RESEARCH IN AQUACULTURE

AQUACULTURE RESEARCH IN AFRICA

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1. INTRODUCTION

Aquaculture Research conducted in Africa and elsewhere has resulted in the identification of a small number of species as potentially important and efforts are directed towards development of suitable technologies for their culture. Research has been directed towards culture of tilapia by controlling overpopulation through cage culture, sex-direction and mono-sex culture, genetic selection and selective breeding and on integrating with agriculture and live-stock systems. Simple techniques of breeding and seed production are available for difficult-to-spawn species but are yet to reach target users, namely village level fish farmers in many countries. Non-availability of seed of economically important species in many aquaculture centres is still a major problem. The Regional and sub-regional centres of aquaculture organised by the Aquaculture Development and Coordination Programme of the Food and Agriculture Organisation of the United Nations has initiated several research and training programmes. Collaboration of the national aquaculture research centres with well established institutions and Universities will accelerate progress in scientific research on local aquaculture problems as well as involvement of modern technologies. This will also help in the quicker dissemination of research findings and exchange of technologies in the region.

2. AQUACULTURE RESEARCH IN AFRICA

The FAO/UNDP workshop on Aquaculture Planning in Africa and the FAO/CIFA Symposium on Aquaculture in Africa, both held in 1975 in Accra, were the two concerted efforts that looked into the status of aquaculture in Africa as a whole. While the former took note of the aquaculture requirements for two decades ahead, the latter reviewed the status of technology available in the scientific management of aquaculture.

In most countries in Africa the mainstay of aquaculture in the past has been small-scale fish farming in domestic ponds, integrated in many cases with rural development programmes.

As a result of the various regional workshops and symposia held in 1975/76 the strategy accepted for worldwide development of aquaculture, aimed at achieving a major increase in production in the next two decades included (a) the selection of a small number of aquafarming systems as against a variety of species and culture systems being experimented with (b) wider application of the selected farming systems and the promotion of greater investment to achieve sizable increases in production (c) organisation of appropriate assistance for the formulation of sound investment projects based on feasibility studies of pilot projects and (d) provision of support services in the form of applied research to facilitate technology transfer and improvement of techniques. According to Arrignon (1982) aquaculture in Africa is subject to considerable risks due to lack of information and knowledge on hydrobiology, ichthyology, zootechniques as well as problems of sociological aspects. The lack of technical know-how and financial constraints in development of aquaculture in Africa were also recognised decades earlier.

2.1 World tilapia production through aquaculture

Some thirty years ago world production of tilapia through aquaculture was around 20,000 tonnes. This has increased to 200,000 tonnes by 1983 of which four Asian countries alone (Taiwan, Indonesia, Thailand and Philippines) accounted for 180,000 tonnes. Taking this trend into account it is now projected that an annual world tilapia production of 2,000,000 tonnes is feasible.

2.1.1 Comparison with other livestock and agricultural products

Through genetic and technological improvements in the last thirty years, and while the poultry and pork industries have increased by a factor of 2 and the new improved Asian rice (IRS) varieties have a potential factor of 10, tilapia in the same time period has improved in potential productivity by a factor of 100! (ICLARM, 1984).

2.2 Species utilised and available for aquaculture in Africa

The most important fish that are being cultivated in Africa at various levels are the Tilapias. Tilapias are well known for their hardiness, good growth rate, adaptability to supplemental and artificial feeding with a wide range of feeds, tolerance to wide fluctuations in physico-chemical parameters, pond breeding habit and local acceptability as a good quality fish. Bardach *et al* (1972) have suggested 14 species of Tilapia as important from a fish culture point of view, while Balarin and Hatton (1979) listed 23 species of *Tilapia* and *Sarotherodon* that have been tried in aquaculture. Though there are several species of tilapias available, it is now generally accepted that the following species have the most potential and are economically important ones. These include *Oreochromis niloticus, O. mossambicus, O. aurea, O. macrochir, O. andersonii, O. esculentus, O. spilurus niger, T. rendalli, T. guineensis, T. zillii, Sarotherodon melanotheron* and *S. galilaeus. While the first seven are material mouth brooders and the three species of tilapia substrate spawners with semi-adhesive eggs and a greater fecundity, S. melanotheron* which has a distribution in West African Coastal areas is a paternal mouth brooder, whilst *S. galilaeus* is a biparental mouth brooder. In addition to this there are several other species of tilapias that are economically important in certain localities as a capture fisheries item from open water or being used in small-scale domestic fish farming.

