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Quality Seed *Sinequa Non* for Sustainlable Aquaculture

S. D. Tripathi

Former Director and Vice-Chancellor, Central Institute of Fisheries Education, Mumbai, Maharashtra 400061 (India)

Abstract

Given the call for doubling the farmers' income and products, the importance of quality fish seed has gained considerable significance. However, production of quality seed is beset with many challenges beginning right from the selection of brood stock (parents), its rearing and maintenance, and raising of healthy fingerlings for stocking. Sufficient information has been generated on inducing agents and their dosages as well as on environmental conditions. Methods for pond preparation, rearing spawn, fry and fingerlings, feeding and fertilization, and maintenance of optimum water quality parameters have been developed but measures to control diseases are yet to be developed and standardized. Urgent attention is required to improve the survival rates during nursery and rearing phases to meet the requirements of "more crop per drop of water". Methods to breed the fish artificially in confined environments were developed using a variety of inducing agents but an indigenous product is the need of the hour. Hatcheries have mushroomed but their quality control and certification are long overdue. Systems have been developed to spawn the same brood fish 3-4 times in the breeding season using rich feed and manipulating the photo-thermal regime to enable round-the-year seed availability. Eco-hatcheries are an asset but these need large quantities of water hence systems such as recirculatory syatem, aquaponics and biofloc technology need to be incorporated to economise on water, feed and land for nurseries. Among the many carps that constitute the base of Indian aquaculture, only *Labeo rohita* has been genetically improved through selective breeding (*jayanti rohu*). It is time that some high value species that mature in a year are developed through selective breeding and inducted to diversify aquaculture and increase the farmers' income. Recent success in breeding and seed production of the prized Indian shad *Tenualosa ilisha* will pave the way for mass production of its seed for commercial culture.

Key words: Quality seed, Multiple spawning, J*ayanti rohu*

Introduction

India is the second largest producer of fish in the world, the total production during 2016-17 being of the order of 11.41 MMT contributed largely by the inland sector (7.77 MMT; 68.1%) as compared to 3.64 MMT from the marine (GOI 2017). However, 80% of inland fisheries production is constituted by aquaculture. India also occupies the second position in aquaculture production (> 6 MMT), being next only to China which produces more than 63 mmt (World Bank 2017).

If fish production is to be doubled along with farmers' income, aquaculture needs to be targeted as there is hardly any possibility of increasing the production from rivers and estuaries, large flood plain lakes and other natural water bodies which are getting fast degraded in the absence of proper conservation measures. The freshwater aquaculture resource in terms of ponds and tanks being only 2.36 m ha, another 1.2 m ha of floodplain lakes/wet-lands and 3.15 m ha of reservoirs could as well be utilised for cage and pen culture to indirectly help in augmenting the total production from these water bodies. However. proper stocking of these water bodies needs 3,000 million fingerlings (DAHD F and 2016), but the present production of fingerlings is only a fraction of the huge requirement. Bulk of the fish seed produced in the country is sold in 'fry' or 'early fry' stages.

The Government of India has taken a new initiative captioned as "Blue Revolution" with funding support of ₹ 30,000 million which envisages construction of new and renovation of old and derelict ponds for horizontal

***Correspondence :** sd_tripathi@rediffmail.com
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expansion and supporting ancillary activities such as establishment of hatcheries and feed mills, training and skill development of farmers. This will ensure a steady supply of quality seed as a prerequisite for achieving the blue revolution targets. Quality seed may be defined as uniform-sized fry, fingerlings, or juveniles that would subsequently express good performance attributes during culture. Other important traits are desirable color, shape, good growth, health, efficient feed conversion, high reproduction, tolerance to and survival in poor and/or extreme environmental conditions. Success in the sustainable production of aquatic species for human consumption depends primarily on the availability of such good quality seed besides adoption of optimal husbandry techniques. With the intensification of aquaculture systems and the environmental challenges such as those resulting from climate change, both factors- genetic quality and culture management should be considered as equally important in ensuring a steady yield of good quality seeds and later, marketable products from aquaculture.

