

DELIVERING BETTER QUALITY TILAPIA SEED TO FARMERS

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Abstract

A cornerstone of upgrading productivity of tilapia culture is the continuous improvement in the quality of seed used by farmers. This statement is relevant to the spectrum of tilapia production systems, but 'quality' is subjective and requires to be defined for specific contexts. An overview of strategies to improve the quality of seed under different conditions is presented. Consumer, marketing and producer perceptions of quality are assessed using examples drawn from a range of situations. The potentials and constraints of different approaches to tilapia seed improvement are considered; these include self-sufficiency at farm level through to upgrading at farm, specialised hatchery or institutional levels. The impacts of germplasm transfers, selective breeding and genetic manipulation are considered. Impacts of changing consumer demand, culture system and level of intensification on seed quality are discussed before an assessment of the roles of Government and private sector in maintaining and improving seed quality to farmers. Strategies that promote centralised hatcheries, in which large-scale production occurs at relatively few locations, are compared to a more decentralised approach with respect to quality, consistency of supply and equity of benefits. Finally, the implications of promoting mono-sex compared to mixed sex tilapia seed are compared.

Introduction

The objective of this article is to review the background, current status and potential for delivering improved quality tilapia seed to farmers. The primary focus is to assess what strategies result in better seed becoming, and then remaining, available to farmers, rather than attempting to give a conceptual overview of technical approaches to quality improvement. An important first step is to accept that the main groups of stakeholders are likely to have somewhat different views on 'quality', what it is and on priorities to improve it. Undoubtedly, the perceptions of some producers and consumers of tilapia seed are that the quality of seed available to them, and of the product that results from their culture, is acceptable and that their major problems are of different nature perhaps in terms of marketing or production cost. A glance at the much longer established plant and livestock 'seed' producers show that, in common with most productive endeavours, improving efficiency and productivity is relentless. As the establishment of tilapia as a global commodity over the last two decades has exposed producers to greater market competition, increasing the quality of tilapia seed has to be perceived as a process rather than an end product.

‘Delivery’ of high quality seed is an issue as even if quality is improved in research stations it does not guarantee it will reach producers as required; ensuring availability of consistently high quality seed at the farm gate is a major challenge. Policy makers that shape the broader environment for change have to understand the options; local organisations promoting aquaculture can provide various forms of support but it is usually a range of private-sector entrepreneurs that practically deliver, and technical innovations have to be appropriate to their needs. A major challenge in this task is to unpack the hype from the reality and to distinguish what is possible from what is ideal. Technical progress has to be reviewed in terms of how technical gains can reach farmers and result in improved livelihoods.

In the following background section the key strategies to improve the quality of tilapia seed under different conditions are highlighted. The shape of the future tilapia industry is examined and its likely profile compared to the broiler chicken assessed. This is important because the characteristics of tilapia production in the future will also determine the requirements for seed supply. The perceptions of quality are then examined from different positions; different approaches to improving seed quality may stimulate conflicts or synergisms and these need to be well understood. Finally the constraints to institutions taking a more process orientated approach to improving seed quality are assessed.

Background

Leaps vs. incremental improvements; experimental vs. practical

Strategies to improve the quality of tilapia seed can theoretically be classified within two broad groups: those based on one-off actions (Penman and McAndrew, 2000) and those that are more incremental. One-off actions such as the introduction or upgrading of improved strains and species, the application of genetic manipulation techniques such as Genetically Male Tilapia (GMT) and introduction of hormonal sex reversal can result in immediate step-wise improvements in productivity. Transgenic fish would also be in this category. Incremental approaches, including selective breeding and improved husbandry and management, produce steady improvements in performance. In practice even so-called one-off approaches are highly dependent on management and the two approaches can be integrated to improve overall performance. The value of mono-sex, all male stocks, has been a particular driver and has resulted in a plethora of research, much of which remains experimental rather than practical. This is mainly related to the reproductive behaviour and biology of the fish. Obtaining significant numbers of exact same stage eggs makes both triploidy-induced sterility difficult to scale-up in the same way that it constrains application of immersion in hormone solutions of larvae (Gale *et al.*, 1995).