However, in most of the fish culture attempts with tilapia, the major problem encountered has been the early maturation and breeding of the species in short periods leading to overcrowding in the ponds and very low levels of production of market sized fish. It was this trend, coupled with several other factors that led to the lack of interest among aquaculturists, particularly among small-scale fish farmers in Africa. However, in recent times, particularly in the last decade there was a general awakening of interest in aquaculture particularly because of demonstrations of simple technologies that led to profitable production of fish through small-scale as well as large scale farming systems. These farming systems developed as a result of carrying out research on several aspects of applied values particularly on the control of over-population and stunting in tilapia culture.

3. MONO-SEX (ALL MALE) CULTURE

It is known that males among tilapia grow faster than females and that when all males are stocked in a pond, reproduction and overcrowding could be overcome. Hence considerable work has been carried out on the development of this technique either through physical segregation of the sexes or through modification of the sex by hormone treatment.

3.1 Mono-sex culture by differentiation of sexes

The better growth rate among males is regarded as a genetic factor and not associated with reproductive processes. However this growth superiority could be modified by environmental factors (Fryer and Iles, 1972). The technique includes manual sexing of tilapia based on several characteristics. The technique has been tried in several countries in Africa as well as outside. (Guerrero and Garcia 1983, Lovshin and DaSilva 1975). Manual sexing is laborious and needs some skill. In addition to this, females which constitute some 50% are wasted. Clear identification of sex is possible in fishes of around 50g. It is reported that a person could segregate about 2,000 males per working day. However, the accuracy of this is not guaranteed. Use of mechanical graders to separate larger sized males also has been tried in some countries (Bard *et al* 1976) but the accuracy of this method also is not assured.

Sex-segregation by observing secondary sexual characters and sexual dimorphism is also possible among tilapias. Differential coloration among males and females at breeding time is a characteristic phenomenon. It is observed that the pelvic fins among males reach far beyond the anal and genital openings posteriorly while among females it is short and do not reach anywhere near the anal and genital openings. At Buguma (ARAC, Port Harcourt) following this criterion sexes could be successfully segregated among *T. guineensis* and *S. melanotheron*. However, in mono-sex culture of all males in *S. melanotheron*, manual segregation results in the occurrence of fry in ponds since the species is a paternal mouth brooder and many adults will be carrying eggs in their mouths.

3.2 All-Male hybrid culture

Several inter-species crosses among tilapias have resulted in 100% or higher all-male hybrids. The all-male crosses include *O. mossambicus* × *O. hornorum, O. niloticus* × *O. hornorum, O. niloticus* × *O. macrochir, O. niloticus* × *O. aureus, O. niloticus* × *O. variabilis* and *O. spilurus niger* × *O. hornorum* (Hulata *et al* 1981, 1983), Pullin and McConnel 1982).

The system has given some positive results and is now being practised in several parts of the world. However, many centres are finding it difficult to maintain separately the different species and strains. Wohlfarth and Hulata (1983) have reviewed the applied genetics of tilapias and its role in aquaculture.

3.3 Genetic improvement in tilapia and production potential

In South East Asia, culture of *O. mossambicus* alone in the 1950s has given a yield of 2.5 t/ha/yr with a growth of 140 g/yr. By the 1970s this production rate had improved to 60 t/ha/yr and a growth rate of 700 g/yr with hybrids of *O. mossambicus x O. niloticus*. In the 1980s, the production of red tilapia (*O. niloticus* x albino *O. mossambicus*) has led to the very high production of 600 t/ha/yr and a growth of 1,000 g/yr. It is now expected that tilapia yields of 600 - 800 t/ha/yr could be attained through genetic research coupled with intensive farming technology (ICLARM 1984).