Fish Seed Production

Natural vs Artificial Sources

Seed being the prime requirement for aquaculture, steps need to be taken to procure/produce it. The indigenous carps, the mainstay of freshwater aquaculture in India, spawn only in the rivers or flooded waters during the monsoon and have been the only source of seed during the past. Collection of the seed from these natural resources was beset with many problems such as (i) location of the spawning/collection site, and (ii) methods of collection, storage and transport of eggs/hatchlings for rearing to fry or fingerling stages when it could be stocked in larger water bodies for raising to marketable size. Both eggs and hatchlings were being collected in the past from established centres on the rivers or flooded sites as also from ponds/tanks (wet *bundhs*) where fishes were observed to breed by adopting suitable methods. However, the biggest drawback of these collections was that it was always a mixture of several species including the predatory ones and despite all precautions and care taken to rear the seed in nurseries, the survival was lowand one was never sure as to what percentage was constituted by the desirable species.

However, an intelligent farmer who observed these species to breed in small ponds and tanks (*bundhs*) and studied the conditions conducive to the phenomenon, tried to emulate the same in ponds filled with incoming rain water during the monsoon and stocking it with mature fish. To his utter surprise, the fish spawned and this developed as a major and reliable source of fish seed of select species, these were designated as 'dry' as opposed to 'wet' *bundhs* referred to above.

Midnapur and Bankura districts in West Bengal were well known for dry bundh breeding as conditions congenial to spawning were naturally available there. The factors inducing spawning of carps in rivers and *bundhs* were discussed at a symposium organised by the National Institute of Sciences, India, in 1945. Each speaker had his own views ranging from pH, temperature, rain, smell from the forest, lightning and thunder and so on but the carps have been found to breed under a variety of conditions, hence no single factor could be considered responsible. Based on a series of experiments, Swingle (1953) considered the presence of a hormone-like excretion or secretion of fish that acts as a "repressive factor" inhibiting reproduction in ponds but the fish breeds when this factor gets diluted with incoming freshwater or when put directly in freshwater. Thus, it is the "repressive factor" that plays its role. Since fish culture was fast gaining popularity as a source of nutrition being supported by the community development programmes of the Government of India, seed requirement and its demand were fast increasing. In order to meet this requirement, surveys to locate new seed collection centres on various rivers were conducted by CIFRI in collaboration with the State Departments, with an emphasis on *bundh* breeding. At least one dry *bundh* was established in each district of the Madhya Pradesh while about a dozen were in and around Nowgong in Chhatarpur district and, as compared to Bankura-Midnapur *bundhs*, these were improved and sophisticated.

Owing to non-availability of the to-be brood fish near dry bundhs, these needed to be collected from perennial ponds and transported to the site of dry *bundhs* which not only stressed the fish but also occasionally led to its mortality. Further, the process did not involve the selection of brood fish based on its maturity stage and with no attention to the male-female ratio or its size. Quite often, it resulted in production of hybrids which did not survive for long and, if survived, were a potential danger leading to genetic retrogression.

With the development of induced breeding technique and establishment of hatcheries, this cheapest and easiest method of seed production in dry bundhs gradually lost its importance and was virtually thrown into oblivion. However, in the present circumstances, it needs to be revisited following the Best Practices for large scale seed production and economising on the heavy expenditure incurred on establishing the hatcheries as well as on water requirements.

Artificial Spawning

An alternative and a dependable source of supply of quality fish seed being an imperative requirement, resort was taken to breed the fish artificially and use of various hormones such as mammalian placental gonadotropins, steroid and pituitary hormones came into vogue. While Ramaswami and Sundararaj (1956) and Ramaswami and Lakshman (1958) used placental gonadotropins to spawn the two cultivable catfishes, *Heteropneustes fossilis* and *Clarias magur*, Ranganathan *et al*. (1967) bred *rohu*, *Labeo rohita*, just by an injection of centrifuged human pregnancy urine. HCG has been widely used for spawning the carps till such time that hypophysation came into every day use. Steroid hormones, however, failed to induce spawning in *H. fossilis* (Ramaswami 1962, Sundararaj and Goswami 1966) but DOCA (deoxycorticosterone acetate) when injected at 5 mg brought about profuse spawning. Suffice it to say, that eventually use of pituitary gland extract was found to be an easy, convenient and practical way for large scale spawning of indigenous cultivable fishes as well as in bringing about advanced maturity (Panicker and Bagchi 1968).

Briefly, the hypophysation technique comprises (i) collection of pituitary glands (PG) from fully mature fishes and their preservation in acetone or absolute alcohol under refrigeration; (ii) selection of broodfish; and (iii) preparation of extract for injection and dosages. The entire process is adequately described by Chaudhuri (1963), Bhimachar and Tripathi (1967) and Tripathi and Bhimachar (1972).

