of factors such as fry density and water flow rate on the fry survival, showed higher densities e.g. 20,000 – 30,000 yolk-sac fry are even better.

Several trials were conducted in order to improve survival and increase percentage of males in the fry populations. These included determining the optimum dose of methyl-testosterone in feed, frequency and length of feeding period and so on. As a result high percent of males (100% or close to) were consistently achieved. Methods of nursing and advanced nursing (Little et al., 2003) when they needed to keep longer period also were developed through research.

With a gradual improvement in the end step of the whole process, a complete package of mass-scale fry production technology was developed through untiring efforts of number of researchers. Research is still on-going especially to make it more adaptable to the environmental conditions and for the manipulation of fry production and supply market demand (e.g. Bhujel et al., 2001; 2007). Many research projects secured/launched, and also the student research, were either only on tilapia or in combination with other species. Until now, more than 100 student theses (M.Sc. and PhD) have been produced related to tilapia. Majority choose research on tilapia. In some batches e.g. in 1985, out of 14 theses produced, 10 were on tilapia, similarly, 10 on tilapia out of 18 in 1989. Research areas covered varies. Initially, tilapia was used as means for waste recycling (AIT, 1994; Edwards and Pullin, 1990), its fry as feed to other species e.g. snakehead (Kaewpaitoon, 1992) and dominant species with others in polyculture e.g. carps, catfish and prawn/shrimp from semi to intensive production systems (Little et al., 1998). More than 150 peer reviewed journal articles have been published in tilapia alone (Bart, 2004). Significant numbers of popular articles have also been appeared in several magazines and newsletters. They served as main information outlets to the outside world and have contributed significantly to the adoption, culture tilapia technologies and overall development of aquaculture in Asia and beyond. For example Brazilian aquaculture has grown significantly as a result of *Chitralada* broodstock and AIT's hatchery technology.

3. TECHNOLOGY TRANSFER AND DISSEMINATION SOLUTION STEP-II

While continuing the research for further improvement in the technologies, dissemination of research findings and the technology packages was taking place in various ways. The major approaches used are briefly discussed in this section.

3.1 Formal Education

Both theoretical and practical aspects on tilapia culture and breeding techniques were well incorporated into the post-graduate curriculum at AIT, a post graduate academic institute where students from about 50 countries enroll each year. A course, Aquaculture systems covers general overview comparing with other species and where tilapia fits in. A course named, Fish Breeding or "Aquatic Seed Production" is the one to cover tilapia breeding aspect while in other courses such as Water Quality Management and Aquaculture Nutrition and Feed Technology, tilapia grow-out is included as group studies. Students are assigned to manage tilapia grow-out trials for which water, sediments and fish samples are collected for laboratory analysis. Many of these students are lecturers at the Universities in their home countries. Several of them were/are even high ranking Government officials who are involved in planning and management of aquatic resources in those countries. Inclusion of tilapia farming while designing of curricula has a great longer and long lasting impact in the promotion of tilapia especially in developing countries. AARM-AIT has also played significant role by assisting its partner institutions for example in Bangladesh (Bangladesh Agriculture University and others), Cambodia (Royal University of Agriculture), Nepal (Institute of Agriculture and Animal Sciences, Chitwan) Thailand (Various vocational colleges) and Vietnam (University of Agriculture and Forestry, Ho Chi Minh City, Nha Trang University, Nha Trang, and Research Aquaculture No. 1, Hanoi) in developing their curricula for both undergraduate as well as post-graduate levels. In those curricula, emphasis has been given more on practical aspects and case studies of various aquacultured species in which tilapia has appeared one of the main species not-to-miss in their syllabi.