3.4 Sex-direction and all male culture

The principle underlined here is that before sex differentiation in tilapia (which is immediately after yolk absorption and when the fry is about 9 - 12mm in length) the fry are fed with ethyltestosterone or methyltestosterone along with feed at 30 to 40mg/kg of feed fed at 4% body weight for 3 weeks. This resulted in 98 - 100% male offspring. It was found that the hormone treated fish had a fast growth rate and that the system had the advantage of reducing reproduction, with females not being wasted, and higher yields due to faster growth rate and a higher stock density. However, some of the points raised against this technique are the requirements of technological skill for effective treatment, increase in overall cost of fry production and possible side effects to man and fish by the drug. Since there is a considerable time lapse between treatment and consumption of fish the hormones would have been metabolised completely by the time the fish is consumed.

3.5 Cage culture

Culture of tilapias in cages is reported to eliminate the problem of breeding and over-population. Even when breeding takes place, the eggs are either not fertilised or are passed through the mesh and hence no production of fry. However, unlike hormone treated all males, in this system considerable amount of energy is utilised in the maturation and gonadal development which in turn means wastage. In recent years cage culture of tilapias has been attempted on a commercial scale in Ivory Coast, the Philippines and other countries (Campbell 1978, Coche 1982, Coche 1983, Guerrero 1979, Pagan 1975).

In most of the countries, tilapia cage culture is carried out on an experimental and small scale basis except in Ivory Coast, Costa Rica, Puerto Rico and Philippines where commercial scale cage culture of tilapia is practiced. According to ADCP (1978 and 1980) there is a definite potential for Tilapia cage culture in lakes and rivers in Latin America and Africa, both on commercial and subsistence levels. The size of cages varies for different culture systems and the level of technology available. According to Coche (1982) at experimental stages and at subsistence levels, generally, cages should not exceed a few cubic metres. However, he recommends medium sized cages (6 to $20m^3$) to be used at artisanal levels, while larger cages of 50 - $100m^3$ could be used at industrial levels.

The maximum carrying capacity for a cage depends on the mesh size, cage size, type of fish and level of dissolved O_2 in water. For $1m^3$ cages the recommended safe limit is about 73kg and it is known that as the size of the cage increases the maximum carrying capacity decreases. In Ivory Coast a production of over $70kg/m^3$ cages is reported.

3.5.1 Research requirements

A review on the research requirements for Tilapia cage culture (Anon 1979) has identified further research and standardisation of cage material which could present less fouling and toxicity problems, layout and positioning. In Latin America (ADCP 1978) and in Africa (ADCP

1980) cage culture has been identified as a priority culture system in the Research programme of the FAO/UNDP Regional Aquaculture Centres.

In rural areas where facilities are available, like rivers, brackishwater, lakes etc. cage culture opens up ample opportunities at individual entrepreneur level or at co-operative level.

Small scale tilapia cage culture projects carried out in two fishing villages in the Philippines indicated that the household income of participating families increased from P6183 to P41768 per year and household savings from zero to P7102 per day. The participating families consequently purchased gear for sustenance fishing and luxury foods for their households (Gonzales 1984, P14.00 - US$1.00). However in addition to mobilising the required funding, procurement of equipment and locally available materials and identifying indigenous potential species it will be necessary to import training and guidance, at least initially. In addition to this, feed requirement has to be taken into account and preferably locally available raw materials should be utilised.

3.6 Use of predator to control over-population

Stocking predator fish in Tilapia ponds to control overpopulation is an age-old practice and has been tried in most parts of Africa and elsewhere. In Thailand using *Clarias sp*, and *Ophiocephalus* as predators in *O. mossambicus* ponds a production of 17.8 ton/ha/yr has been obtained. In Africa, production up to 5 ton/ha/yr in tilapia culture has been reported by using predators like *Lates niloticus, Clarias sp, Bagrus* etc. In Africa, the most common predators available are *Lates niloticus, Clarias lazera, Bagrus sp, Micropterus salomides* (introduced), *Hemichromis fasciatus*, etc. In many cases, predator-prey ratios have been worked out and satisfactory production is reported. A ratio of 1 : 10 for *C. Lazera* and *O. niloticus*, 1 : 20 and 1 : 84 for *L. niloticus* and *O. niloticus* and other combinations also have been reported (Guerrero 1982).

Though relatively larger sized tilapias and good production are obtained through use of the predators, the problem of availability of required numbers of fry of suitable sizes at the proper time and lack of well-tested standardised predator-prey ratios among others, have limited the use of this technique.

