Journal of the Indian Fisheries Association
18, 1988, 109-119

# SCOPE FOR COMMERCIAL CULTURE OF TILAPIA

T.J. PANDIAN

School of Biological Sciences Madurai Kamraj University Madurai 21.

## INTRODUCTION

Thanks to the green revolution, several developing countries have become self-sufficient in cereal production but lag behind in the production of high protein containing pulse, meat and fish. For instance, India produces presently an adequate quantity of about 155 m tonnes of cereals; but it produces only 12.5 m tonnes of pulses and harvests only 2.1 m tonnes of fish, which fall short of requirements. Aquaculture not only opens a new avenue but also adds substantial areas for protein production. As the demand for water increases, water reuse will play an ever increasing role in the planning and development of additional water supply (Crook et al., 1980). As aquaculture requires a much lower quality of water than the common agricultural crops, it is the only way that the wastewater can be utilised to produce food in the years to come (Pandian, 1987).

## SUITABILITY OF TILAPIA

Fish have been shown as better convertors of food than broilers, pigs and cattle, and have proportionately larger dress-out weight. Among fish, herbivores/omnivores like tilapia are known to produce the maximum protein with high quality of flesh (Bardach, 1972). Tilapia is an excellent table fish with firm white flesh and no intermuscular bones. The other attributes, which make tilapia more suitable for fish farming are their general hardness, resistance to diseases, ability to survive at low oxygen tension (e.g. *Tilapia mossambicus:* 1.7 mg/1; *Sarotherodon macrotis:* 0.26 mg/1), a wide range of salinity (e.g. *T. mossambicus:* 75%), temperature (e.g. *T. mossambicus:* 10-42°C) and on a wide range of foods (Pandian and Varadaraj, 1987).

In fish farming, procuring adequate seedlings is one of the major problems; for instances, with all techniques developed for induced spawning and capturing, India procures today only 4 billion carp seedlings, although its projected requirement for 2000 AD is 17 billion seedlings. Tilapias present no such problems; indeed, it is difficult to prevent them from producing seedlings. The uncontrolled breeding, the consequent overcrowding, and competition for food and space have resulted in the 'ubiquitous' presence of 'bony' tilapia all over India; as a matter of fact, there is a wrong move to eradicate tilapia from India. Controlled reproduction in tilapia has become possible in recent years. Tilapias are amenable for interspecific/integeneric hybridization (Table 1), hormonal and chromosomal manipulation for sex reversal (Pandian and Varadaraj, 1987), as well as for production of transgenic forms through gene manipulation (Brem et al., 1988). Besides their economic importance, tilapias represent an unique group of animals, which offer the widest scope for academic understanding of sex determining and sex regulating mechanisms.

## TILAPIA CULTURE

As many as 23 species of tilapias are cultured as food fishes; of them, *Tilapia aurea, T. niloticus, T. zilli and T. mossambicus* are recognized as the most important culturable species. Because of its colour, the red tilapia, a hybrid of *T. niloticus* with *T. aurea or T. hornorum* has become marketably more popular in recent years. In general, male tilapias grow faster than the females. Under favourable conditions, tilapias attain a body weight of 450-850 g in a year. However, in the natural habitats most tilapias realise only about 100g growth annually due to competition among the cohorts. Tilapias mature at the age of 2-3 months and then onwards produce 75-1000 offspring once in every 22-40 days (Balarin, 1983). Excess reproduction has been a recurring problem in tilapia culture. Regulation of reproduction is most desirable in order to channel the available energy for efficient growth and to quickly harvest marketable sized fish. Endocrine and genetic engineering techniques have great potential for the control of reproduction and enhancing the growth efficiency of tilapias.

## SEX REGULATION

Control of reproduction in tilapias may be achieved by several methods: (i) use of predators and (ii) monosex culture. The latter is most effective and is a widely used technique

TABLE 1: SUMMARY OF STUDIES ON HYBRIDIZATION IN TILAPIAS

| Species used | | in hybridization | $F_1$ offspring | % |
|---|---|---|---|---|
| Oreochromis aureus. | X | O. niloticus | 100 | 0 |
| O. hornorum | X | O. niloticus | 100 | 0 |
| O. hornorum | X | O. mossambicus | 100 | 0 |
| O. macrochir | X | O. niloticus | 100 | 0 |
| O. variabilis | X | O. niloticus | 100 | 0 |
| O. aurea hornorum* | X | O. niloticus | 100 | 0 |
| O. mossambicus | X | O. spilurus niger | 0 | 100 |
| O. hornorum | X | O. aureus | 0 | 100 |
| O. vulcani | X | O. aureus | 0 | 100 |
| O. niloticus | X | O. leucostictus | 0 | 100 |
| O. niloticus | X | O. spilurus niger | 0 | 100 |
| O. niloticus | X | O. mossambicus | 0 | 100 |

* hybrid resulting from the cross between O. aureus and O. hornorum.