3.2 AARM graduates and staff

After acquiring knowledge and skills at AIT many graduates or alumni and staff are directly or indirectly involved in tilapia farming and its promotion. Many of them are successfully running tilapia hatcheries and farms in Thailand while few others in other countries. Among them few are given here as examples. Mr. Randy Bevis (Alumnus 1994), a US citizen, established a tilapia hatchery called the Chiang Mai Aquatic Development Farm outside of Chiang Mai, Northern Thailand. It is operated under the Northern Thailand Foundation for Enablement, a non-profit foundation. It employs 40 people and produces about 2 million Nile tilapia and 1 million red tilapia SRT fry per month. They have started a cooperative for producing fingerlings for the cage culture industry, providing micro loans to the nursery farmers. A Thai alumnus, Mr. Amorn Luengnaruengmitchai, runs Manit Farm as Managing Director. The farm was established in 1993 adopting AIT technology. Located in coastal area called Phetchburi Province of Thailand, it produces about 10 million sex-reversed tilapia fry per month to supply to over 1,000 tilapia farmers. The Manit farm has played very important role in promoting tilapia especially in the private sector as it was the one which adopted the technology earlier than any others. It has been one of the leaders for the production and supply of tilapia fry being itself as a grow-out farm. Another Thai alumnus Mrs. Rachada (Pui), Head of the Fisheries Section, College of Agriculture Technology in Udonthani Province has established and run a hatchery in her college with the aim of teaching students about tilapia breeding and also produce and supply fry to the farmers in the province.

Mr. Mark Amechi (Alumnus 1995) has established a farm in Ghana named Tropo Farms which employs more than 35 staff, produces and supplies fish and fingerlings, has served as an example of a successful tilapia farm for African continent. Similarly, several AIT graduates from Bangladesh are directly or indirectly involved in tilapia promotion and also running of hatcheries. For an example, Mr. Shahbuddin, a recent graduate, has just started a tilapia hatchery in Bangladesh by taking AIT fish and incubation jars. More recently, one of the AARM alumni, Dr. Madhav Shrestha has started a prototype hatchery at the Institute of Agriculture and Animal Science (IAAS), Nepal. The purpose of the hatchery will be to teach students and show his students and also produce and supply fry to the farmers. Even in Myanmar where outside influence is considered minimal, one of the AIT alumni and the former Training and Consultancy Unit (TCU) staff Mr. Tin Maung Thann decided to return back home country being confident that he could rely on tilapia hatchery business. He established three hatcheries after mid-90s.

There are several staff and technicians who left AIT and established their own tilapia hatcheries. Among them the most successful tilapia hatchery has been the Nam Sai Farm located in Prachinburi Province of Thailand. Mr. Warren Turner, a British national and former employee of AIT who was involved in tilapia research established the farm in 1994 and has been running successfully. The farm has grown up to 80 ha of land employing about 200 staff from just about 10 ha of land with less than 10 staff. Now more than 20 staff are aquaculture graduates. The remarkable achievement is that the farm has been able to produce and supply up to 20 million fry of Nile and red tilapia together in a single month. The farm has moved further in franchising other producers by supplying management techniques and required materials. This can be considered as reflection of growing tilapia industry in Thailand. This farm serves as an attractive site for research and work experience. Several students from AIT, Thai colleges/universities and University of Stirling (UK) have already been placed. In addition, the farm itself produces and provides grow-out manual to its customers or others whoever is interested as a technical support that actually promotes tilapia farming. The farm has also been featured several times by various TV channels/programs as one of the successful tilapia hatcheries in Thailand.

3.3 Demonstration

A prototype hatchery built at AIT on-station has been running till now. It has served as a demonstration site for many visitors from abroad and students of Thai Universities, colleges and even secondary schools. Tilapia hatchery has been an interesting unit also for distinguished guests of AIT even Royal families, when there are visits graciously paid by Royal families of Thailand and other countries, for examples, visits of Princess Mahachakri Sirindhorn and the King of Sweden in 2003. The hatchery and technology are additionally highlighted including live TV coverage. Basic purpose of the AIT hatchery was to produce for research but started to supply also to farmers who come and picked up the fry. In doing so, they see the system and some ideas and spread the words from mouth to mouth. This is a model demonstrating of non-profit organizations. Others including government stations could do to generate income so that further research and technology dissemination can be continued in the long run using the income from fry sale to farmers.

In Vietnam, facilitated by AIT's partner institutions, a manager of Vietnamese company visited private hatchery in Thailand established by AIT's technical assistance, has established a hatchery (Fig. 3) near Ho Chi Minh City in the Children's park where children enjoy also seeing and learning about tilapia incubation and larval rearing system.

Similarly, few groups representing private companies and cooperatives from Bangladesh have visited AIT's tilapia hatchery as well as private hatcheries. Without having formal training some of them have established tilapia hatcheries in Bangladesh. It was possible because, they were so keen on and measured all the specifications with photographs of each section so that they could imitate the system.