Direct use of hormones remains the main technique applied by the commercial sector to produce mono-sex fish but the success of this technique has focused attention to a narrow development path that may be limiting opportunities in the future; this is discussed in a later section. Improving hatchery and nursery management has been largely ignored by the research community despite evidence of its importance. Also, handling and transportation

post-production is often underestimated as a factor affecting the quality of seed available to farmers.

Most of these approaches focus on performance; individual growth, survival and overall production as indicators of 'quality' but it is worthwhile to reflect on specific characteristics of quality that people involved in producing, supplying and using tilapia seed require.

Quality- a matter of perception?

An assessment of the major stakeholders within seed production and supply networks in four countries in Asia found that the major 'voice' in demands for improved quality of seed was often knowledgeable food fish farmers keen to improve production and returns. In contrast sometimes it was less experienced farmers keen to pin their poor results on the seed they stocked rather than their inexperienced management. Understanding different perceptions is important for identifying what research and development needs are most urgent and to improve feedback to the people whose livelihoods are based on production and consumption of tilapia.

A major issue is if the priorities for improving seed quality among the range of different 'actors' in seed networks can be resolved. Hatcheries, typically also nurseries for tilapia, may have quite different criteria than the traders that purchase the seed or the foodfish farmer who ultimately grows them. In turn retailers may have different concerns to any of these people; their priorities may match more with their customer, the final consumer. Thus, whereas hatcheries may be more concerned with fish that survive early development well and have a low proportion of deformities, traders may favour fish that tolerate high stocking densities and rapid fluctuations in water quality. Food fish farmers may favour seed that does not compete too aggressively with other species under polyculture or that are easy to harvest by seining. Retailers may prioritise seed that as food fish retain their natural colour while preserved on ice or have a high fillet percentage whereas their customers may favour organic status and flavour/texture of the fish they buy. MacNiven (2003) concluded that 'quality is best seen as an outcome of all decisions taken by different stakeholders in the system'. Clearly, before major investment is made in improving tilapia seed quality, a range of opinions should be solicited.

Seed needs of a changing industry

The development of the broiler chicken industry over the last few decades is a model often cited (*e.g.*, Pullin, 1984) as appropriate for tilapia to follow. In brief this has depended on scientific development of fast growing strains responsive to intensive management and feeding. Typically urban markets are initially targeted and the system remains almost entirely dependent on outside feed ingredients and technical support. Clearly a fast growing section of the tilapia industry has many similarities, especially those in Central America, but as a whole the situation is very different. Fundamentally the link between better seed and improved and 'complete' nutrition has not, and does not have to be, so interdependent. In contrast to chickens, the herbivorous tilapia is capable of performing well on less than complete supplementary diets if raised in systems that also promote natural feed. It also means that a higher proportion of tilapia production will continue to be raised under more

diverse, and less intensive, production systems. Thus, whereas village chicken was typically a 'feast food' to poorer rural people, tilapias where introduced and established are typically everyday food. This is important because it raises the potential for a relatively large part of the market for tilapia seed to remain based on less specialised production systems that serve subsistence and local markets rather than being driven entirely by urban and export demand in the manner that 'improved' chicken has become.

Undoubtedly global markets requiring improved tilapia seed will continue to follow trends set by the chicken industry but increasingly fillet yield, colouration and disease resistance will become important as opposed to 'growth'. Late maturing fish with potential to remove the need for hormonal sex reversal could be a major advantage and this is discussed further below.

Genetic improvement of tilapias

Transfers

Germplasm transfers have had the most radical effect on the quality of tilapia seed available to farmers and the development of the species in any given region or country. Thus the importance of tilapia in Asia as a whole is based on introductions; in many cases repeat introductions and transfers. The initial transfer of the *Chitralada* strain of Nile tilapia to Thailand in 1965 and its onward distribution elsewhere in Asia has been recorded (Pullin, 1988). This strain was the basis of the development of tilapia in Thailand and its recent transformation to a major intensive industry. More recently its introduction to Brazil has had a phenomenal effect on production (Zimmerman, pers. comm.). However the lack of impact in Bangladesh, until recently, and the poor strains of tilapia that constrained development in the Philippines, and to some extent Vietnam, are evidences that transfers alone are insufficient to ensure quality seed remains available to farmers.