3.7 Tilapia breeding and seed production

Considerable work has been carried out on this aspect in tilapia which included stocking density brood fish, spawning frequency, male - female ratios, breeding behaviour, incubation and fry rearing, feed requirements of spawners and fry. For large-scale fry production in tilapia two systems are now being practiced (1) land based hatchery and (2) lake-based hatchery. While in the former fry production is being carried out on land in the confinement of a hatchery, in the latter breeding and seed production is practised in nylon hapas fixed in marginal areas of a lake or reservoir. Fry production figures given by different authors for different systems vary considerably. Further fry production is also influenced by several factors like size and age of brooders, season, water quality, type of feed available, species, etc. Stocking densities for brood fish suggested are 5,000 brood fish/ha (Guerrero 1983) and 100 - 200kg brood fish/ha (Boussard *et al*, 1983). Fry production figures reported include 880 fry/m^2/month using cage spawning (Guerrero 1979), 4.2 fry/m^2 in ponds using supplemental feeding (Campbell 1978) and 3 fry/m^2/ month in 350m^2 pond (Lovshin 1982). A sex ratio of 1 : 3 and 1 : 5 (male to female) for O. niloticus & O. aureus) has been reported by many to give excellent fry production. According to Boussard et al (1983) large scale fry production using the open pond system is simple and suited for developing countries. The technology is simple and can easily be adapted by large and small scale fish farmers.

4. CULTURE AND BREEDING OF *CLARIAS LAZERA*

Clarias lazera is another African species that meets various aquaculture requirements which includes fast growth rate, quick adaption to various types of artificial feeds and adjustability to adverse environmental conditions. Even a growth rate of about 5g/day has been reported for this species. The species has been successfully cultivated in the Central African Republic, Arab Republic of Egypt , Cameroon, Ivory Coast and several other countries. Suitable breeding techniques have been developed under controlled conditions. However, there is a considerable amount of work to be carried out on larval and fry rearing in the hatchery and nursery ponds so as to obtain high rates of survival. This is one of the species that holds considerable prospects for cultivation as mono-culture or in combination with other species like tilapia.

Among other species that are presently being cultivated and which need much more research work to be carried out include *Chrysichthys nigrodigitatus, Bagrus docmac, Heterotis niloticus* etc. Among the introduced species common carp (*Cyprinus carpio*) and Chinese carps are now available in many African countries. Standard techniques of breeding and cultivation of these species are available, however, only in few places where these techniques are practiced systematically.

5. CONSTRAINTS IN AQUACULTURE RESEARCH IN AFRICA

5.1 Aquaculture Research when carried out on a regional basis can lead to better understanding of the problems as well as development of suitable technologies. Establishment of Regional Centres will help in identifying and tackling problems of local aquaculture interests in relation to wider regional projects. The establishment of the FAO/UNDP/NIOMR African Regional Aquaculture Centre at Port Harcourt and the planned sub-centres is the first step towards this.

5.2 At present there is a lack of adequately qualified and trained aquaculture scientists to carry out research and over a period sufficient numbers of scientific personnel have to be built up.

5.3. Infrastructure in the form of laboratories and farms have to be established along modern lines so that research programmes could be implemented.

5.4 There should be collaboration with agriculture and livestock departments so that expertise and resources in many fields could be shared to maximum advantage.

5.5 National and international aquaculture institutions should accept collaboration with established and specialised institutions and universities in Africa and abroad, initially or till newly established centres are well grounded.

6. AQUACULTURE RESEARCH AND TRAINING AT FAO/UNDP/NIOMR AFRICAN REGIONAL AQUACULTURE CENTRE, PORT HARCOURT, NIGERIA

The Research work conducted so far falls within the broad outline given by ADCP (1980) under outline Research Programme for the African Regional Aquaculture Centre. Brackishwater aquaculture research was carried out at the 3.6ha fish farm at Buguma; since the construction of the freshwatger fish farm and infrastructure at Aluu was not completed, limited work on freshwater species was conducted at the freshwater fish farm at Okigwe, Imo State.