Fig. 3 A Nile tilapia hatchery in Ho Chi Minh City in a children's park

Another hatchery named Phu Huu Tilapia hatchery is located near Ho Chi Minh City run by Mr. Liem, an alumnus of University of Agriculture and Forestry (UAF), a long term partner of AIT.
This hatchery was established in 1988 and produces mono-sex fry of Nile and Red tilapia. A company called Minh An owned by Ms. Minh An, a former student of UAF produces a red tilapia fry and table fish in cages in the river Dong Nai in Bien Hoa, Dong Nai province. The company started producing chicken now produces tilapia since 2000. Now there are several tilapia farms nearby the area along the river.

3.4 Training

Successful launching of aquaculture program at AIT and its activities in the region increased demand not only for formal education and degree programs but also created the interest in short-term, need-based skill development training. As a result, AIT established a Training Unit" in 1989 which has trained over 1,000 personnel so far from about 30 countries. Participants of more than half of these countries were mainly for tilapia training programs. Training was started with two courses; a) Integrated Aquaculture in Asia, and b) Nile tilapia: Techniques for Mass Fry Production and Grow-out. Interestingly, the course on tilapia attracted more participants than by Integrated Aquaculture probably because it was completely different and about new techniques developed as compared to the traditional techniques of aquaculture dominated by carps. This training course has a significant role in promoting tilapia not only in Asia but also in African and American countries. In addition there were several participants for hands-on work experience in tilapia hatchery. One of the remarkable examples is that some private companies (e.g. Chareon Pokhaphand) sent their staff for training and they have established tilapia hatcheries. It served as the base for the company's tilapia business that also involves fillet export to US now. In a decade's time (1989-1999), out of 843 people trained, 26% were from Bangladesh, 22% from Vietnam and 12% Cambodia; mostly for tilapia only or in combination with other species. Many officials of the governments, research institutions have also got this training where they have established and run tilapia hatcheries in their countries, specifically e.g. Bangladesh, Thailand and Vietnam. A USAID project trained a person of a research institution in Nepal, who established and ran a hatchery in Tarahara, Eastern Tarai. The hatchery is in infancy and plan to expand when the demand for tilapia increases. Although, there are others who got training at AIT on tilapia didn't establish any tilapia farm or hatcheries; however they have served as extension agents at least spreading the words about tilapia culture in their countries or locations.

3.5 Aqua Outreach

Outreach program of AIT has been one of the models of technology dissemination. The program was started in mid-80s from North East (Isan), the poorest region, of Thailand with DFID funding, it expanded its activities, especially small-scale aquaculture, tilapia as the main focus to Cambodia, Laos, and northern and southern Vietnam with SIDA funding in the second phase of Aqua-outreach.

Before launching outreach activities Aqua Outreach conducted survey and/or visited farmers in order to identify the problems faced by the farmers in the field. Two main problems were identified; i) majority farmers said that their fingerlings disappeared after stocking in the pond, and ii) other farmers complaint that their fish didn't grow at all. These problems were analyzed to find the real causes. The outreach team came up with explanations that the reason of fingerlings disappearing after stocking was mainly due to predators such as snakehead, snakes, catfish and other animals. The solution proposed was "nursing of fry in hapas installed at the corner before releasing into the pond". Basic principle was that fingerlings are safe in hapas and get larger after nursing of about one month. They are stronger, often called as "predator resistant" and when released into the water they could survive. In addition to this, farmers were also recommended to dry, liming and clear their ponds before stocking in order to make the ponds free of predator animals, wherever possible. At the same time, in order to cope with the problem of slow growth of fish, fertilization was recommended as tilapia could consume plankton as the main source of food. Easily available chemical fertilizers such as with Urea and TSP and/or on-farm resources such as animal manures (e.g. buffalo manure) were suggested to use as inputs. The reason was that with feeding tilapia culture would not be profitable. Although, these two solutions proposed looked simple, they worked very well. Many farmers started harvesting more fish. AIT experience shows that at the level of farmers, especially in rural areas, a simple solution could be a miracle. In addition, AIT included farmers as part of research team for field testing also called participatory research. They feel proud being a part of the scientific research.AIT continued to focus on the production of quality mixed sex tilapia in the early 1990s even when AIT was commercializing the monosex approach. This was because it was perceived that even though there was a rapidly increasing demand in the commercial sector for monosex, poor rural households needed quality tilapia to be available locally and centralized commercial monosex operations were unlikely to meet their needs in the short to medium term. Hence, AIT also focused studying on decentralized seed production resulting in large impacts in some marginal agricultural areas such as in Bangladesh. Benoy Barman's work for PhD at AIT, showed fry could be produced cheaply in rice-fish fields. There was number of research work in this aspect on-campus funded by DFID and then through various mechanisms e.g. DFID's support in Bangladesh and subsequently supports from SIDA/DANIDA in Vietnam and elsewhere in Indochina.