The level of formal institutional support is often a key issue to success but there are also instances of where private sectors' interest has overcome official indifference. The spread nationally, and continued good quality, of the Thai *Chitralada* strain was a product of official support to aquaculture by establishing provincial level fishery stations and a simple but effective management plan to replace breeding stock regularly from a central repository. As commercial sectors began to develop, government-produced fry continued to provide a benchmark of quality and availability, and to be available at the provincial level. In contrast government indifference, or at times antagonism, has not prevented mixed sex tilapias becoming dominant within wastewater-fed systems around Kolkata, India. This can be explained by a competitive and mobile private sector accessing them through informal channels and a high demand that has developed in the market. The successful transfer of the *Chitralada* strain to Brazil was more a product of private sector-research organisation collaboration and, critically, the process for mass production of mono-sex production being transferred at the same time.

Hybridisation

Hybridisation has been a major focus for improving performance of tilapia seed but the research has rarely been sustained in any commercial context for a variety of theoretical

and practical reasons. Examples of interspecific or intergeneric hybridization in which performance of the hybrid has been compared against parental species under standardized conditions are few and suggest only limited gains through heterosis (Penman and McAndrew, 2000). The large-scale breeding programme (Genetically Improved Farmed Tilapias, GIFT; Bentsen *et al.*, 1998) found gains through heterosis between wild and domestic strains of Nile tilapia were less than 6%. One example of interspecific hybridisation that has had a sustained impact is the use of *O. aureus* in Israel to improve cold tolerance over pure Nile tilapia; this has improved the overwintering performance of fish which is an important consideration (Wohlfarth, 1994). The difficulties of managing separate lines or strains under commercial hatchery conditions have made hybridisation an ineffective approach to sex control however, and have also undermined the promotion of the YY male technology.

Selective breeding

The experience of selective breeding in tilapias has been reviewed by Penman and McAndrew (2000) who concluded that the low heritabilities for growth observed in many trials were an outcome of the low genetic variation typical of the cultured stocks used. The well-funded international GIFT programme based selection on a synthetic base population from wild and domestic stocks of Nile tilapia has resulted in improved growth and survival (Longalong *et al.*, 1999). Based in the Philippines, the programme aimed to produce high performing base stocks that could be further selected by national centres in countries wishing to improve tilapia culture. The benefits to farmers from the programme, which is ongoing, varied by country; in Bangladesh GIFT compared very favourably to many local strains (Mazid *et al.*, 1996) but differences were much less marked in Vietnam and Thailand where local strains performed well (e.g. Dan and Little, 2000).

Some of this research has been carried out in trials with farmers but little work has been carried out documenting the access of farmers to these improved fish. In general much less effort has been expended on ensuring that new strains from such centrally managed breeding selective programmes are available to farmers, especially those with no direct links with the research organisations responsible for producing them. Smaller-scale programmes that would aim to increase or maintain diversity of local strains have been advocated by Doyle *et al.* (1991) and might be an approach to ensure the benefits from selection were delivered and retained in rural areas. Selective breeding methods appropriate for use by small-scale hatcheries have reported an improvement of 3% per generation in performance over controls (Basiao and Doyle, 1999). Recently there is interest in applying the lessons learnt from participatory plant breeding (Tripp, 2001) in the expectation that improving tilapia seed quality and availability in rural areas can benefit from lessons learnt in other sectors.

Genetic manipulation

The major area of genetic manipulation that has begun to impact on farmers has been that of genetically male tilapia (GMT); the impacts of transgenic tilapia although technically exciting, are likely to remain a marketing and regulatory issue at least in the medium term. The replacement of conventional hormonal sex reversal with GMT has been a major objective of research for nearly two decades and built on earlier work looking at sex

determining mechanisms in tilapia. After a decade of large-scale piloting of the GMT approach (Mair *et al.*, 1997) in Asia there are now major questions over its potential. Although significant numbers of seed have been produced in the Philippines the approach has not become established in the commercial sector elsewhere. A combination of the relatively poor performance of GMT fish compared to monosex produced using hormonal sex reversal (*e.g.*, Pham *et al.*, 1998) and lack of availability constrained interest in Thailand. Relatively low ratios of males that are insufficient for population control in semi-intensive systems appear to be caused by contamination of broodfish. This problem, even in more intensive and better managed hatcheries, is exacerbated by the expense of marking systems for individual fish and has been a contributing factor in the high cost of GMT production. The greatest potential for GMT appears to be for producers requiring sex control, but who cannot use hormones directly; the emerging market for organic tilapia may be one potential route in the future.

