CENTRAL INSTITUTE OF FRESHWATER AQUACULTURE
(Indian Council of Agricultural Research)
Bhubaneswar- 751002, Odisha, India

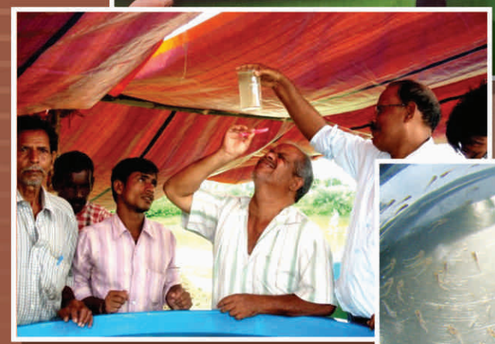
In collaboration with

All India Coordinated Research Project
on
APPLICATION OF PLASTICS IN AGRICULTURE
Central Institute of Post Harvest Engineering and Technology
(Indian Council of Agricultural Research)
Ludhiana-141 004, Punjab, India

COMPENDIUM

National Workshop
On
"Portable FRP Carp Hatchery Technology"

11-13 July 2011



AICRP on APA & CIFA
(ICAR)

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GOVERNOR'S SECRETARIAT, ORISSA
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From

The Aide-de-Camp to the Governor, Orissa.

To

Dr. P. Jayasankar,
Director (Acting),
Central Institute of Freshwater Aquaculture,
P.O-Kausalyaganga, Bhubaneswar-751 002.

Sir,

With reference to your letter No.CIFA/National Workshop/2011-1153 dated 17.06.2011, I am directed to inform you that due to pre-occupations, His Excellency, the Governor of Orissa has expressed his inability to grace the National Workshop on "Portable FRP Carp Hatchery Technology" at Central Institute of Freshwater Aquaculture, Bhubaneswar as Chief Guest during 11th - 14th July, 2011.

However, His Excellency, the Governor of Orissa sends his good wishes on the occasion.

Yours faithfully,

Aide-de-Camp to the Governor, Orissa

डा. एस. अय्यप्पन
सचिव एवं महानिदेशक
Dr. S. AYYAPPAN
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
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D.O. No. Secy.,DARE & DG, ICAR/2011/957
Dated the 23rd June, 2011

Dear Dr. Jayasankar,

Thank you very much for your letter No. CIFA/National Workshop/2011-1198 dated the 20th June, 2011 regarding the National Workshop on 'Portable FRP Carp Hatchery Technology' to be held at CIFA, Bhubaneswar during 11-13 July, 2011.

I wish the programme all success.

With regards,

Yours sincerely,

(S. Ayyappan)

Dr. P. Jayasankar
Director (Acting)
Central Institute of Freshwater Aquaculture,
P.O. Kausalyaganga,
BHUBANESWAR – 751 002 (ODISHA).
Fax No. 0674-2465407

PREFACE

The Workshop on Portable FRP Technology is a step forward towards making the country self-sufficient in quality fish seed production. The Central Institute of Freshwater Aquaculture (CIFA) formerly as a part of Central Inland Fisheries Research Institute (CIFRI), Barrackpore and later as an independent institute has given many options for fish seed production in the country. Among them the Cemented Circular Hatchery forms the backbone of the carp seed production. The portable hatchery is a miniature form of the circular hatchery which can be transported, installed and operated with much less cost and time. The fool proof technology after many years of refinement was made commercially available to the end users from 2006. Form then onwards, the dissemination and adoption of the technology has been rapid and till 2011 about 126 hatcheries have already been dispatched to 25 states. In a landmark decision in 2010, ICAR has decided to install 100 hatcheries in different parts of the country. The Portable Hatchery has widely been used for research experiments, demonstrations, instruction as well as for fish seed production.

It is a high time to re-evaluate the performance of the technology as well as built capacity of the managers and operators of the hatchery. The workshop comes in an opportune time to assess the current status and to impart knowledge on various aspects of the technology. The programme has been designed to give an in-depth exposure to the participants and operators of the hatcheries. Experts in the field of aquaculture technologies will deliver lectures and conduct practical sessions. This compendium is a collection of all these lectures and notes which will be made available to the participants. I am sure this will serve the best interest of the end-users of the technology. I am thankful to all those who have contributed to this compendium.

(P. Jayasankar)
Director (Acting)
CIFA

Bhubaneswar
8 July 2011

PREFACE

It is a moments of immense pleasure that the "National Workshop on Portable FRP Carp Hatchery Technology" is organized at CIFA, Bhubaneswear. The technology on Portable FRP Carp Hatchery is one of the star technology developed under the aegis of All India Coordinated Research Project on Application of Plastics in Agriculture (AICRP on APA) and by the project team at Central Institute of Freshwater Aquaculture, Bhubaneswar. This technology has been developed through a long process of its design, development, laboratory evaluation, and then finally field evaluation which was quite meticulous. It has immense potential and far reaching impact on livelihood of small and marginal farmers by making good quality fish fingerlings available even in remotely located places and generating good remuneration by good fish production.

This technology was released after thorough evaluation in 2006 and allowed mass production. Since then more than 125 units have been installed at various locations in 25 states in the country which includes research organizations, State and Central government agencies, NGOs, KVKs, and individual farmers, and received demands from several quarters in the country as well as abroad.

On this occasion, I would like to appreciate great efforts made by APA team of CIFA, Bhubaneswar in this direction to develop such valuable technology and popularize it among users and stakeholders.

On behalf of project team of APA, we like to express gratitude to Dr. S. Ayyappan, Secretary DARE and Director General ICAR, and previous Director, CIFA, Bhubaneswar whose guidance, inspiration, encouragement and support played a key role in success of this technology.

We are also thankful to Dr. P. Jayasankar, Director, CIFA, Bhubaneswar and all earlier Directors for providing all support and encouragement for the technology development and popularization and holding this National Workshop.

Thankful to all who directly or indirectly helped or contributed for projects under AICRP on APA at CIFA, Bhubaneswar and elsewhere.