Today, several inducing agents, some of which are imported, are available off-the shelf, which can be easily procured and used anywhere and for any species of fish. Unlike the pituitary extract these are not species- and sex-specific. Yet another advantage is that very low doses (0.1-0.4 ml kg^{-1}) are needed as against much higher doses of carp pituitary (5-15 ml kg^{-1}) and secondly, only one dose being enough the fish is much less stressed. To name a few, ovaprim, ovatide, ovulin, WOVA-FH and gonopro are a few commercially available inducing agents.

Hatcheries

Initially, the hatchery comprised a cloth breeding *hapa* (inverted mosquito net) fixed in the river to simulate the natural conditions with a mild current where the injected broodfish were kept and after spawning was over, the eggs were transported to the farm ponds for hatching in double-walled cloth *hapas*. One can easily imagine the disadvantages of the system but over the years it evolved with rectangular followed by circular cement breeding pools (Chinese model) under a shed or in a hall, later air-conditioned, with doubled-walled hatching pools, also cement structures. Improvement was also affected in the hatching system following the European model and Macdonald and Zoug jars ruled the hatcheries for some time. Finally, we developed our own model of portable Fibreglass Reinforced Plastic (FRP) hatchery under the All India Coordinated Research Project on Plastics in Agriculture at the Central Institute of Freshwater Aquaculture (CIFA) at Bhubaneswar which has all the advantages we can presently think of. The model is in the market and has been installed in most of the hatcheries in various states.

The hatcheries should have a continuous supply of good clean water, preferably, at a regulated temperature (28^0 C) for effective spawning and hatching and as such all operations undertaken in air-conditioned hatcheries were cent percent successful.

The standard of hygiene in hatcheries in India is very low. Wet and stinking nets and *hapas* besides empty bags of feeds, fertilisers and disinfectants are often found lying in corners. It is a free for all as anybody can walk in and out at will, there being no need to wash the feet in the disinfectant pool or even to remove the shoes. The hatcheries in Norway and elsewhere do not allow anyone other than the assigned workers and this needs to be adopted to prevent disease entry in the hatcheries in India.

Breeding the carp and other cultivable species

While, on the one hand the Indian and Chinese major carps are being successfully bred on a large scale, there are a few species that are difficult to breed – two amongst these being the catfishes, *C. magur* and *H. fossilis*. Since the males do not respond to injections and release the milt naturally, the testes needs to be dissected out and macerated to prepare a suspension which is sprayed over the eggs, obtained by stripping the female, for fertilisation. This being a cumbersome process, seed production of the species – despite its great demand and high price – has not picked up. Since the two species easily breed in ponds and paddy-fields, the time-tested method of *bundh*-breeding needs to be modified and perfected to suit these species. It needs just a freshwater body and a flooded condition and not a current. In Thailand this practice is followed to breed the fish in rice fields.

Over 30 species have been artificially spawned by now. The techniques do not need to be developed *de novo* for seed production of other species as the methodology already known could be followed keeping all the precautions in mind and go for large-scale seed production, wherever required.

Nursery rearing

Within four hours of spawning, the eggs are collected, measured/counted and taken into the hatching pool- the number depending on the size of the pool -where a mild current of water and aeration are maintained, Normally, 72-hours old post-larvae are stocked in farm ponds, called nurseries, but when retained for a day more and weaned on goat-liver based artificial feed, faster growth and higher survival is obtained.

The nurseries (area 0.02-0.04 ha; depth 1.5 m) are made weed- and predator free, fertilised (to develop natural food, predominantly rotifers) and rendered insect-free 12 hours prior to stocking the hatchlings. These are well recognised steps but, generally, not followed by all fish farmers. The agriculture farmers in the country are now provided soil health cards but similar facilities are not given to fish farmers. Organic fertilisers such as cow dung or goat droppings are good, especially when these are fermented. Use of biogas slurry (30-40 t ha^{-1}) can solve problems associated with oxygen deficiency. Four parameters that need attention are pH (7.5-8.5), DO (5-6 mg^{-1}) total alkalinity (100-300 mg^{-1}) and plankton (predominantly rotifers 3 ml 50 l^{-1}). Appearance of algal blooms or dominance of copepods and other larger planktonic organisms is a warning bell for urgent action. Further, while the hatchlings would be feeding on plankton, it is equally necessary to supplement it with rich and balanced artificial feed to achieve faster growth. Normally stocked at 5 m ha^{-1}, it takes 15-20 days to reach the fry stage with an average survival of 60%. Application of cobalt chloride (100 g ha^{-1}) in split doses along with goat gut extract on the first day of stocking and repeated 5 days later has given over 90% survival at a stocking density of 10 million hatchlings ha^{-1} in 10 days rearing period.