Learning lessons from the promotion of tilapia culture in SE Asia, similar activities have been expanded to Nepal. A project called "Women in Aquaculture" has been launched jointly with the Institute of Agriculture and Animal Sciences (IAAS), Nepal. Tilapia culture was tested or compared with carps at the beginning. After getting positive responses, tilapia has been promoted among ethnic groups and also attempts have been made to expand further with a view to solving the problem of protein malnutrition in the rural areas (Bhujel et al., 2008). In addition to these simple techniques, Aqua Outreach also tried establishing tilapia hatcheries at various partner institutions. For example, in Research Institute for Aquaculture No. 1 in Hanoi, Univ. of Agriculture and Forestry (Ho Chi Minh City), Pathumthani and Udonthani Provinces of Thailand.

Aqua outreach played a considerable role in building regional institutional capacity in aquaculture and aquatic resources management and related fields through innovative approaches. It established a network of partners which included vocational colleges, research institutes, universities and department of fisheries (provincial or national levels) under the ministries. AARM assisted to establish tilapia hatcheries under outreach activities. For example, Department of Fisheries in Udonthani Province of Thailand, a tilapia hatchery was established with a view to supplying fry to the farmers of the province. Similarly, a hatchery in an Agricultural college, which is managed by one of the AIT graduates, also serves the same purpose. More interestingly, various non-profit organizations in the same province and also in Chiang Mai established and have run tilapia hatcheries e.g. Udonpatana Foundation, as a means to serve the poor families providing an evidence for earlier the notion that tilapia is poor men's fish. Table 1 is a list of hatcheries in Thailand established with direct and indirect assistance of AIT and its partners.

Table 1. Chronology of establishment of AIT-type tilapia hatcheries in Thailand.

Established Year	**Name of tilapia hatchery**	**Location**	**Production (fry/month)**
1984	AIT Hatchery	Pathumthani	<1m
1990	Rom Sai Farm	Ayutthaya	<1m
1991	Udonpatana	Udorn Thani	2m
N/A	DoF Provincial hatchery	Udonthani	~1m
N/A	DoF, Klong 5	Pathumthani	N/A
N/A	Agriculture College	Udonthani	~1m
1993	Manit Farm	Phetchaburi	8m
1994	Nam Sai Farms	Prachinburi	10-20m
1994	Boonholme Farm	Khon Kean	3m

1995	CP Hatcheries (5) *	Ayutthaya, Samut Sakorn, Nakorn Sawan, Kalasin, Ubon	>30m
1998	Chiang Mai Patana	Chiang Mai	>2m
2001	Bor Charoen *	Chachoengsao	>10m
2003	Jam Nong *	Chiang Rai	5m
2003	Wiboon *	Kalasin	4m
2003	Uthai Phan Pla	Ayutthaya	<2m
2003	Thep's Farm	Sakon Nakorn	NA
2003	DoF, Nong Khai *	Nong Khai	NA
2004	Winit's Farm	Mukdahan	<0.1
2005	Nam Sai branch	Nakorn Pathom	NA
2005	Prasit Farm *	Suphanburi	>2m
2006	Wanida's Farm*	Amnatcharoen	1m
2007	Pung Thai Farm*	Prachinburi	NA
2007	Watcharin's Farm*	Suphanburi	NA

Note: * Information about the farms were obtained from Ben Belton, a PhD student of the University of Stirling.