Ludhiana
08 July 2011

(P.R. Bhatnagar)
Project Coordinator
AICRP on APA
ICAR

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INDIAN FRESHWATER AQUACULTURE

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Introduction

At the World Food Summit organized by the Food and Agriculture Organization (FAO) in Rome in 1996, food security was defined as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." At the same summit the participating countries committed to reduce the number of malnourished people in the world by half by the year 2015 (Haylor, 2004). It is a well-known fact that fish is an important source of protein, rich in essential amino acids. It is also a good source of calcium, vitamin A and $B_{12,}$ apart from possessing a high content of polyunsaturated fatty acids *i.e.*, Omega-3 fatty acids. The persons in all stages of their life who cannot obtain sufficient nutrients from cereal-based diets would be benefited from the inclusion of fish in the diet. In addition to supplying dietary essentials for human consumption, aquaculture provides excellent opportunities for employment and income generation, particularly in the more economically depressed rural areas. According to the report of FAO (2002), 50 million people are directly engaged, part time or full time, in primary production of fish, either by fishing or in aquaculture.

Aquaculture is the fastest growing animal food-producing sector, growing at a rate more than 6% annually and accounting for more than 50% of the world's food fish (FAO, 2009). In 2007, the global aquaculture production of freshwater finfish was 26.768 million tonnes worth US$32.5 million and accounted for 53.2 % of total global aquaculture production (FAO, 2009). With the tremendous increase in demand for fish and stagnation or steady decrease in capture fish production, the importance of aquaculture has increased. A number of studies have pointed a positive scenario for the role of aquaculture in providing the much-needed animal protein to the world population (www.ncbi.nim.nih.gov; Tidwell and Allan, 2001; Sugiyama *et al.,* 2004). The aquaculture production has been projected to be 74 million tonnes in 2015 (FAO, 2004) and 83 million tonnes by 2030 (FAO, 2002). Recognised as a powerful income and employment generator, aquaculture stimulates growth of a number of subsidiary industries and is a source of cheap and nutritious food, besides being a foreign exchange earner (Ayyappan and Krishnan, 2004)

In India aquaculture contributed 45 per cent of the country's total fish production of 7.582 million tonnes in 2008 (FAO, 2010). Indian aquaculture has demonstrated a six and half fold growth over the last two decades, with freshwater aquaculture contributing over 95 per cent of the total aquaculture production. The three Indian major carps, namely catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) contribute the bulk of the production, followed by silver carp, grass carp and common carp forming a second important group. Average national production from still water ponds has increased from 0.6 tonnes/ha/year in 1974 to 2.2 tonnes/ha/year at present, with several farmers even demonstrating production levels as high as 8–12 tonnes/ha/year. The technologies of induced carp breeding and polyculture in static ponds and tanks virtually revolutionized the freshwater aquaculture sector and turned the sector into a fast growing industry. The research and development programs of the Indian

Council of Agricultural Research (ICAR) as well as the development support provided by the Indian Government through a network of Fish Farmers' Development Agencies have been the principal vehicles for this development. Additional support has been provided by several other organizations, state departments and financial institutions. The farming of giant river prawn (*Macrobrachium rosenbergii*) has gained increased interest in recent years, due to its high economic value and an annual production of over 30,000 tonnes has been achieved through the use of monoculture practices. In addition, the sector has been witnessing increased interest in diversification with the inclusion of high-valued species including medium and minor carps, catfishes, murrels, etc. While carp and other finfishes are grown for the domestic market, a large proportion of freshwater prawn production is exported.

Fish contributes substantially to the domestic food security of India which has a *per capita* consumption of 8 kilogram. With freshwater aquaculture being a homestead activity in several parts of the country, besides adding to the nutritional security, it also helps in bringing additional income to rural households. Considering the substantial contribution, aquaculture makes towards socio-economic development in terms of income and employment through the use of unutilised and underutilised resources in several regions of the country.

Aquaculture in village water bodies (VWB) in India, in general, utilizes poly carp culture and is practiced with the utilization of low to moderate levels of inputs, especially organic-based fertilizers and feed. The main problems faced by fish farmers are poaching, water scarcity and credit. Even then, there has been a marked shift in the intensity of fisheries in some states. This change is charged by the entrepreneurial acumen of individuals who with the help of innovative management practices shaped the way fishing is practiced in the multi use and multi ownership VWB across India. With the consumption of fish rising steadily, the rising demand for fish can be met only if the growth in aquaculture occurring in the VWB is sustained.

Since inland fishery is a state subject, the states decide on the policies regarding utilization of the resources. The state governments prepare policies keeping in mind the livelihoods of the rural poor. The state governments prefer handing over the fishing resources to co-operatives of the local communities. Leasing policy is the main instrument in the hands of the government to effect any change in the sector. Most of the initial funding for propagating culture fishery in inland water bodies came from the Fish Farmers' Development Agency (FFDA) program of the central government with an initial World Bank Assistance. It provides technical, financial and extension support to fish farmers for taking up culture fishery in village ponds and tanks. There are 429 Fish Farmers' Development Agencies (FFDA) and 39 Brackishwater Fish Farmers' Development Agencies (BFDAs) for promoting freshwater and coastal aquaculture.

Inland Fish Farming and Associated Considerations

Aquaculture Resources

Aquaculture resources in India include 2.36 million ha of ponds and tanks; 1.07 million ha of beels, jheels and derelict waters; 0.12 million km of canals; 3.15 million ha of reservoirs and 0.72 million ha of upland lakes that could be utilised for aquaculture purposes. Ponds and tanks are the prime resources for freshwater aquaculture, however, only about 0.8–0.9 million ha is used for aquaculture currently. Ponds in eastern India are typically homestead ponds of less than 1 ha in size. In several parts of the country ponds and tanks are state-owned or communal and are leased out for periods of 3–5 years.