Raising Fingerings

Although 25 mm fry was long considered good enough material for stocking, of late, there is a widely accepted view that fish, smaller than 10 cm (advanced fingerling) should not be stocked. It requires larger ponds (0.2-0.4 ha) to grow to such size and takes not less than 60 days. If the fish has spawned in mid-July, the fingerlings would be available for stocking in late September. But, by that time, winter sets in which affects the growth. This is one reason why the farmers do not rear it to fingerling size. However, to achieve a higher rate of survival and consequently production, the fry needs to be reared further in rearing ponds prepared in the same way as the nurseries except that the last operation of 'insect eradication' is not normally required unless large-sized predatory insects are present. The ponds are fertilised fortnightly and the fish fed daily, initially at 10% of the weight of the fry stocked during the first month and later at 8% during the second month on a ration comprising groundnut oilcake and wheat bran (1:1 by weight) which is fortified with vitamin-mineral mixture and fish meal.

Acute shortage of suitable water bodies to be used as rearing ponds is another reason for not rearing the fish to fingerling size but its need led to a search for alternative methods to use the available water resources. Cages and pens, installed in tanks and reservoirs, can be used to circumvent the problem of rearing fry to fingerlings. Fingerlings raised in cages and pens can either be sold or can be stocked in the water body itself for production of table fish. Lately, fingerlings have been raised in high density poly-ethylene (HDPE) net cages where 3-cm fry are stocked at 100 m^{-3} to attain 10-12 cm size in 60 days. Pens were known in West Bengal but not used for seed rearing. However, pens were used for raising fry/fingerlings in Tungbhadra reservoir (Karnataka) during the 1980s, where pens covered as much as 5 ha to rear the huge quantity of seed produced at the Induced Breeding Centre to meet the demand of the State Department of Fisheries and the farmers of Andhra Pradesh (AP) as per the Agreement between the two States. Pen culture has been tried by CIFRI in the *beels* (floodplain wetlands) of Assam and West Bengal as also in Bihar but it is no longer practiced. Rectangular pens (0.2 ha) with a depth of 2.0 m are easily manageable. The pens need to be prepared the same way as the rearing ponds and it is possible to get three crops of 15-cm fingerlings between April and September. Care, however, needs to be taken that the pen is not over fertilized as it would then lead to eutrophication of the main water body.

Production of hybrids

With the success in breeding, the Indian and exotic carps and the catfishes, possibilities of selective breeding and hybridisation for improved growth and disease resistance became a reality but commercial application of this technology was a difficult task in view of lack of expertise and facilities. Hence, the easier route to hybridisation was taken and in course of time 42 hybrids were produced. However, none of these was found to have any advantage except the *catla* x *rohu* hybrid, which had a head like the *rohu* and a deeper body like *catla*. As for growth, it was a little better than *rohu*. Unfortunately, this little advantage of a smaller head was exploited by the hatcheries that took up voluntary production of *catla* x *rohu* hybrids without realising the damage that was being done to the genetic make-up of the two species. There is no need to go for hybridisation is the lesson we should learn from our experience (Tripathi 1992).

The first project on selective breeding' of rohu was taken up at CIFA in 1994 in collaboration with AQUAFORSK, Norway, where the scientists from the Institute were also trained. The programme resulted in the production of "Jayanti" *rohu*, the only selectively bred fish in the Indian subcontinent with 18% gain in growth per generation. While it is now being further developed for immunity against aeromoniasis in vestigations are on to selectively breed *catla* (*Catla catla*) and *magur* (*Clarias magur*) for growth and disease resistance.