Table 2. List of Established Tilapia Hatcheries in Bangladesh (Mr. Sahabuddin)

Name of hatchery	**Location**	**Country**	**Year established**	**Technology transfer**	**Production (fry/m)**
Chitralada Aqua Park(CAP)	Pabna	Bangladesh	2007	AIT/BAU Alumni	1,000,000
Niribili Hatchery	Cox's bazaar	Bangladesh	2003	BFRI/BAU	16,00,000
United Aqua	Cox's bazar	Bangladesh	1999	Thai technician	3,800,000
Reliance Aqua Farm	Mymensingh	Bangladesh	2004	AIT visitor	4,000,000
Allah Wala Hatchery	Cox's Bazar	Bangladesh	2003	Local technician	8-900,000
Cox's Bazar Hatchery	Cox's Bazar	Bangladesh		Univ. Alumni/technician	6-800,000
Jubin Agro based industry	Noakhali	Bangladesh	2007	BAU alumni/locals	370,000
Pioneer tilapia hatchery	Chandpur	Bangladesh	2006	AIT trainee	7-800,000
Bangla Fishgen	Gazipur	Bangladesh	2005	Local technician	250,000
Testy super Hybrid monosex Tilapia	Jamalpur	Bangladesh	2005	BFRI	2,500,000
Chittagong Fisheries	Chittagong	Bangladesh	2004	Thai technician	800,000
Pacific Aqua Farm	Potuakhali	Bangladesh			
Rahman Agro Fisheries	Sathia	Bangladesh	2006	Local technician	800,000
Midway Scientific Fisheries Ltd.	Cox's Bazar	Bangladesh	2003	Thai technician	800,000
Nobarun hatchery	Tangail	Bangladesh	2004	Local technician	1,600,000
Agro-3 Fisheries	Mymensingh	Bangladesh	2005	Local trainer	1,000,000

Table 3. List of Established Tilapia Hatcheries in Brazil and world-wide
(Sergio Zimmerman)

Name of hatchery	Location	Country	Year established	Technology transfer	Production (fry/month)
Aquabel AquaMalta BGE Rei da Tilapia	Several locations in South and Notheast	Brazil	1997, 1998, 1999 and 2000	AIT as visitor I learned with David Little	3 million 1 million 1,5 million 0,3 million
AquaPrimvera	Villavicenzio	Colombia	2000	Same as above	5 million
Acuasur	Campeche	Mexico	2001	Same as above	0,5 million
GenoMar	Pampanga	The Philippines	2002	Same as above	0,5 million
GenoMar	Hainan Isl.	China I	2003	Same as above	~15 million
TPA	Caixito	Angola	2004	Same as above	0,3 million
UMB – Exp. Unit	Aas	Norway	2005	Same as above	Few thousand
GenoMar	Yishum	Singapore	2005	Same as above	1 million (?)
AFGC (Akvaforsk Genetics Center)	VeraCruz	Mexico	2007	Same as above	0,3 million
RSS - AFGC (Akvaforsk Genetics Center)	Hainan Isl.	China II	2007	Same as above	~15 million
TJN	Belanga	Zambia	2007	Same as above	0,3 million
Modercorp/Garzal	Taura	Ecuador	2007	Same as above	2 million

3.6 Private-Public Partnership (P-PP)

AIT tried a lot with public and government organization to disseminate the technology with the aim of supplying large number of high quality mono-sex tilapia fry. However, the level of production and supply was not up the expectation. Shortage of quality fry was still at large. It was probably due to the lack of realization on the potential of tilapia farming by those organizations and their aims were to serve as extension agents rather than doing business by themselves. However, the most obvious reason has been the lack of performance based incentives or rewards for and control over the staff in public organization. Fortunately, these problems were identified well in advance and attempts were also made to quickly shift to partnership with private sector. Unique contractual agreements were made with private companies realizing the importance of strict imposition of technological procedures or protocol was necessary in the production of high quality tilapia fry production at every step of the process that involves careful management of brood stocks, collection of eggs, artificial incubation of delicate fry and hormonal sex-reversal. Some of the private organizations have been technically supported by AIT both for technical as well as regular quality monitoring aspects. The main breakthrough in supplying large number of quality seed was possibly only when private sector picked-up the technology. Although, the technology was thought to be cumbersome but private sector adopted quickly due to its profitability and increasing demand. More importantly, after the successes in the private sector, public sector has re-focused on this technology. As a result, tilapia became number one species in Thailand in mid-90s. Sooner or later tilapia industry may take off other countries too. Bangladesh, Malaysia and Vietnam, governments are aggressively promoting tilapia. Tilapia has been officially allowed to culture in commercial scale. In addition to AIT's partnership with private sector, GenoMar, a Norwegian company has also made remarkable contribution hiring a consultant, Mr. Sergio Zimmermann a professor at a university in southern Brazil who was successful in establishing tilapia farming and as a result Chitralada monosex becoming dominant strain raised in Brazil after bringing a group of farmers to study the system and purchase broodfish in Thailand. He was initially hired by GenoMar for setting up AIT style hatcheries in the Philippines and subsequently China as well as Latin America. GenoMar also has established a hatchery in Singapore.