Culture of Carps

The culture systems adopted in the country vary greatly depending on the inputs available in any particular region as well as on the investment capabilities of the farmer. While extensive aquaculture is carried out in comparatively large water bodies with stocking of the fish seed as the only input beyond utilizing natural productivity, elements of fertilization and feeding have been introduced into semi-intensive culture. The different culture systems such as Composite carp culture; Sewage-fed fish culture; Weed-based carp polyculture; Biogas slurry-fed fish culture; Integrated fish farming with poultry, pigs, ducks, horticulture, etc.; and Pen culture have been standardized with optimum achievable production rates of 3–6 tonnes/ha/yr (Sinha *et al.,* 1973; Jana and Mohapatra, 2001; CIFA, 2004; ICAR, 2005). Intensive culture systems like Cage culture and Running-water fish culture (Tripathy *et al.,* 2000) have given productions of 10–15 and 20-50 kg/m²/yr respectively

Carp culture is based around the 'polyculture' of the three Indian major carps (catla, rohu and mrigal) as well as 'composite carp culture' of the three Indian major carps with the three exotic carps (silver carp, grass carp and common carp) (Jena *et al.,* 2002). Standard practices in carp culture include: i. the stocking of carp at combined densities of between 4,000–10,000 fingerlings/ha; ii. pond fertilization with organic manures from cattle or poultry as well as inorganic fertilisers like urea and single super phosphate; and iii. provision of supplementary feeds mainly in the form of a mixture of rice bran/wheat bran and groundnut/mustard oilcake in equal ratio. In spite of the fact that the country also possesses several other cultivable medium and minor carp species which show high regional demand, including, *Labeo calbasu*, *L. fimbriatus*, *L. gonius*, *L. bata*, *L. ariza*, *Cirrhinus mrigala*, *Puntius sarana*, *Hypselobarbus pulchellus*, *H. kolus* and *Amblypharyngodon mola* as well as several others, commercial farming of these species has been almost non-existent or slowly picking-up.

Culture of Catfishes

The pond culture of catfish involves mainly magur (*Clarias batrachus*) and singhi (*Heteropneustes fossilis*) and is practiced in states like Assam, Bihar, West Bengal and Odisha (Thakur and Das 1986; CIFA 2004; ICAR 2005). Though modern farming techniques for these species advocates monoculture at stocking densities of 20,000–50,000 fingerlings/ha, inadequate availability of juveniles has restricted these as a component in carp polyculture systems. Considering the high market demand for catfish and the availability of a huge potential resource in the form of swamps and derelict waters, commercial farming of these species are being given important attention at present. In recent years, attempts have been made to develop the culture of non-air breathing catfishes like *Pangasius pangasius*, *Wallago attu*, *Sperata seenghala*, *S. aor* and *Ompok pabda*.

Culture of Other Finfishes

The other finfish species of importance include climbing perch (*Anabas testudineus*), murrels (*Channa striatus* and *C. marulius*) (Khan, 1969) and tilapia (*Oreochromis mossambicus* and *O. niloticus*).

Culture of Freshwater Prawn

Successful breeding and larval rearing of the giant river prawn (*Macrobrachium rosenbergii*) and the monsoon river prawn (*M. malcolmsonii*) provide scope for the farmers to diversify their culture practices (CIFA, 2004; ICAR, 2005). *M. rosenbergii* is the largest and fastest growing species being farmed and possesses considerable demand both in domestic and international markets. *M. rosenbergii* is cultured either alone

(monoculture) or in combination with carps (polyculture). The monoculture of giant river prawn is mostly confined to earthen ponds with moderate stocking densities of between 20,000–50,000/ha, fertilization and supplementary feeding can result in a moderate yield of 600–1,500 kg/ha/8 months using single stocking and both single/multiple harvesting. The polyculture of freshwater prawn juveniles as densities at 10,000–15,000/ha alongside carp at 3,000–4,000/ha has also been demonstrated to be economically viable.

Non-conventional Culture Practices

Sewage-fed fish culture and paddy-cum-fish culture are two important culture systems practiced in certain areas of the country. Sewage-fed fish culture in bheries in West Bengal is an age-old practice. About 5,700 ha is presently utilised for fish culture using the input of primary-treated sewage and produces over 7,000 tonnes of fish per annum, mainly consisting of the major and minor carps. The culture system usually involves multiple stocking and multiple harvesting approaches, with harvest size usually in the range of 300–500g. Though stocking densities of 10,000–20,000/ha are common, densities as high as 50,000/ha has also been reported from several farms.

Paddy-cum-fish culture is undertaken in medium to semi-deepwater paddy fields in lowland areas with fairly strong dykes to prevent the escape of cultivated fish during floods. Trenches and pond refuges in the paddy fields provide shelter for the fish. The system mostly relies on natural stocking, however, modern farming techniques involving major and minor carps stocked at the densities of 5,000–10,000/ha alongside freshwater prawn are also practiced in several areas. Production levels of 3.5 tonnes of rice and 0.5–1.0 tonne of fish/ha can be achieved in a well-managed paddy-cum-fish farming systems within a year.

Fish Seed Production

Collection of spawn and hatchlings from rivers and other natural water bodies is a traditional method of obtaining Indian major carp seed. The quality of the product is low and the cost of transportation from the seed collection grounds to the fish growers is high. The period of collection is very short and the quantity of the annual collection fluctuates considerably with the variation of climatic conditions. In fact, a rapid decline in both quantity and quality of collection has resulted from the deterioration of river environments in recent years.

Since the latter part of the fifties, Indian scientists have successfully achieved artificial breeding of Asiatic carps (including major Indian and Chinese carps) by application of the hypophysation technique. This achievement has significantly contributed to the methodology of fish seed production and supply of right kind of fish seed to the farmers. Carp hatcheries in both the public and private sectors have contributed towards the increase in seed production from 6,321 million fry in 1985–1986 to over 18,500 million fry at present.

Constraints for Development of Aquaculture

The major constraints of aquaculture development in India are enumerated below.

Availability of fish seed in time

The quality of fish seeds collected from the wild is low because of the mixture of undesirable species, including larvae of predatory and weed fishes, and the quantity collected has, in fact, been rapidly decreasing in recent years. On the other hand, the quality and quantity, and the period of fish seed

production by hypophysation are, to a large extent, controllable. Although quality fish seed supply from the State Government's fish seed farms has been substantially increased in the past decade, it is quantitatively still very limited and far below the existing demand.

Land tenure

Land tenure problems hamper fish farming expansion and discourage fish farming investment. Except for research and demonstration, ponds suitable for fish farm development should be transferred to farmers and entrepreneurs on a long-term lease basis, so that the lessees will be able to invest more capital in improvements for farm production.

Social issues

The main problem perceived by fish farmers is poaching.

Water availability

Water availability to maintain a minimum level in the ponds for the fish to survive during the lean months is also a major problem.

Availability of Feed

Non-availability of right feed at right time is the major constraint for aquaculture. The feed should be prepared with locally available ingradients.

Availability of technology to the end user

It is seen that the scientific aquaculture practices have not reached to many farmers of the country. It needs a strong extension mechanism for the propagation of the technologies.