Advancing seed availability to take advantage of growth period

As already mentioned above, by the time fingerlings are ready for stocking in the ponds, the period of growth is lost in a greater part of the country as the temperature starts going down. To overcome this problem, maturity and breeding were advanced to make the seed available latest by February-March. Manipulation of photo-thermal regime such as exposure to long photoperiods resulted in advancing maturity in *Cirrhinus reba* which were induced to spawn (Verghese 1968 a and b) and even repeatedly as in *H. fossilis* (Sundararaj and Goswami 1969). Borah and Bania (2014) spawned *Labeo gonius* and *L. calbasu* using Gonopro in February in Assam in a polyhouse maintaining a temperature higher than outside. At CIFA, Bhubaneswar, photo-thermal manipulation was used to postpone the normal (SouthWest monsoon) breeding till October-November by reducing the temperature and photoperiod. The fish that had already spawned in July-August was spawned by gradually increasing the temperature and photo-period to spawn it from December to February. Thus, almost year-round breeding is now possible provided the required facilities are organised and handled properly.

Further, the same brood fish has also been repeatedly spawned three to four times in a single season (April-September) but without photo-thermal manipulation, just by using a rich formulated diet and replenishing pond water, thereby yielding in 3-4 times the quantity of spawn obtained in a single spawning. The technique involves stocking the spent broodstock of the preceding year at 1,000 kg ha^{-1} and partially replenishing the water every fortnight between January and March with regular feeding on a formulated diet comprising 30% protein. This fish is ready to spawn by April and the operation repeated in June and again after an interval of 45 days in August. Depending on the temperature, if the fish mature by March, one could also spawn it for the fourth time. *Catla*, considered to be a difficult-to-breed fish, was spawned four times at CIFA (Gupta *et al*. 1995). Pandey *et al.* (2003) found that supplementation of feed with lysine and methionine advanced the maturation of carps by one month and the fish could be bred by late April.

Use of waste heat for advancing maturity and spawning the carps

It is now well-established that carps and quite a few other species start maturing with rising temperature after the winter is over and once mature, it can be spawned using the hormones. We have a good number of thermal power and hydro-electric projects which are discharging heated effluents that are polluting the rivers and damaging its ecology. There are no plans to use the waste heat either for advancing maturity and seed production or even for enhancing fish growth in aquaculture systems. One of the brilliant examples of the use of heated effluents is known to us. At Sarvaz in Hungary, heated effluents from the power plant are taken in the hatchery and all the carps (silver carp, grass carp and common carp) are bred and fingerlings raised saving a period of full one year and when stocked in ponds are ready to be marketed after two years instead of the normal three years. The growth period being limited to six months, the fish stays in wintering ponds for the remaining six months of the year. Heated effluents generated in India can be similarly utilized.

Natural spawning during North-East Monsoon

Though carps also spawn during the northeast monsoon, no attention was ever paid to exploit this situation. About 70 years ago, Chacko and Kurian (1950) observed that *catla* breeds twice in the Cauvery river. Today, the entire ecology of the river has changed together with its fauna and it is now a tilapia dominated river. Mrigal was induced-bred during December under the All India Coordinated Research Project on Composite Fish Culture at the Tuticorin (now Thuthukudi) Centre. Fully mature *calbasu* (*L. calbasu)* – oozing males and gravid famales – have been recorded in Bhawanisagar reservoir (Tamil Nadu) in November. Indian major carps, transplanted in the Udawalawe reservoir in Sri Lanka, are found to spawn naturally during the north-east monsoon where from the eggs and hatchlings have also been collected (Deepananda *et al*. 2014). Who knows where else mature carps are available or breeding too as we have an ingrained notion that carps breed only once in a year and that too only during the South-West monsoon. This is an area that deserves thorough investigation and exploitation to enhance seed production and 'out-of-season' availability.

Care and Management of Broodstock

Healthy broodstock needs to be developed by collecting fingerlings/yearlings from natural breeding grounds or alternately from various independent hatcheries and raising it at the farm after quarantining to prevent inadvertent entry of diseases, to ward off genetic drift and inbreeding depression. Since our rivers have also a mixed stock now and quality fingerlings are not easily available at hatcheries, the National Fisheries Development Board (NFDB) has established a Brood Bank at Kausalyagang, Bhubaneswar, with the support of CIFA and National Bureau of Fish Genetic Resources (NBFGR, Lucknow) to supply quality broodstock for production of quality seed to help enhance fish production.