Genetic improvement of tilapia is often constrained by the capacity of the private sector to manage broodstock. Non-genetic factors also directly affect seed quality however and these are now considered.

Non-genetic issues affecting seed quality

A range of non-genetic factors can reduce the availability of quality seed to farmers; these include the technical, climatic and institutional. Seasonal variation in demand can have a major effect on the quality of seed available to farmers, as it can undermine efforts by hatcheries to produce them. This is commonly ignored in the planning of hatchery strategies.

Effects of demand for seed on approaches to improving quality

A consistent year-round demand for seed is quite unusual among the major tilapia producing areas; typically patterns of water availability or temperature affect stocking and harvest regimes. Mismatches in supply and demand of seed production can negatively affect quality in a number of ways. The timing and onset of wet seasons can greatly affect the volume and timing of demand for fish seed in rainfall-dependent culture systems. Poor predictability of sales can affect quality in different ways; delays and consequent high stock inventories can lead to management problems and disease outbreaks. In particular the prolonged holding of mixed-sex tilapia seed can result in early breeding, and subsequent runtting of stocked fish and progeny, when stocked into production ponds (Little *et al.*, 2003). But it has also been shown that extended holding of juveniles, or overwintering, is a management strategy that can increase the window of supply of quality seed. Dan and Little (2000) showed that although mono-sex can exhibit compensatory growth and improve returns to producers compared to smaller younger fry, similar gains were also possible for mixed sex fish of the same age and genetic stock with appropriate management.

A related issue is a need for large centralised hatcheries to manipulate the natural reproductive patterns of tilapias better so as to produce large numbers of seed synchronously to meet peaks in demand. Better control could potential reduce broodfish maintenance costs and any need to hold large inventories of fry.

Management of production and delivery

Production of same size, same aged seed is a major objective for tilapia seed producers but many commercial systems rely on continuous production of fry from broodfish cohorts (Little and Hulata, 2000). This has implications for both productivity and quality of the seed produced in such systems. Grading imposes stress on fish and large differences in seed size require more frequent grading. Other important parameters include water quality and feed management. The level, quality and frequency of juvenile feeding have all been implicated in the production of poor quality juvenile seed. Transportation and related handling stress is a key factor in the perception of the low quality of tilapia seed available at the Mekong Delta compared to that purchased closer to their site of production around Ho Chi Minh City (AIT/CAF, 2000). Poor survival post stocking is a common characteristic of tilapia transported over long distance. Alcocer-Hartley (2001) compared open and closed transportation of monosex tilapia over 12 hours periods in Thailand and found that open systems showed significantly higher post-stocking survival than closed oxygenated plastic bags. A need to establish the relative 'quality' of different batches of seed prior to long distance transportation stimulated research into stress or challenge tests on mono-sex tilapia (MacNiven and Little, 2001). The outcome, based on developing a simple saline based test that determined relative quality within 2 hours, was the finding that survival was related to size and that this was a quick and efficient way to identify the best fish to transport.

Improving quality-roles of Government and other 'actors'

The level of private sector capacity to maintain and improve tilapia seed quality is becoming increasingly evident as performance of, and investment in, the sector increases. Large commercial hatcheries increasingly offer a range of seed products and attempt improvement programmes. Vertically integrated operations tend to maintain and develop their own broodstock. The role of the government sector in maintaining and upgrading seed quality clearly varies in different parts of the world and aquaculture in general and tilapia specifically can learn from research into the public:private delivery debate in other areas of agriculture (*e.g.*, Tripp and Pal, 2001).