Natural calamity

The floods and droughts are of the main problems for taking up intensive fishery.

Other issues

The problems like market access, labour, and disease to fish and resistance from villagers are also hampering the fisheries development in these states.

Credit facility

As aquaculture intensifies, the input costs increase, thus making credit availability one of the main constraints.

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PLASTICULTURE - A REVOLUTIONARY STEP IN AGRICULTURAL DEVELOPMENT

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Introduction

The word "Plasticulture" refers to application of plastics in agriculture. The invention of plastics more a century ago, gave remarkable material, which have miraculous properties that no other material has. Therefore, it become so important for all parts of human life and made it easy and comfortable without jeopardising environment and any other adverse effect. It revolutionised the agricultural production all over the world.

The benefits of plasticulture was realised in the era of 1940s in Europe and afterwards it spread like anything to almost all parts of the world. However, it picked up more in areas having poor resources availability but more opportunities like in Israel and Netherlands. In India, the importance of plasticulture was realised in late 1970s and then efforts were initiated in early 1980s decade to implement and popularise among Indian farmers. Establishment of National Commission on use of Plastics in Agriculture (NCPA) was the first step towards this goal by Min of Chemicals and Petrochemical, GoI in 1981. But, the technologies developed elsewhere were not found implementable in Indian conditions and need for development or refinement of such technologies were felt at all levels. In order to facilitate the implementation of Government policies with some refinement of technologies, Plasticulture Development Centres were established under the NCPA. Indian council of Agricultural Research was also a part of the NCPA, and in order the facilitate development of pertinent technologies and popularising them in Indian farming communities, ICAR started *All India Coordinated Research Project on Application of Plastics in Agriculture*. Initially, it had five centres including CIFA, Bhubaneswar that was fully devoted to fish culture technology development using plastics. At present it has eleven centres, five located in mid hills of Himalayas, one in eastern plateau region, two in north Indo-gangetic plains, one in western coastal hot semi arid region of Saurashtra, one in undulating Aravali tracts, and one on fish culture technologies.

Importance of Plasticulture

Plasticulture is a system of growing crops or allied commodities (e.g. animal, birds, fish, etc) in a way so that a significant benefit is derived from using the plastic polymers. It has potential to solve most the problems that agricultural production in the country is facing. Using the plasticulture interventions, the production is not only improves in its quality and quantity, but it makes possible to produce most of important commodities as and where needed, irrespective of its location or season. Such techniques can prove to be effective tools in meeting out the nutritional requirement in remote areas where fruits and vegetables are not produced and also cannot be transported due to topographical and economic constraints.

The scope of application of plastics for agricultural activities is wide due to useful properties like higher strength to weight ratio, created with any strength and varying properties using processes or additives, mouldability in any shape and size, developed in any colour or transparent, corrosion resistance, chemically

non-reactive with normally used liquids or solids, can have water / gas permeability from almost zero to desired level, etc. It can have strength from soft sponge to bullet proof sheets. It is relatively economical (in most of cases) and environment friendly as the plastic manufacturing industry is least polluting as compared to industries based on other materials. However, disposal of plastic material posing problems in many developing countries, for which several efforts have been made. There have been several attempts to solve the problem, including development and use of photodegradable or biodegradable materials (which just disappear and converted into gas and less polluting material), re-using the plastic material (delaying the problem), incineration (to use as fuel in furnaces). But proper collection, preparation and transportation to the processing site economically, still remain to a challenge worldwide.

In the agricultural activities, plastics can be used as fibre, films, sheets, pipes, tubes, woven fibres, netting, mouldings, bags, etc. Plastic industry continue to make rapid progress by way of making available newer and better materials, it is for the agricultural professional to make its effective use of improving the overall production system, based on the research conducted under varying farming conditions which change from one location to other. Efforts in these directions are being made under the All India Coordinated Research Project on Application of Plastics in Agriculture since 1988.

Although, plastics have been employed in almost all the agricultural activities in one way or the other, the major known areas of plasticulture where concentrated efforts are being made:

- Water resources development using plastics as lining material.
- Irrigation systems including plastics pipes channel lining, micro irrigation systems, etc.
- Drainage in waterlogged areas using sub surface plastic pipes.
- Protected cultivation including polyhouses, shade houses, low tunnels, etc.
- Root environment control using plastics mulching, soil polarisation.
- Polythene bags, plastic containers, nursery trays, etc. for plant establishment and growth.
- Farm tools and machinery made of or components made of using plastics.
- Animal / bird shelters and feeding devices.
- Intensive fish culture systems / devices including carp hatcheries, feeders, cages, pens, *etc.*
- Handling and packaging of agricultural inputs and produce

So many schemes and projects have been launched by the Central Government (through National Horticultural Board, Water Resource Ministry, Department of Agricultural Cooperation, etc.) and State Governments (in their respective states) to popularise the plasticutlure technologies among farmers of different regions. Subsidies are also available on such interventions, which depend on nature of commodity / crop, locations and status of farmers.

The plasticulture technologies are useful for all production systems including field crops, horticulture crops (fruits and vegetables), forestry, fishery, animal husbandry, poultry, and so on. After 1980s, such technologies have made great impact on overall production of all productions systems. Few such technologies, which are in great use and have potential are discussed below.

Plastics Lined Ponds

Plastics film lined ponds have been found very suitable for rainwater harvesting in uplands where scarcity of water becomes major bottleneck in agricultural production or diversification from poorly remunerative production to scientifically recommended production considering local climatic and soil advantages. In Himalayan hilly tracts, such ponds are being used for rainwater harvesting or storing the water from low discharge springs which otherwise cannot be directly used for irrigation purposes. The farmers in Uttarakhand and Meghalaya were found to use such ponds for vegetable cultivation or fruit tree irrigation and earning good profit as compared to meagre cereal production from the hilly terraces. However, rainwater harvesting ponds have limited water availability, while collecting or routing water from perennial springs are provide sustained water availability for round the year vegetable or fruit production. Fish culture in such ponds is additional advantage to farmers who are deprived of such food material due to remoteness.