Broodstock ponds

Broodstock should be maintained species-wise and, if possible, sex-wise too in ponds (0.1-2.5 ha; depth 1.5-2.5 m), preferably narrow and rectangular, with facilities for draining as well as replenishing the pond water; the stocking density may vary from 1,000 – 2,500 kg ha^{-1} – lower density is more rewarding in case of *catla*. The ponds should be periodically fertilised with organic manures to maintain plankton production of 3-5 ml 100 l^{-1} of water, with zooplankton predominating in *catla* ponds. Supplementary feeding is a basic need for proper development of the gonads. Feeding is at a lower rate during the winter months but needs to be increased with the rise in temperature. The feed needs to be religiously provided twice daily and punctually at the same time. While grass carp grows well on aquatic vegetation such as *Hydrilla*, *Vallisneria* and duckweeds, feeding it on land/lawn grass, napier, banana leaves and supplementary feed without oil cake helps prevent accumulation of fat resulting in higher fecundity and easy breeding. Formulated feed containing almost twice the protein content compared to cake-bran mixture is now becoming popular. CIFA has developed a specific feed known as CIFABROOD™ (crude protein 31.3%, crude lipid 11.7%) which is highly effective and giving excellent results. The formulation is licensed and now commercially available.

As vaccines are not available in India for the common fish diseases, it is necessary to be vigilant regarding the entry of parasites –both protozoan and crustacean – which if carried over to the nurseries can cause colossal losses.

Seed quality largely depends on the quality of broodstock. Based on a study of all big and small hatcheries in Karnataka, Wilkinson (2012), former Editor of AQUACULTURE ASIA, had also observed that 'broodstock is effectively unmanaged in the region, rather mismanaged and the practices adopted by the hatcheries are downright detrimental to the integrity of the stock and the quality of seed they produce'. India is no exception. The greatest drawback lies in (i) having a limited broodstock in almost all hatcheries thus limiting genetic diversity and further developing the fresh broodstock from its own produce resulting in inbreeding in a few generations; and (ii) spawning two or three species together leading to inadvertent hybridisation.

The importance of quality seed of proper size and its timely availability for sustainable aquaculture need not be re-emphasised. Here are three new systems which could be explored to produce large quantities of healthy fingerlings to meet the shortage.

Recirculatory and Biofloc Systems

Though not so well-known and hardly in use, the two systems – Recirculatory Aquaculture System (RAS) and Biofloc Technology (BFT) – are highly productive and, while the former economises on land and water giving 'more crop per drop of water', the latter in addition to land and space also economises on feed and provides protection against diseases.

Recirculatory aquaculture system (RAS)

RAS is known for raising table fish but none has so far thought of using the system for producing repeated crops of large quantities of fingerlings in a short time also making up for the shortage of nursery/rearing space. Often used for breeding and raising of ornamental fish, it can be as well be used for rearing carp spawn to fry and fry to fingerlings. However, it needs to be noted that the Central Marine Fisheries Research Institute (CMFRI), Cochin, which has only recently taken up mariculture has set up this facility at three centres where the entire process of seed production from management of broodstock to breeding and seed rearing is done in the recirculatory system, the species involved being cobia (*Rachycentron canadun*) and silver pompano (*Trachinotus blochii*) at Mandapam, pink-ear emperor at Vizhinjam, and, the demersal orange spotted grouper (*Epinephelus coioides*) and the pelagic Indian pompano (*Trachinotus mookalee*) at Visakhapatnam. While the grouper spawned naturally, the pampano were injected HCG at 350 IU kg^{-1} body weight. Water quality parameters need to be kept under strict watch and so also the oxygen levels as well as the electric supply for round-the-clock operation. It is the fingerlings which are finally taken for stocking the cages. Though expensive, it works out quite economical as the eggs are available throughout the year, the cost estimates and financial analysis indicated high economic returns with a payback period of less than a year and the IRR of more than 100%. Like pompano, rohu could also be injected to spawn. It would be worthwhile using high value species that are in great demand such as seabass (*Latescal carifer*) and pearlspot (*Etroplus suratensis*) which can be profitably reared and cultured in freshwater.

The components of RAS are a (1) growing tank, (2) sump, (3) biofilter, (4) oxygen injection/aeration, (5) water circulation pump, (6) water heating system (when required to maintain a temperature higher than the ambient), and (7) ozone and ultraviolet sterilization units, besides a good source of water, adequate in both quantity and quality.