Typically key objectives of Government support are skewed towards large players and export-led development. The rationale, presumably, is that smaller and domestically-orientated development will 'look after itself' and that 'trickle-down' will inevitably occur to eventually benefit smaller producers alike. This reasoning, quite outdated in most development circles, persists in the tilapia sector perhaps because of the rapid growth in demand for tilapia in developed country markets. Key issues to resolve include whether or not an export-based tilapia production sector will be globally competitive and the nature of current and future domestic demand. Support for introductions/transfers, for breeding programmes and associated support can then be more effectively designed. Clearly, close communication with those producing tilapia is required; this is usually easier with larger producers and the development of linkages with smaller players is often a challenge. For example, promoting mono-sex tilapia will require contact with a very different target group than if the objective was to promote improved mixed sex tilapias (see below). Producer groups of various types appear to be one mechanism to make linkages more cost effective; these often develop with normal commercial pressures among seed producers, but more

structured links may be required with formal Government organisations. Similarly, Tripp and Byerlee (2000) identified a need for ‘public sector plant breeding to improve its links with the commercial seed sector and to become more proactive in promoting its products and moving them through appropriate private channels to ultimate users’. The instinct by Government to attempt to improve quality through regulation or certification of private sector seed producers should be resisted however. In plant seed development, regulatory bodies are increasingly moving towards technical and policy support for the development of seed provision options (Tripp and Louwaars, 1997). Regulation burdens the sector with extra costs and are unlikely to be effective –better links to information and stimulation of action-learning are more likely to yield longer term gains in terms of improved quality (Little *et al.*, 2004).

A major strategic issue for any improvement in availability of quality tilapia seed to farmers is the direction of Government support towards centralised or more decentralised approaches to production. This is considered now, after which the issue of choices to support the promotion of mono-sex compared to mixed sex tilapia seed is discussed.

‘Centralised’ or ‘de-centralised’ approaches?

Investment in freshwater fish seed production to stimulate aquaculture development has generally been targeted at strategically located Government hatcheries. Typically this has resulted over the last few decades in rapid private sector adoption to the point where most seed is now produced in small, household level enterprises. The targeting of specific areas for this initial investment has probably affected the nature of such private businesses, which tend to occur in geographical ‘clusters’. This ‘centralised’ seed production is often less about very large enterprises under the same management and control (either within the State or private sector) and more about clusters of small commercial operations typically networked together by kin and other relationships. Clearly this brings significant advantages to both producers and intermediaries, whose role is essential for producers to be able to reach often distant and highly scattered fish farmers. Clusters of enterprises have been associated with success in other sectors; they may create positive externalities that assist in managerial and technical learning (Altenburg and Meyer-Stamer, 1999).

Typically, institutions external to the communities within which such enterprise clusters develop have had important influences on their development initially. Analysis suggests that Government, Non-Government and private institutions have provided such roles in Asia often in combination. For example the development of the concentration of tilapia producers in Chonburi/Chachoensao provinces, Thailand (Little *et al.*, 1994) had important inputs from a local Christian church and the Department of Fisheries who provided initial broodfish.

Generally the concept of ‘centralised’ and ‘decentralised’ tilapia seed production has conventionally focused on the former being related to progressive, commercially orientated culture and the latter towards subsistence small-holder production. In fact the reverse situation has become common. Many large vertically integrated enterprises are self-sufficient in fry largely to ensure consistent supply with quality seed, whereas in Asia most

smallholder producers rely on hatchery seed for re-stocking after exhaustion/harvest. Contract farming, an approach that has become standard in many areas for shrimp and poultry, has had more mixed success largely because of the relative inconsistency of production by large stand-alone hatcheries to date. For example in Thailand tilapia seed production by Charoen Pokaphand, despite many years establishment has regularly failed to meet demand by their contract growers at critical points during the year. In contrast networks of mixed sex fry producers appear more robust in their facility to respond to short-term surges in demand stimulated by changes in the weather.