6.1 Brackishwater fish culture

Among the various species of Cichlids occurring in the West Coast of Africa *Sarotherodon melanotheron* and *Tilapia guineensis* are the common species occurring in Buguma fish farm. Hence from the beginning research was directed towards development of suitable technologies for culture of both species. While the former is a paternal mouth brooder the latter is a substrate spawner. *S. melanotheron*, though considered a plankton feeder, is known to consume algae, detritus, sand and invertebrates when cultivated in ponds. Similarly *T. guineensis*, though known as a macrovegetation feeder, is also known to consume algae, detritus and other invertebrates whilst under cultivation.

Fish culture work carried out with both species when stocked at density of 2 fish/m^2, with supplementary feeding as well as with fertilisers, gave a production of 2.5 - 3.0 tons/ha/yr. However, this included a high percentage of smaller-sized fish. While standard methods of pond preparation, fertilisation and pond management were adopted, fish were fed with poultry feed with a protein content of about 20%. The rearing period lasted 3 - 4 months. At the time of harvest there was a 400 - 600% in fish numbers but the so called market sized tilapia (50g) constituting only about 25%. The different feeding systems adopted indicated that there has been no significant difference in growth response of fish fed with NIOMR fish pellet (35 percent crude protein), a wheat bran mash (15 per cent crude protein), a poultry layer mash (15 - 19 per cent crude protein) or with fish receiving a supplementary feed but pond receiving only fertilisation. This possibly could have been due to the relatively low standing crop of fish (starting av. 198kg/ha and end of culture period av. 1,171kg/ha). The cost of one kg fish produced ranged from Naira 0.067 to 1.86.

6.2 Culture of Chrysichthys nigrodigitatus

The species enjoys excellent market in Nigeria as well as in some other West African countries and because of its fast growth rate the species is being cultivated in Ivory Coast, Nigeria and a few other countries. Hence research work has been initiated at Buguma and Aluu. Under supplementary feeding the growth of the stock is being monitored and plans are underway for hypophysation of the species leading to seed production.

6.3 Acclimatisation of 0. niloticus to brackishwater conditions

Preliminary trials indicated the species could tolerate salinity up to 25ppt, beyond which mortality occurred. The experiment is in progress and needs further confirmation.

6.4 Hypophysation of Clarias lazera and large-scale seed production

In the absence of facilities at Aluu and at the request of the Officers of the Federal Departments of Fisheries, Okigwe, Imo State, the technique of hypophysation of *C. lazera* was demonstrated at 4 fish farms. The fishes were bred with carp hypophysis and the technique of using synthetic Kakabans was demonstrated.

6.5 Mono-sex culture of S. melanotheron and T. Guineensis

When the fishes attained a size of 30 - 40g they were manually sexed by examining the genital openings as well as the relative size differences of pelvic fins. This has given an accuracy of over 70% males. However, the method is time consuming.

6.6 Other aspects

Several important and related research aspects in connection with brackish and fresh water aquaculture were carried out by the aquaculture trainees as part of their curriculum, under the guidance of ARAC staff. These included: Studies on the food and feeding habits, maturation and fecundity, physiological studies including salinity tolerance, influence of various physico-chemical parameters on the growth, survival and production, use of various anaesthetics in fish transportation and control of the predators and pests in the pond. These items of work were carried out mostly on *S. melanotheron, T. guineensis, T. zillii, O. niloticus, Clarias lazera, Hemichromis fasciatus*, a few predators and oysters.

7. TRAINING

The one year training course for senior aquaculturists (post-graduate level) started in 1980 at ARAC, continues with an increasing number of participants. Four courses have been completed bringing the total number of graduates to 82; the fifth course (1985) is on-going with 24 trainees. The countries that have participated are Ethiopia, The Gambia, Ghana, Kenya, Liberia, Malawi, Nigeria, Sierra Leone, Sudan, Tanzania, Uganda, Zambia, Zimbabwe, Cameroon, Central African Republic, Congo, Gabon, Guinea, Ivory Coast, Mali, Rwanda, Senegal and Zaire. The successful candidates are awarded a Diploma by ARAC and qualifying candidates an M. Tech. by Rivers State University of Science and Technology. The course is conducted in English and French. The funding agencies for the trainees so far include ADB, FAO/UNDP Field Projects, CFTC, USAID, GFID, EEC and some governments. Estimated expenditure for an individual trainee per year is about US$9,500.00.

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