CP group of companies, which runs five tilapia hatcheries using the AIT technology, has also played a significant role in promoting tilapia further especially red variety. The company has given completely different name "Thapthim" which means "ruby" rebranding the name tilapia that gives the impression to the common people that it is something completely different. The company promoted it by producing and distributing an attractive picture of a food item of red-tilapia to almost all the restaurants in Thailand in order to boost domestic demand. The company now has several tilapia growers in groups in various pocket areas under contract farming. Under the agreement, farmers get a complete package of technology, inputs such as fingerlings and feed. They also buy back the fish so that farmers would not need to worry about market. This is a very good lesson strategy to learn from CP, while promoting any new species like tilapia.

In 1989, David Little has worked with Regal Springs when they first started tilapia production in Java to introduce the AIT approach. More recently, AIT has initiated with a company in India for the transfer of tilapia farming technology in bio-secure way, where previously tilapias were not officially approved for culture. More groups from Bangladesh and India have showed interests for the establishment of AIT style hatcheries and quality control/certification systems.

3.7 Aqua Internship/hands-on work experience

About 15 persons have done hands-on work experience from AIT hatchery alone so far in the past. They didn't have formal training course but were just worked with hatchery staff and learn by doing the work as regular staff. Most of these people were the ones who were supposed to start and/or run hatcheries in their countries. This type of activity could have been under internship program. Realizing that there is a value for such type of program, AIT hatchery and also others have been included as one of the best internship placements for European students under a new project funded by EU under Asia Link under which students of all the Asian partner institutions are sent to communities and private hatcheries/farms to spend 2-3 months for work experience so that they could identify the real problems. This would help them design a practical research for their thesis work aiming at solving those problems faced by the industry. For this purpose many students choose tilapia hatcheries/farms for their work experiences. The project also has a provision for students enrolled in European Universities who chose tilapia farming and hatcheries in Asia for exposure where they may also carry out their research at the same time. Tilapia hatcheries have been selected one of the best places (hosts) where the European students learn something new. The project team also plans to continue this program even after the project period ended by sharing the costs among stakeholders. For examples, participant Universities provide airfares, interns bear food costs by themselves and Asian partner institutions provide free accommodation either in their student dormitories/hostels, guest houses or arrangement to live with staff families in communities.

4. CONCLUSIONS

Right focus on tilapia species, identification of shortage of quality fry as the main constraint of its expansion and continuous research carried out to find the solutions served as foundation for developing a practical technology package, for the transfer of knowledge and technology. Inclusion of tilapia in formal education, training, outreach and internship activities helped in the promotion of tilapia culture. Several individuals who were formally educated from, trained by and/or exposed to AIT have contributed tremendously. However, the major breakthrough was possible only when private sector took up the technology. Some modifications and/or improvements, or adaptations in the technologies have been made in different parts of the world by various groups. From this, millions of people have and going to have directly or indirectly benefitted from tilapia research and technology transfer. Aquaculture program of AIT has established itself in international arena because of these activities carried out over two decades that have contributed significantly in the improvement of indigenous capacity for education, research and development in the region and beyond. Therefore, approaches/strategies used and role played by AIT in the promotion of tilapia should serve as a model for other organizations which have similar goal of contributing to food security and poverty reduction. However, more research is still necessary to improve the technology as well as strain. For examples, improvement in survival of fry, development of cold and salinity tolerance in various strains, solution to heat stress during summer and its drastic drop in egg production, various new and emerging diseases, minimization of cost of production and so on. One of the researchable issues has been always raised is the impacts of MT (methyl-testosterone), a steroid hormone, on the health of technicians who are directly and daily involved in preparing and feeding MT feed, and the impacts on the environment.

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