For pond lining, three types of polythene films are normally used, although there are many more types available. The cheapest film is Low Density Polyethelene (LDPE) which is used in 150-300 micron thickness. This polythene sheet is very handy, easy to use and easy to join at site, but is photodegradable in nature. It gets deteriorated chemically under exposure to sunlight. Hence, it is to be covered such that it is protected from sunlight. If the film is protected from sunlight (especially UV rays) and any mechanical damage is avoided, it can last for very long life. Srivastava and Bhatnagar (1991) reported life more than 20 years, while other claim it upto 50 years. The covering material and style of covering may change from one location to another depending on locally available material. Boulders / stone / brick pitching with thin soil layer, stepped sides with soil covering, coal tar felt covering are some of the methods developed from time to time for different locations. The construction technology has been standardised for various topographical conditions. However, strategies for its effective use with package of practices need to be developed for varying conditions.

Irrigation Systems

Irrigation system is the largest consumer of agri-plastics. Irrigation pipes made of HDPE or PVC are a used extensively all over for water conveyance. Such pipes are very useful as they are handy, low weight, smooth and easy to use, water leak proof, and easy to convey water to the point of its use without un-necessary loss. They are cheap as compared to other alternatives and portable. PVC pipes are also used for tube wells which is one of the star contributions of AICRP on Groundwater Utilisation through Wells and Pumps.

Canal lining to save irrigation from seepage losses is in practice in India since several decades and had success in Gujarat, Punjab and other parts of the country. Alhtough several plastics material options are available but mostly LDPE film lining with 100-150 micron film is done with covering of either brick masonry or tiles.

The use of plastics for pressurised irrigation system e.g. sprinklers and drip system has been increased greatly. In 2005, the coverage under drip irrigation was only 42311 ha that increased to 10, 82,330 ha by 2010-11, while sprinkler irrigation was increased from 13,117 ha to 12, 70145 ha during the period (Iyenger and Lall, 2011). Earlier Aluminium was used as material for sprinkler irrigation pipes, but now it has been replaced by HDPE. The drip irrigation system is completely manufactured using plastics materials like LDPE, LLDPE, etc, while main and sub main are mostly consists of PVC pipes. With use of such

modern irrigation technologies using plastics, farmers are getting substantial benefits in terms of increased production of horticultural and field crops on the one hand, while improved quality and perishability enabling them to fetch better prices. In addition, it is helping to save national water resources from pumped ground water at most of the places, saving in labour, saving in inputs (fertiliser and pesticides), etc are other benefits realised by user farmers.

Protected Cultivation

The surface covered cultivation or alternatively called "Protected Cultivation" means modification of the plant environment to achieve optimum plant growth and maximum production by avoiding the harmful effects of climatic factors like temperature, humidity, rainfall, etc. and controlling the factors like atmospheric gas composition, nutrient, disease and pest attack, etc. The technological developments in structural design and climatic control, coupled with high quality crop varieties and controlled input are integrated into a system of agricultural production to achieve best production and quality of the produce. The surface covered cultivation includes the interventions like greenhouses (high structures, walk-in-tunnels), net or shade houses, low tunnels, row covers, and mulches. Such interventions offer several advantages to grow crops of high quality and yields, and thus using the land and other resources more efficiently. Intensive cropping on small patch of land can be achieved with higher productivity per unit of natural resources. It saves inputs like water, fertilizers, and pesticides and enhances their use efficiencies on the one hand; protect the environment from excessive use of the inputs. Organic production with higher productivity may be achieved under the system.

Different types of polyhouses are in use with varying cost of construction (Rs/m^2 of floor area) and degree of climate control. The high cost greenhouses are designed to control the greenhouse temperature and humidity in a narrow range using automated systems, which may involve cost as high as Rs 10,000/m^2. The medium cost greenhouses are constructed with relatively less control on the climatic parameters and have relatively wider range of temperature and humidity variations and construction cost varying from Rs 600-1500/m^2. Both the structures are made strong enough to sustain wind pressure and other anticipated forces and have longer life i.e. 15 years or more (excluding cladding material). The low cost structures have bamboo or wooden frame, which has the life of 3-5 years and constructed at a cost of Rs 200/m^2. The shape of the polyhouse is quite varied and mostly designs to suit local climatic conditions and have minimum external energy requirement. They may be gable, Quonset, semi circular, gothic arc shaped, or Ladhaki design where polyhouse is constructed using a dug out trench or pit and then covered using polythene so that geothermal heat is used for partial heating. Under the AICRP, low cost bamboo or locally available wooden stick frame polyhouses have been popularised as entry-level technology to popularise the polyhouse cultivation among small and marginal hill farmers.

Floriculture and cut flowers for export as well as domestic market, is the main use of polyhouses in India and estimated to occupy 90 - 95% of the area under greenhouse cultivation in the country, while coloured exotic varieties of capsicum (red & yellow) and some other exotic vegetables occupy rest. In hilly and cold climatic areas, polyhouse are used for off-season vegetable nursery or plantation material development. In Kashmir valley, grafted walnut plant development in polyhouses was found more beneficial as it has high success rate as well as earliness in fruiting. In Himachal Pradesh, off-season vegetable nursery has changed the vegetable growing scenario and farmers are fetching good prices of their off-season cultivated vegetables using nursery produced in polyhouse during cold climate.

Plastic Mulching

In order to reduce soil evaporation, maintain congenial temperature in root zone and reduce weed growth mulching is used to cover soil area around the plant. Previously organic mulching in the form of grass, straw, or wooden flak were used as mulch material. Plastic film has been found to be very effective material for mulching, which is gaining importance in Indian agriculture to reduce soil evaporation, weed control, and soil temperature control. Black plastic film as well as clear plastic film is being used for the specific purpose as per need. Unfortunately, labour requirements to remove plastic mulch from the field after the growing season can be high. New bio and photodegradable polyethylene and combinations of polyethylene-paper and polyethylene-starch show promise in eliminating the need for mulch removal. However, their techno-economic feasibility needs to be thoroughly studied. In Saurashtra region, farmers expressed that they do not want to use biodegradable plastic mulch, which gets deteriorated in one season, while they are able to use the same film for three or more season, and thereafter re-sale at a reasonable prices. In this region, farmers are using black or double layered (top silver and bottom black) polythene of 40-50 micron thickness for watermelon, tomato, bottle guord, and other vegetable cultivation. In Mahabaleshwar region, farmers are using black mulch film extensively for strawberry cultivation.