TABLE 2: ADVANTAGES AND LIMITATIONS OF USING DIFFERENT METHODS FOR THE PRODUCTION OF ALL MALE TILAPIAS

| Method | Description | Advantages | Disadvantages |
|---|---|---|---|
| Use of predators | predators eat fry | Minimise intraspecific competition | Predator's role often inadequate or too strong |
| Monosex culture Manual | Sexing & culturing all males | Eliminates breeding; as male grows faster than female productivity increases | Skilled and laborious job; wastage of females; human error possible |
| Hybridisation | Production of all males via hybridisation | Eliminates breeding; increases productivity | Difficult to maintain pure parental stocks; low fertility. |
| Hormone treatment | Production of all phenotypic males by treating food or water with androgen | Exposure time, duration and dose are species specific; easy and economic to supplement hormone; productivity increases. | High dose causes stunted growth due to hierarchy, fry eating-low dose becomes intersex or female |

for population control (Mires, 1977; Pandian and Varadaraj, 1987). This is achieved by: 1) Manual sexing of fingerling 2) Hybridization (Table 1), 3) Sex reversal by hormone treatment.

Table 2 summarises the advantages and limitation of these methods. The most promising and widely used technique to regulate reproduction is production and culture of all male population through feeding a steroid supplemented diet (Guerrero, 1975).

Sex reversal using androgens on a large scale has been shown to be commercially feasible by Koplin et al. (1977) and Guerrero (1979); however, the disadvantages of this method are the need for synchronizing the required large number of brooders and the timing of the treatment accurately. Secondly, due to the establishment of size hierarchy in mass culture technique, dominant or submissive ones acquire extremely high or low doses, and hence, may become abnormal male or female. Lastly, the utility of the direct hormone-treatment method remains uncertain because of the consequences on human beings due to consumption of the hormone-treated fish (Shelton et al., 1978).

The yield from all-male populations consisting of about 50% genotypic females would probably be less than the yield from all-male genotypic populations, if the growth superiority of males has a genetic basis (Anderson and Smitherman, 1978). Yamamoto's (1975) pioneering work on the functional sex reversal of goldfish demonstrated that monosex offspring is obtained, when sex reversed fish of the homogametic sex are mated with normal fish of the same sexual genotype. The method diagrammatically represented in Fig.1 for sex reversal has also been developed for *T. mossambicus* by Varadaraj and Pandian (1988) in the School of Biological Sciences, Madurai Kamaraj University,

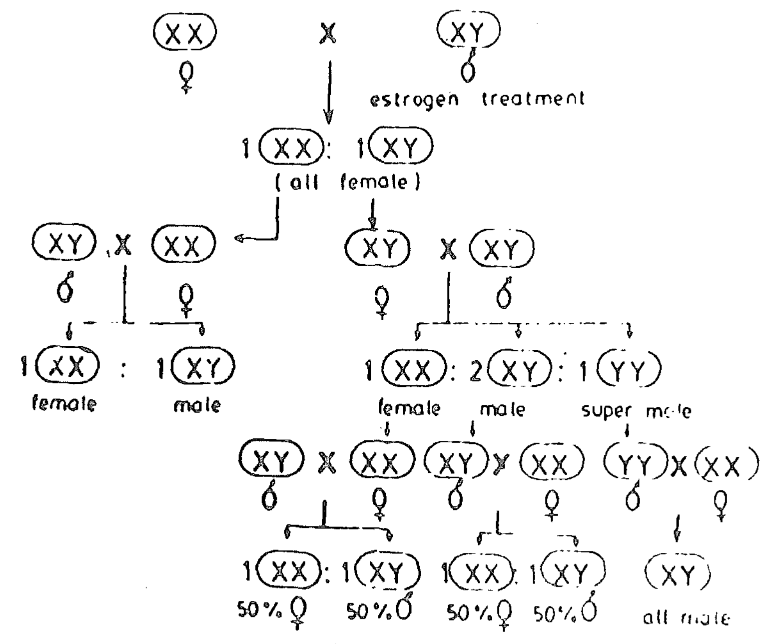


Fig.1. All male population through super male

Madurai, India. Tilapias produced by this method are genetically and functionally males, but have not been fed on hormone supplemented diet.