Decentralised approaches

Decentralised seed supply is essentially the production of juveniles close to where they are raised to marketable food fish. This definition emphasises the relative proximity of juvenile production to their use rather than the size or management of the hatchery *per se*. In general a higher proportion of seed produced at any concentration of hatcheries would need to be marketed at distance, whereas small dispersed enterprises can thrive serving local demand. Decentralised approaches encompass a range of options however, ranging from the 'self-sufficient', in which local demand is met from the complete cycle of production (broodfish to juvenile), to situations where small juveniles are purchased from centralised hatcheries and nursed to a larger more valuable size locally. The origins of the seed used however can have very different implications for upgrading and maintaining seed quality (see below).

Local nursing of both mono-sex and mixed-sex tilapia seed in fine mesh cages (*hapas*) to meet local demand has been piloted and resulted in large gains in productivity in both South and Southeast Asia. The high costs of production and transportation of large fingerlings results in the seed from concentrations of hatcheries usually being small in size; this is believed to be a common cause of failure as the seed are vulnerable to predators. Promoters of aquaculture have identified stimulating local nursing as a way to improve the quality and timing of seed available, whilst enhancing employment opportunities for the poor (Lithdamlong *et al.*, 2002).

A potential advantage of linking centrally produced seed with rural areas through such private sector networks is that the genetic quality of the seed used can be more easily maintained and upgraded as improved material becomes available. A weakness is that rural communities remain dependent on a distant source of supply that, if it becomes unreliable, totally undermines their system. Ensuring that quality seed can be produced from a hatchery located within a cluster improves the viability of this as an option but this has proved a major constraint in Thailand where periods of low hatchery output are experienced by the sector as a whole.

The efficiencies and economic viability of such systems rely on well-developed infrastructure and linkages between suppliers and hapa-nursers, which can be a problem, especially if there is reliance on poorly performing government hatcheries to supply small fry for local, decentralised nursing. This has been an issue in Lao PDR in efforts to stimulate local nursing of seed. It was concluded that support for local trading networks to connect

with the private sector in neighbouring Thailand would be the most pragmatic approach (Haitook *et al.*, 1999).

In contrast, the delivery of broodfish to the local level for spawning and nursing, whether in hapas or irrigated ricefields, can support greater self sufficiency if mixed sex tilapias are acceptable. Barman (2000) piloted both hapa-based spawning and nursing and spawning/nursing in irrigated ricefields in several communities in NW Bangladesh. Whereas hapa-based systems were not retained, for a variety of reasons, the stocking of a few high quality GIFT tilapia in ricefields to produce advanced fingerlings quickly became established and has spread rapidly to surrounding farmers in neighbouring communities. Local NGOs have also integrated the concept into the curricula of farmer fields schools (FFS) promoting integrated pest management. A preliminary analysis of communities and households to which the approach has been promoted indicates that farmers are benefiting in a variety of ways. Ricefield-based fingerling production appears to work particularly well where tube-well water is abundant and few other cash income earning opportunities have developed (Barman *et al.*, 2004). The initial numbers of GIFT tilapia introduced and the level of understanding among FFS trainers are both important to ensure the practice becomes established among farmers in any community. The approach is now being piloted by external NGOs elsewhere in the country and its impact assessed.

The relative risk of genetic deterioration, and opportunities for maintenance and upgrading, for tilapias produced and distributed from concentrations of production compared to those produced locally (Mair and Little, 2004) are discussed below.

A review of the management practices of mixed sex tilapia hatcheries that occur in clusters around Ho Chi Minh City and Bangkok suggest that awareness and knowledge of reproductive biology of tilapias is high among operators, and that attempts to maintain and upgrade genetic quality are typically based on introductions of new strains (Little *et al.*, 1994; AIT/CAF, 2000). Management to exclude feral strains may be attempted but complete exclusion or isolation of improved stocks is limited by the nature of open pond production systems and their location within deltaic ecosystems prone to flood events that result in periodic contamination. The entry of feral *O. mossambicus* into ponds and the unintentional hybridisation and resulting introgression in then Philippines led to reduced performance of the stocked *O. niloticus* and *O. aureus* (Taniguchi *et al.*, 1985; Macaranas *et al.*, 1986). The movement of broodstock between individual operators is dynamic and usually based around relatively large numbers required to achieve significant production. However initial founder stocks may be relatively small.