Biofloc technology (BFT)

Biofloc technology was developed by Avnimelech (1999) in Israel for shrimp culture but is now finding an application for fish too. It is well known that intensification of aquaculture generates huge quantities of organic pollutants causing mortality as well as leading to environmental problems which can be avoided either by continually replacing the pond water which is neither available in such proportions nor feasible. However, reusing it by adopting the recirculating aquaculture system (RAS) that takes care of the pollutants appears a possible solution. While only a small fraction - 10% of the total water volume - needs to be replaced on a daily basis (Twarowska *et al.* 1997), high operational and maintenance costs prohibit its use on a large scale. An alternative was found in Biofloc technology which is cost-effective and environment friendly and besides maintaining water quality, it enables production of 'biofloc' - protein-rich 'natural food' – a macro-aggregate of organic material and microorganisms including diatoms, macro-algae, feed and faecal remnants, bacteria and invertebrates. Bioflocsare rich in proteins, vitamins and minerals but limiting in arginine and lysine. To sum up, the advantages of BFT are economy of feed, with almost no dependence on fish meal, and water, high biosecurity, reduced risk of pathogens, increased growth and survival leading to increased production.

ICAR-CIFE (Mumbai) has taken a lead on using the biofloc system where students have registered for their Ph.D. degree. In a 60-day experiment, Ahmed *et al*. (2016) raised fingerlings of *Labeo rohita* challenged with *Aeromonas hydrophila* in a tapioca-based (as a carbon source) biofloc system and found significantly higher serum protein, serum albumin, total immunoglobulin, respiratory burst activity than in wheat, corn and bagasse-based systems. Growth, feed conversion ratio (FCR), feed efficiency ratio (FER), and specific growth rate (SGR) of fishes in the biofloc treatments were significantly better (p b 0.05) than control. Tapioca based biofloc treatment showed significantly (p b 0.05) higher RPS (66.66%) than other treatments. The study suggests that the fishes reared using in-situ biofloc produced by tapioca can enhance growth and non specific immune responses under zero water exchange system and hence ensure sustainability when compared to wheat, corn, sugar bagasse based biofloc system and control.

In another experiment Haridas *et al.* (2017) evaluated the growth performance and immunophysiological response of GIFT strain of Tilapia in biofloc-based rearing system as well as the relative percentage survival in 3 days after challenging with the virulent strain of *Aeromonas hydrophila*. Biofloc-based units recorded significantly better ($P < 0.05$) growth performance though a decreasing trend with increasing stocking density but with 100% survival in all units. The stress parameters were significantly lower in biofloc-based rearing units where the fish was stocked at lower densities as compared to the higher densities.

Maybe, one could also think in terms of a pond breeding species with a high demand like *Amblypharyngodon mola*- a rich source of vitamin A -in a backyard BFT units. The field is now open and a challenge for scientists and entrepreneurs (aquaculturists and engineers) to work together and produce disease-free and immune fingerlings of all those species which are in demand for culture. Greater amount of essential amino acids, fatty acids (both PUFA and HUFA) and other nutritional elements supplied by the bioflocs enable better performance of fish under the system. This system can be complemented by harnessing solar energy.

Aquaponics

Aquaponics is another version of RAS combined with integrated farming that is based on cultivation of aquatic animalsand plants (vegetables, fruits or flowers) and of late, even poultry. Though known for over two thousand years to Aztec Indians, the term 'aquaponics' or 'pisciponics' was coined in 1970. It is one of the most lucrative organic food production systems that can be easily adapted in rural as well as urban settings on a backyard or commercial scale.

Basically, a closed system in two parts comprising (1) a tank for rearing fish/prawns on artificial feed, and (2) another where plants are grown on rafts or gravel that receives nutrient rich water from fish tank. In addition, an aerator is provided for supplying oxygen to the fish and a pipe line to take the faecal matter and residual feed from the fish tank to a settling sump and a biofilter. Fingerlings of the cultivable freshwater species are cultured along with green leafy vegetables such as spinach, lettuce, tomatoes, cucumber, cauliflower, cabbage, broccoli, okra and egg plant in aquaponic system. Both plants and fingerlings can be harvested in about two months.

The system is kept live by the bacterium, *Nitrosomonas*, that converts ammonia released by the fish into nitrites which are further converted by *Nitrobacter* into nitrates that is absorbed by the plants. The key constituent of the system is the biofilter which facilitates the growth of bacteria. It is necessary to monitor the four parameters *viz*, ammonia (0.25-2.0 ppm), nitrite (0.2 -1.0 ppm), nitrate (2.0-150 ppm) and pH (6.0-7.0) and action should be taken to make good any change. In addition, DO (4-8 ppm) and temperature (20^0-34^0 C) are equally important.