For the sustained production of male-only-stocks, it is necessary to generate a batch of sex-reversed males each year. This is done by feeding a selected batch of YY fry produced as described above on a diet containing an estrogen. The sex hormone analogue diethylstilbestrol at about 100 µg/g diet for 11 days is very effective (Varadaraj, 1988).

## TILAPIA IN POLYCULTURE SYSTEM

Monosex mass culture can also be done in polyculture ponds,. In such cases the density is always less than the density in monoculture of tilapia. The culture of an all-male population removes the restriction on final age and thus on weight at harvest associated with mixed sex culture and also removes the fear of extinction of native species.

In Israel, Tal and Ziv (1978) state that the majority of *T. nilotica X T. aureus* hybrids are raised in polyculture with common carp and silver carp. The tilapia assumes the role of a pond cleaner, maintaining the water in good culturable condition by consuming organic material and waste feed that would otherwise decompose and pollute the pond environment. In most cases, the tilapias are able to increase total fish production without significantly reducing growth or production of the other species. (Lovshin, 1982). In Brazil, Lovshin et al. (1977) tested the culture of the *T. niloticus X T. hornorum* all-male hybrid with common carp *(Cyprinus carpio)* and produced significantly more harvestable fish than with carp alone. Moreover, the combined culture averaged 105 kg/pond of tilapia hybrids and carp raised on 295 kg of feed, while 108 kg of tilapia hybrids stocked alone required 441 kg of food. Thus, less feed was required to raise an equal weight of hybrids and carps than was needed to raise hybrids alone.

## CHROMOSOME MANIPULATION AND SEX REVERSAL

In the last few years, there has been a burst of research on salmonids and carps in this field in several countries except India. Most of the research has been on rainbow trout and common carp. However, there has also been research conducted on *Tilapia* *aurea* (Valenti, 1975; Chourrout, 1984) and *T. nilotica*. Chromosomal engineering has great potential for control of reproduction in fish. The primary interest in triploid fish induction by chromosomal manipulation lies in their stability, better growth and survival Thorgaard, 1986). Sterility is also advantageous in situations where the control of reproduction is desirable. In tilapia, triploids may be desirable to eliminate overpopulation and associated stunted growth. Another application on induced triploidy in fish lies in the fact that triploid hybrids are typically much more viable than diploid hybrids (Allen and Stanley, 1981; Chevassus et al., 1983; Scheerer and Thorgaard, 1983). This may make it possible to combine desirable characters from the two different species of tilapia in a sterile hybrid. A possible application of induced triploidy may lie in the fact that triploids have higher heterozygosity than diploids (Allendorf and Leary, 1984). This has been shown to be associated with higher developmental stability as measured by fluctuating assymetry (Leary et al., 1985). Bingham (1980) proposed that increased heterozygosity was a primary advantage of using polyploids in plant breeding programmes. Heterozygosity might be maximized in induced triploids by using hybrids between two strains as the female parent and crossing them to males of a third strain/species. Among tilapias, triploidy has so far been reported in *T. niloticus* only (Chourrout, 1984).

For the first time, Pandian and Varadaraj (1987) made a series of tests and determined that heat shock at 42°C on 2.3 min. old (post-insemination) eggs for a period of 3 min. induced triploidy; likewise a heat shock at 40°C on 40 min. old eggs for a period of 10 min. induced tetraploidy. Thus it has been possible to produce viable adult sterile triploid *T. mossambicus*; however, the tetraploid produced dies immediately after yolk absorption. We are informed by the Philippine and British scientists that their tetraploids too succumbed for some unknown resons.

When the triploidy technique is scaled-up to commercial level, one is however faced with problems such as the need to possess a large number of brooders on the desired day and the need for synchronization of spawning and insemination of eggs upto an accuracy of a few seconds. The production of tetraploid parent and its crossing with a diploid will produce natural triploids. Pandian and Varadaraj (1987) successfully produced tetraploid tilapia, but it did not survive beyond the fry stage. Scientists from Philippines and Britain also informed their inability to rear the tetraploids beyond the fry stage.

We are exploring the possibility of sustained production of the tetraploid beyond the fry stage. With the endocrine and chromosome technique, it has become possible for us to produce the following varieties of tilapia: a. triploid sterile b. super males and c. gynogens and hence we are confident of producing viable tetraploid and other genetic varieties. Besides, we have also embarked on a project to produce transgenic tilapias.