The advantages of the mulch are also being realized by visible light to reflect back towards the plants that aid in photosynthesis. The colour and texture of the film also matters in this respect. In a study carried out in Maxico, the black and white (both opaque) coloured mulch produced better effect on production of red pepper (*Capscicum annum L.)* while the development of plants with blue and red mulch was poor because of high ground temperature, but did not had appreciable yield reduction (Quezada-Martin, *et al.,* 2004). The transparent or clear plastic film has no herbicidal effect, but soil heating is better with marginal heat retention. Hence the clear film mostly recommended for cold areas where heating is required along with use of herbicides to control the weeds. While the black opaque film do not require application of herbicide and its has pronounced herbicidal effect to control the weeds. But soil heating is poor with better heat retention as no radiation is returned back. But it needs careful use as the film temperature increases and if any fruit is touched, it may be damaged. White / silver opaque film has better light reflection and aid in higher vegetative growth. In order to achieve better results, co-extruded double layer film of black and white combination may be used which have combined effect e.g. better herbicidal effect, more heat retention and more light reflection.

Horticultural production with plastic mulch needs drip irrigation since other means of water application cannot meet out the crop water demand. Plastic mulch with drip irrigation enhanced the strawberry productivity by 36% in open field and 22% in walk in tunnel type greenhouse as compared to without mulch i.e. respectively 7.0t/ha and 18.4 t/ha, respectively in two conditions in Srinagar, J&K. On the other hand, if the plastic mulched crop is irrigated with other methods e.g. sprinkler irrigation, the yield have been found to reduce. In Meghalaya, a sprinkler irrigated cauliflower yield was reduced by 38% with plastic mulching, while the reduction was only 13% for Broccoli. Less water penetration in the soil was the reason for reduced yield under sprinkler irrigation.

Farm Machineries

Plastics has been used to develop several farm tools and machinery used for agricultural activities *e.g.* plastic drum seeder, etc. or replacement of components with plastic fabricated components in place of earlier steel or other materials as per suitability. Such efforts are made to reduce the weight and cost, improve workability and efficiency, and reduce drudgery involved in agricultural operations. It all results in better operations in less time, less cost, and less labour.

A pedal operated paddy thresher with plastics (polycarbonate sheet) body has been developed at VPKAS, Almora centre to reduce the weight (35 kg) to nearly 50% of similar metallic body thresher (70 kg) with a throughput capacity of 100 kg/h and operated by one person. Present cost of the pedal thresher is Rs 3500 with nominal saving in cost, but it enhanced transportability on hilly terrains, higher threshing efficiency, ergonomically effective (operated in sitting position with power transmission through pedal as compared to standing operation and power transmission through cam drive in conventional thresher), straw is recovered for further use without any damage. This enabled continuous working up to 4 hours as compared to only one hour for similar design. Hence, the operational cost is less as compared to traditional threshers of similar kind. The machine was well accepted by the farmers as 350 such machines have already been supplied to the farmers in Uttarakhand. Similarly replacing wooden handles of most of the farm tools by plastic resin handles improved their workability and becoming more popular among women farm labours. The maize sheller with iron body was modified by replacing the iron body with plastics (PVC) body. The change of material resulted in the reduction of the weight by 50.5%. The modified plastic covered maize sheller has weight of only 89 g against the 180 g of conventional tubular maize sheller. The shelling efficiency was not affected by changing the material of construction.

A lot of scope exists to utilize the plastics as a material and more concentrated efforts are needed in this direction.

Packaging and Post Harvest Processing

Packaging is the largest consumer of the plastics, as it accounts for 42% of the total consumption. However, actual use in packaging of the agricultural commodity is not available; however, it must be a significant proportion. Plastics packaging of different kind have been investigated and are in use for enhancing the shelf life of the perishable or semi-perishable agricultural commodities. In addition to plastic packaging is being done for agricultural inputs e.g. fertilizers, pesticides, etc. for their safe transport. About 1000 t of PP leno bags were consumed in 2005 for packaging of fruits and vegetables. For storage of food grains with Cover & Plinth technique, about 5000 t of PE was used in 2005. Plastic crates are steadily becoming popular for on-farm handling and transfer of horticultural produce.

Drying and dehydration polyhouse type drier has been worked out under several projects and has been popularised among farmers and entrepreneurs. Efforts have been made to design low cost structures for drying of the vegetables and fruits to ensure availability of dried fruits and vegetables during non-availability periods in the Kashmir valley. Poly tunnel drier was designed and constructed which was portable and movable and could be placed in a sunny location in the valley. Such device is of similar size of solar cooker and can be used at household level. It can be a remarkable contribution as no vegetables are available in the area after October due to cold climate and snowfall.

Intensive Fish Culture Devices

Plastic has found very important use in aquaculture field. Nylon fishnets, plastic pipe framed and nylon net cages, pen culture in water locked areas, etc are some of the important uses of plastics in aquaculture. Under the AICRP, CIFA, Bhubaneswar centre is working since inception in 1988 and contributed several technologies on application of plastics in aquaculture, which has been found very useful in improving the overall scenario of inland fishery sector. Portable FRP Carp Hatchery, Mini Portable FRP Carp Hatchery, FRP Mangur Hatchery, Automatic and demand FRP feeders, solar operated automatic feeders, Portable FRP Fish silos for Hi-tech aquaculture, HDPE floating cages, Live fish transportation tanks, PVC aqua filters, are some of important contributions made by the centre.

Among all of these, FRP Carp Hatchery has made remarkable impact in providing fish fingerlings in remote places where fish culture is impeded due to non-availability of good quality fish fingerlings. So far, the hatchery has been installed at more than 100 locations in 25 states in the country covering all type of institutions including research organisation, Central and State Governmental development departments, Non-governmental organisations (NGOs), individual farmers, KVKs, etc. The installation of Hatchery unit provides benefits not only to its operating organisation or farmer, but to a large number of farmers around the installation, who were deprived of good quality fish fingerlings previously.

In future, plastic will have greater impact to further increase the fish production of inland fisheries. Similar options are also available for marine fish culture, shrimp culture and other aquacultural commodities and activities.

Apart from the above, plastics has made remarkable impact in other areas of agricultural production, e.g. corrugated drainage pipes for removal of excess water from waterlogged areas and to reduce impact of secondary salinisation, plastic bags and trays for vegetable / orchard nursery production, roof and side walls of animal shelters, feeding troughs of animals and poultry, and so on which may be a long list.