The fry/early fingerlings should be fed on a rich and balanced diet at 3-5% of its body weight. Any deficiency of macro-or micro nutrients should be made good. The system should be a balanced one to be profitable. If the wastes exceed, fish may suffer mortality and, if not adequate then plant growth will suffer.

Aquaponics was first introduced in India in St. Alberts College, Cochin, Kerala and later a large facility was created at Nanniode (Palakkad District) where research and training programmes are going on. It is to Kerala's credit that the world's first Seabass Aquaponics Nursery has also been installed at Nanniode where MPEDA organises demonstration programmes. The system is now available at Hyderabad, Pune, Chandigarh, Jaipur and Kolkata. Aquaponics is another system that provides more crop per drop of water as it requires only 5-10% of the normal requirement and utilises land unsuitable for cultivation while providing the highest quality of food and could employ many a farmer and skilled youth. Our Agricultural Universities should introduce credit courses as in USA so as to help young entrepreneurs who could work with the improved plant varieties and produce high quality organic food in India and export it to European countries where it is in great demand and fetches a high price.

Fish Seed Trade

There was a time when all the surplus inland fish produced in India was sent to Calcutta (now Kolkata) and almost all the fish seed requirement in the country was met from the supplies from Calcutta. While West Bengal still remains the leading fish consuming as well as seed producing State, there are others states too that have come up like Andhra Pradesh. In West Bengal, there were exclusive 'fish seed markets' like fish markets, especially in Naihati near Kolkata where the late Nil Ratan Ghosh, the doyen who lived and contributed to the growth of fish seed industry. He was the first to establish an Induced Breeding Centre and was awarded Hiralal Chaudhuri National Fish Farmer Award for producing 260 crore carp spawn. There is another elite farmer, Mr. Sultan Singh, who owns a large farm in Haryana and has visited many countries and adopted most of the modern techniques at his farm. He has also been recently awarded by the Agriculture Minister for his work. Some of the farmers in Andhra Pradesh are practicing aquaculture on an industrial scale and sending fish by trucks to markets as far away as Bihar, Assam and Tripura. Presently, they are producing seed for their own consumption but once they start round-the-year seed production adopting the RAS and BFT, there would be no seed shortage and aquaculture will be much more diversified than what it is today.

Fish seed is transported in various ways such as headloads, cycle, rickshaw, autorickshaw, car, bullock carts and trucks besides train and air, depending on the distance and the quantity. Open containers like aluminium *hundies* to drums of all sizes and shapes or even a make-shift ‘pool’ made by placing a large plastic sheet covering the entire space of the truck are known to be used. However, mortality due to stress in a confined space as well as metabolite accumulation goes unnoticed. It is not understood as to why the tankers that are used for transporting water or milk are not being used for the purpose. It was long demonstrated that splashless tanks have little mortality, especially when provided with an oxygenator. This needs to be focussed and brought home to the traders.

Fish Seed Certification and Accreditation of Hatcheries

Seed attributes have a major role in quality and quantity of fish production and while the total aquaculture production has been increasing, there is no corresponding improvement in average survival rates which calls for quality control measures on a priority and rather regular basis.

Bulk of the seed for aquaculture comes from the hatcheries which are yet to adopt scientific principles of management, both for collection of the basic material – spawn, fry or fingerlings – for raising the broodstock and for the broodstock itself. We need to follow the agriculture sector for seed certification and accreditation of the hatcheries and adopt strict regulations. There are likely to be initial problems owing the unorganised and highly dispersed nature of the industry but such action will be in the interest of both the farmers as well as the hatchery owners who should willingly come forward and cooperate. The importance of quality seed is all the more relevant from the view point of international trade where labelling and certification are basic parameters. FAO also lays a great emphasis on the need for developing seed certification and accreditation systems.

While the guidelines for accreditation of hatcheries and certification of seed have been developed and the Agency responsible for doing it also identified by the DoF, Ministry of Agriculture, Government of India, and the States informed, no progress has been made so far. Further, a highly significant development within the recent months is the announcement of the creation of a separate Department of Fisheries under the Ministry of Agriculture and Farmers’ Welfare. It is time that the new Department focuses on various issues that have remained unaddressed for so long on a priority basis. Once the National Inland Fisheries and Aquaculture Policy is approved and comes into force, the pace of not only aquaculture but development of fisheries in Indiawould make rapid strides.

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