India has established several research institutions for "Genetics and Plant Breeding" as well as "Genetics for Animal Breeding" (Cattle: e.g. Izatnagar); unfortunately, it does not have a centre for "Genetics and Fish Breeding". The talents available at Madurai Kamaraj University should serve as a nucleus for establishing a centre for Genetics and Fish Breeding at the School of Biological Sciences. The city Madurai is not blessed with abundance of water and is not surrounded by great lakes and live rivers. Hence, Madurai is ideally located for Genetics and Fish Breeding research, as the good or bad strain developed by them cannot easily find its way into natural waters like river Ganga running through several states of India.

## NUTRITION AND FEED FORMULATION

The second recommendation that this report is placing on record is that a centre for "Fish Nutrition and Feed Formulation" should be established. As already indicated, tilapias are herbivores/ omnivores. To increase the availability of food, one should induce the blooms of phytoplanktons by fertilizing the pond. In certain intense Aquaculture Firms tilapias do also receive supplementary diet. As the feed cost makes more than 50% of the production cost of fish in any aquaculture firm, there is a need for understanding fish nutrition in greater detail. As in the case of cattle, there is a need for the establishment of fish feed industry like cattle feed industry. This statement should be considered in the light of the fact that Taiwan increased its fish feed industrial production from 12,000 t in 1973 to 1,86,000 t in 1984 (Chuang et al., 1986).

To the best of our knowledge, tilapias are not commercially cultured in India except at Chingleput (Tamilnadu) by Vorion Chemicals and Distilleries Ltd. This distillery produces 3000-5000 litres of methane containing molasse pollutant. The distillery releases it into the river Palar, which is now being opposed by environmentalists. The owners of the distillery purchased the "know-how" of culturing the hybrid red tilapia, fashionably called by them as golden fish; this tilapia tolerates the pollutant-containing water and survives in water containing less than 2.5 mg oxygen/litre. With the assistance of about 2 crores from the NABARD, the company has purchased about 75 acres of land, of which 50 acres is the water-spread area. They have about 100 raceways, each with water-spread area of half an acre. The daily water requirement is quite substantial (25 lakh litres) of which 1/5 comes from the distilleries and the remaining is pumped from the river Palar. Stocking is made at 12-15 thousand/raceway. They harvest about 50 ton/ha/annum. The company is now developing a network of golden tilapias, including commercial culture centres at Erode (Tamilnadu) and other places. They are also endeavouring to manufacture the synthetic diet at the cost of Rs.3-4/kg.

TABLE 3: CULTURE AND COST OF TILAPIA PRODUCTION IN DIFFERENT COUNTRIES

| Country | Harvest (t/ha/yr) | Production cost($/Kg) | Selling price($/Kg) | Culture level |
|---|---|---|---|---|
| Columbia | 250.0 | 0.06 | 0.5 | Intensive,cage culture |
| Phillippines | 0.6 | 0.80 | - | Semi-intensive, pond culture |
| El Salvador | 12.5 | 0.14 | 1.0 | Fertilized water bodies |
| Israel | 25.0 | - | 1.1 | Commercial culture. |
| Central Africa | 6.2 | 0.26 | 1.0 | Extensive culture. |
| Kenya | 600.0 | 0.66 | 1.5 | Intensive tank culture |
| Taiwan | - | - | 0.3 +<br>0.8 * | Commercial<br>Commercial |
| Togo | 4.7 | 0.12 | - | On supplemented diet |
| Britain | 300.0 | 2.00 | 5.0 | Intensive,tank culture |
| South Africa | 6.4 | 0.30 | 1.0 | Semi-intensive fertilized pond |
| Brazil | 4.3 | 0.07 | 0.6 | Semi-intensive, fertilized pond & on supplemented diet. |
| Sudan | 10.0 | 1.20 | - | Semi-intensive, fertilized pond and on supplemented diet. |

+ - Local price
* - Export price.

Table 3 summarises the availale information on commercial culture of tilapias in other countries. Understandably, tilapia culture is a commercially viable, and economically profitable enterprise, hence, it deserves all encouragement in India. The fact that carps do not survive in low quality waters, in which tilapias flourish strongly suggests that tilapia is a quick producer of high quality animal protein but also provides an opportunity to utilise waste water.