Conclusions

The use of plastics has revolutionised the agricultural production system and have great impact in improving the overall scenario in all the production systems e.g. field crops, vegetables, fruits, fishery, animal production, etc. Enough technologies have been developed in this direction, which is being used by farming communities all over the country. But still, there is long way to go, as so many technologies are still not reached to farmers or the technologies are not fully standardised for Indian conditions. Certainly the use of plastics in such systems are increasing day by day as new and more promising applications are invented and executed along with expansion in present use pattern. But still, Indian agriculture is much behind to realise potential of plasticulture technologies. Along with its use, environment concern is often raised about safe disposal of used plastic materials. Hence, it is time for all including researchers, policy makers and implementer to work out strategies for its use and disposal.

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ROLE OF HATCHERIES IN DEVELOPMENT OF SUSTAINABLE AQUACULTURE

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Introduction

Hatcheries are a *sine qua non* for development of sustainable aquaculture with varied objectives. It is a facility used to cultivate and breed a large number of fish, normally or artificially, on a certain time and a certain day, in an enclosed or sometimes even in an artificial environment. The purpose could be to produce the seed of fish to be raised for food or for ornamental purposes, or for *ex-situ* conservation of rare and endangered species, or for release in a river, lake or reservoir and the sea for ranching or to support recreational fishing, or to provide stocking support to strengthen the stocks for commercial exploitation. There are two types of hatcheries:

(1) Flow through Hatchery System : This is simple to design and build but needs an abundant supply and sustainable source of very good quality water. The well-known concrete eco-hatchery or the portable FRP carp hatchery is based on this principle but does not require large quantities of water as the **trout hatcheries in India or elsewhere**.

(2) Total Recirculation Hatchery Systems. These are sophisticated hatchery systems which economize on the quantity of water as it is re-used by purifying through a series of filters but is rather complicated and expensive. However, it is justified in situations with scarce water availability as it needs only 200 l of new water to produce 1 kg of fish provided energy is easily and cheaply available.

The present 'Portable FRP Hatchery' has been designed with a specific objective of spawning the fish in remote rural areas, not easily accessible for four to six months during the monsoon season or thereafter, to rear the spawn locally and to make the seed available for raising marketable fish in the ponds studded and strewn all over, either for sale or for domestic consumption or both. While some would say that it serves only a limited objective, it should not be forgotten that it meets the food and nutritional requirements of the poor people besides getting them some recreation, employment and generating income.

Hatcheries in India

In India, there are hatcheries for carps, trout and mahseer but it is the carp hatcheries that are largely discussed here. However, a stand-alone hatchery for carps or for any other species is just not enough as a hatchery is, truly speaking, an important component of a farm and it would be no exaggeration to say that 'they are made for each other'. Look at our own world-bank hatcheries or the farms in public and private sector all over the country! Not only horizontal but, in some cases, even vertical integration, is known (trout hatcheries in Kashmir and Himachal Pradesh) and, perhaps, justified for economy of operations.

Unfortunately, the small size of our farms has a limited brood stock that results in both inbreeding and hybridization which is proving the bane of seed quality from these hatcheries. A number of hatcheries

are purposely producing the hybrids and one of the well known seed markets in India at Naihati (West Bengal) deals with such seed in a large measure. This is also being used by many a farmer for stocking the ponds in the vain hope of getting a higher production or a product which has a demand in the market without accounting for its rate of survival as they normally do not maintain proper records. Hybrids are detrimental to our biodiversity. An awareness programme needs to be initiated and the use of hybrids requires to be banned. It is necessary to bring home to the farmers and nursery operators the importance of having the minimum number (N_e) of brood fish of each species to avoid inbreeding. It is not the number alone that counts but the age and quality of brood stock that depends on the feed provided to it during the maturation phase which, in turn, determines the quality of eggs. The diet developed by CIFA for carp brood stock may be further improved and patented, if required, and the formula sold for commercial production.

Besides inbreeding and production of hybrids, the hatcheries suffer from the basic problem of poor water quality and unhygienic conditions owing the presence of opportunistic bacteria – *Pseudomonas*, *Aeromonas* and *Vibrio* – resulting in large-scale or, at times, mass mortality. It is easy to solve this problem through antibiotics but it is risking human health and, in the long run, leading to the emergence of resistant bacteria. However, it is here that application of science could make considerable difference. It is known that the use of probiotic bacteria could prevent the diseases in hatcheries but it would be necessary to identify both the harmful bacteria as well as the probiotic bacteria that would be effective in nullifying the damage being caused by the pathogens.

The present practice is to transfer the spawn from a controlled environment of the hatchery into the open nurseries where it faces innumerable hazards. A micro-diet that was developed at CIFA quite some time ago needs to be patented and commercialized so that it is available to the farmer/entrepreneur to feed the spawn in the hatchery for a day or two to make it strong enough to manage the sudden change. It is also the experience of farmers that the survival of *dhani* (5-day old spawn) is higher than the 3-day old spawn.

Our hatcheries are meant only for production of carp seed. With a view to diversifying the aquaculture product, the technology for breeding the catfishes (singhi, magur and boal) has been developed but these are still produced in small numbers despite their popularity and demand in the market. Quite a few other species (patola, cheetal, gulio, tengara, sal, sol, kawai) have also been induced-bred but the seed is not produced on a commercial scale.

What is unfortunate that our farmers/entrepreneurs have fallen a prey to the production of the seed of invasive species, Thai magur (*Clarias gariepinus*) and Thai pangas (*Pangasionodon hypophthalmus*) and its culture and the entire energy and expertise has been driven by 'profit-reality' to make as much money as possible and as quickly as possible. The fate of shrimp industry is well known where too a similar greed brought about a catastrophic end about a decade ago but no lessons have been learnt either by the farmer/entrepreneur or the government!

Hatcheries in Other Countries

Just to have an idea as to where we stand vis-à-vis some of the leading countries in the world, hatcheries from a few select countries are discussed here.