Specialised large-scale hatcheries increasingly view maintenance and improvement of the genetic status of their stock as critical to their success. There is a trend towards management of high quality broodfish through intensification using hapa and/or tank-based systems to reduce contamination and improve quality control. Closer control of broodfish allows the operator to reduce risk of contamination, and the harvest of early seed and their artificial incubation improves the effectiveness and consistency of hormonal sex reversal (Little and Hulata, 2000). Expectations to improve productivity compared to simpler earthen pond system are often unrealised however.

In Thailand, pressures to expand the range of strains available are also exposing the larger commercial hatcheries to risks of inadvertent contamination between strains unless on-farm management is rigorous.

An assessment of the major likely sources of deterioration in rice-field based fingerling production systems has been made by Chowdhury and Mair (2004). Undoubtedly there are lessons to be learned from other agricultural sectors with regard to management of seed quality in decentralised supply systems. Several approaches have been used for maintaining and improving crop and livestock germplasm available to farmers in rural areas. Approaches in which public systems of variety improvement, multiplication and distribution are managed by NARS have suffered from a range of weaknesses, centred principally on their longer-term sustainability. Alternative approaches have focused on developing local seed sources and their management by individual households and/or communities. However, community seed projects have often been found to have their problems and the distribution of free seed and subsidised seed delivery have been said to undermine the development of commercial seed producers and 'seed saving' (Tripp, 2001).

Mono-sex and mixed-sex tilapias

Tilapia seed was until recently generally considered poor quality because of early maturation and breeding in culture ponds. The precocious breeding of tilapias, leading to stunted populations of low value, was a major fixation of the research and development community as the fish emerged as a major global aquaculture candidate in the 1970-80s (*e.g.*, Pullin and Lowe-McConnell, 1982; Fishelsen and Yaron, 1983, Pullin *et al.*, 1988). The application of direct hormonal treatment of undifferentiated fry, together with more intensive grow-out approaches by the private sector have together led to the current status of tilapia now being an important aquaculture commodity. Alternative approaches to control populations of cultured tilapia have been widely discussed (*e.g.*, Mair and Little, 1991) and still have currency in some areas and for some culture systems. The success of hormonal sex reversal has, however, distorted a broader understanding of the historical background, the current reality and needs for the future of tilapia production.

Firstly, although uncontrolled breeding and subsequent effects did act as a significant break on the growth of commercial production and global trade (Lovshin and Popma, 1996) a lack of mono-sex technology did not prevent a rapid expansion of domestic markets in several countries in Asia (Little and Hulata, 2000). This can be explained by a high demand for relatively small (<300g), whole fish as opposed to larger fish and fillets in Asia where much of the expansion has occurred. On a global scale the growth of mixed sex tilapias almost certainly continues to lead that of mono-sex, reflecting producer and consumer needs and key constraints to adoption of current mono-sex technologies. The limited capacity for scaling up mono-sex production in many contexts is not widely appreciated by investors and policymakers. Production of mono-sex tilapia seed by vertically integrated agribusiness based on intensive production in well selected locations is relatively straightforward. Promoting the emergence of specialised hatchery enterprises to serve widely distributed, often semi-intensive, food fish producers is more problematic (Little and Hulata, 2002).

In the future, alternatives to hormonal sex control will be driven by two major incentives: a continued growth in demand for small fish among poorer, increasingly urbanised consumers in less developed countries and secondly interest in accessing markets for 'organic' tilapias. Selective breeding for later maturing fish, particularly if the reduced associated growth (Longalong *et al.*, 1999) can be overcome through combined selection, appears to be a viable option for controlling reproduction in the less intensive systems.

Conclusions

Ideally, quality improvement in tilapia seed is a process that all stakeholders are involved. The sustained delivery of better quality fry to producers requires attention to genetic, management and institutional issues. A key need to ensure quantity and quality of seed can be maintained is that the nature of demand for tilapia seed in terms of season, producer intensity and ultimate market is understood. The broiler chicken model of development is inappropriate in many contexts and tilapia production systems, and seed needs are likely to remain more diverse. Government roles in supporting continuous improvement in tilapia seed quality are location specific but often crucial. Decentralised approaches that produce high quality mixed sex fry are appropriate in many contexts, especially given the difficulties in promotion of mono-sex technology.

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