## ACKNOWLEDGEMENT

This paper is based on a Technical Report submitted to the Department of Biotechnology, Govt. of India.

## REFERENCES

Allen, S.K. and J.G. Stanley, 1981. Polyploidy and gynogenesis in the culture of fish and shellfish. Coop. Res. Rep., Int. Counc. Explor. Sea Ser. B. 28: 1-18

Allendorf, F.W. and R.F. Leary, 1984. Heterocygosity in gynogenetic diploids and triploids estimated by gen-centromere recombination rates. Aquaculture, 43: 413-420.

Anderson, C.E. and R.O. Smitherman, 1978. Production of normal males and androgen sex reversed *Tilapia aurea* and *T. nilotica* fed a commercial catfishdiet in ponds. In: R.O. Smitherman, W.L. Shelton and J.H. Grover (editors), Culture of Exotic Fishes Symposium Proceedings. Fish Culture Section, Am. Fish Sco., Auburn, Ala., pp. 10-33.

Balarin, J.D. and R.D. Haller, 1983. The intensive culture of Tilapia in tanks, raceways and cage. (eds.) Recent advances in aquaculture, Croom Helm Publishers, Westwinsen, P.265.

Bardach, J.E., J.H. Ryther, and W.O. McLarney 1972. Aquaculture: the farming and husbandry of freshwater and marine organisms. Wiley-Interscience, New York.

Bingham, E.T. 1980. Maximising heterozygosity in autopolyploids In: W.H. Lewis (Editor), polyploidy. Biological Relevance. Plenum, New York, NY. pp. 471-489.

Brem, G., B. Brenig, Horstgen, G. Schwark, and E.L. Winnacker. 1988. Gene transfer in tilapia *(Oreochromis niloticus)* Aquaculture, 68: 209-219

Chevassus, B., R. Cuyomard. D. Chourrout, and E. Quillet. 1983.

Production of viable hybrids in salmonids by triploidization. Genet. Sel. Evol., 15: 519-532.

Chourrout, D. and J. Itskovich, 1984. Three manipulations permitted by artificial insemination in tilapia: Induced diploid gynogenesis. production of all triploid populations and intergeneric hybridization. In: L. Fishelson and Z. Yoron (eds.) International Symposium on Tilapia in Aquaculture. the Tel. Aviv. Uni. Publications.

Chuang, J.L. J.C. Lee, S.L. Shik, and C.G. Shiau, 1986. Aquatic animal feed industry of Taiwan. In: Chuang, J.L. and Shiau, S.Y. (eds.) Research and development of aquatic animal feed in Taiwan Vol. 1: pp. 35-42. Fisheries Society of Taiwan.

Crook, J., P., David and P. Spath, 1980. Water reuse-health and other aspects. In: N.M. Trieff (eds.): Environment health. pp. 503-531. Arbor Science Publishing Inc. Arbor.

Gureero, R.D. 1975. Use of androgens for the production of all-male *Tilapia aurea* (Steindachner). Trans. Am. Fish. Soc., 2: 342-348.

Guerraro, R.D. 1979. Use of hormonal steroids for artificial sex reversal of tilapia. Proc. Indian Natl. Sci. Acad. Part B 45: 512-514.

Koplin. S.J., J.G. Woiwode, and S.E. Jenkins, 1977. The feasibility of commercial production of sex-reversed *Sarotherodon mossambicus* utilizing flow-through tanks at three hatcheries. Unpublished report, U.S. Peace Corps Volunteers. p.6

Tal, S. and I. Ziv. 1978. Culture of exotic fishes in Israel, p.1-9. In: R.O. Smitherman, W.L. Shelton and J.H. Grover (eds.) Culture of exotic fishes symposium proceedings. Fish culture section, American Fisheries Society, Auburn, Alabana.

Thorgaard, C.H., 1986. Ploidy manipulation and performance. Aquaculture, 57: 57-64.

Valenti, R.J., 1975. Induced polyploidy in *Tilapia aurea* (Steindachner) by means of temperature shock treatment. J. Fish Biol., 7: 519-528.

Varadaraj, K., 1988. Feminization of *Oreochromis mossambicus* by the administration of Diethylstilbestrol. Aquaculture (in press).

Varadraj, K. and T.J. Pandian, 1988. Induction of super males in *Oreochromis mossambicus* by mating estrogen induced XY female and normal XY male (under preparation).

Yamamoto, T., 1975. A YY male goldfish from mating estrone induced XY female and normal male. J. Hered., 66: 2-4