USA: In USA, Arkansas is the home to several commercial and public-sector hatcheries. Commercial hatcheries raise hybrid striped bass, catfish, sport fish, and Chinese carps. Sport-fish hatcheries raise

largemouth bass (*Micropterus salmoides*), several varieties of bluegill (*Lepomis macrochirus*), redear sunfish, hybrid bream, crappie (*Pomoxis nigrofasciatus*), walleye (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*). Farmers of catfish, baitfish, largemouth bass, and hybrid striped bass buy black carp (*Mylopharyngodon piceus*) fingerlings to stock in production ponds to control snails that spread fish parasites - a trematode (*Bolbophorus damnificus*) in catfish ponds and the yellow grub (*Clinostomum complanatum*) in baitfish, largemouth bass, and hybrid striped bass ponds. Catfish hatcheries are totally different than carp hatcheries.

Live hybrid striped bass spawn/fry and fingerlings (100-150 mm) to hybrid striped bass food-fish are shipped to grow-out farms from the east to the west coast In the United States, most fry and fingerlings are transported by eighteen-wheeled trucks with insulated tanks equipped with liquid oxygen. Hybrid striped bass fry are exported to fish farms in Taiwan, Israel, and Europe in insulated boxes air-freighted from Little Rock.

Triploids are also produced and each individual fish is tested (by taking a blood sample and checking it under a Coulter counter) to confirm its triploidy. The Fish and Wildlife Service's Triploid Grass Carp Certification Program sends an inspector to the hatchery to sample fish from each vat and repeats the blood sample and Coulter counter process to verify that the fish are triploid. It is important to know that Arkansas' hatcheries produce only triploid black carp and do not sell fertile black carp.

HUNGARY : Though a small country in Eastern Europe, it has extremely well developed hatcheries, largely in the public sector. It produces mainly common carp followed by the Chinese carps, striped bass, European catfish (*Silurus glanis*) and pikeperch (*Lucioperca* spp.) and has a well developed angling tourism. It needs to be noted that the culture period in the country is restricted to only about seven months because of the snow cover on ponds. The fish are bred in advance of the breeding season at the Warm Water Fish Hatchery (TEHAG) at Szazalombatta by taking in warm water from the Thermal Power Plant and fingerlings raised to be stocked in ponds as soon as the ice cover melts .This results in saving one full year of culture period and producing 1-kg market fish in two years instead of three years. Like our glass-jar hatchery of the 70s and 80s, they have the zoug jars which were also popularized by the FAO expert in Nepal. A Recirculation System is also available at the Research for Fisheries, Aquaculture and Irrigation (HAKI) at Szarvas.

What is surprising is that a country with only 333 pond fish farms covering 24, 702 ha and a total production of 19,926 t – 74% of which is common carp – with a net productivity of 521 kg/ha should be so advanced in breeding and aquaculture technology! Recognizing the lead that the country had, FAO had sent Hungarian experts to set up hatcheries in other countries and also organized International Training Programmes at Szarvas and Szazalombatta wherein some Indians had also participated.

JAPAN : Japan has highly advanced systems in place and has both warm water and cold water hatcheries in Tokyo itself. It raises the anadromous chum salmon (*Oncorhynchus keta*), catadromous eel (*Anguilla japonica*), ayu (*Plecoglossus altivelis*), trout, koi (homophone for love and friendship) and the Chinese carps. Look at the effort it puts in incubating 500 million eggs of salmon and feed them for three months to be released in the river to go back to the sea and wait for its return after two or three years when only 1 or 2% come back home – a much better record than for the Pacific salmon in USA.

Our anadromous *Hilsa ilisha* is still awaiting its turn! Perhaps, it is time that concerted efforts are made by the three institutes – CIBA, CIFA and CIFRI – to breed and release the juveniles in the Ganga to revive its

fishery there and also strengthen its stocks in major rivers draining on the east and west coasts where it once thrived. Culture of Hilsa in ponds and cages could be initiated using the juveniles available in the Hooghly.

Scaling-up and Modernization of Hatcheries

If the country has to provide quality protein to its ever-burgeoning population and increase the per capita consumption from the present 9 kg to 13 kg, it needs (i) to bring a much larger area under the fold of aquaculture, (ii) increase the rate of production per unit area, (iii) develop the capture-based aquaculture from tanks and small reservoirs, and (iv) organize the enhancement programme in large reservoirs besides (v) developing pen and cage culture systems for *beels*, tanks and reservoirs and a number of other measures for which much larger quantities of seed in the form of fingerlings (50 mm to 150 mm) would be required. Though the actual demand has never been assessed scientifically, the present production of 32,177 million fry falls far short of demand. This is based on the loud cry that owing seed shortage, ponds, tanks and reservoirs could not be properly and adequately stocked. A number of hatcheries in the country are lying in disuse or abandoned owing constructional defects, water shortage, poor connectivity, non-availability of brood stock in the vicinity, or the unwillingness of officers and staff to stay at site.

While the demand for small quantities of seed in the rural areas could be easily met by installing portable hatcheries a number of places but the requirement of large quantities of seed for small and large reservoirs would need to be met from large and modern hatcheries. These will require a large area as it would not be just a 'hatchery' as we understand it today but a large farm with brood stock ponds, nurseries, rearing and production ponds besides adequate space for packaging, storage of feed and equipment, back-up generators, laboratory, staff quarters, garages and additional space for future expansion. What is most important that the site should be selected extremely carefully and the entire hatchery designed properly? Some of these hatcheries could probably serve as training and demonstration centres as well for which the required facilities of a Guest House, Hostel, Lecture Room and Lab for practical work should also be kept in mind.

Recirculation System : These systems are installed by manufacturing companies of which there are several abroad but can also be indigenously developed. A mini model was installed at CIFA in late 1980s by our own colleague but it did not have controlled conditions of temperature, light, etc. Those with controlled conditions are truly advantageous and needed. In Chile, UV lamps are being used additionally to disinfect water for make-up supply.

Modern Lab : The lab needs to be furnished with all the gadgets for water quality analyses, detection and identification of pathogens, refrigerators, cold store, cryocans, chemicals, inducing agents and probiotics. One of the most important equipment that should now be available in our hatcheries is the 'Portable Ultrasound Unit' – an Easi-scan monitor – for distinguishing the males and females at a much earlier stage than what has been possible so far, examining the developing testes and ovaries of fish, ascertaining the egg quality and forecasting as to which of the females are likely to spawn. As more females are required, the males thus identified could be sent to stock ponds for future harvest leading to economy of space as well as brood stock feed. This will be a boon to the brood stock development programme. CIFA should have it soon and so also the large hatcheries in Odisha and other States.

We have tankers for transport of petroleum and also for water supply in big cities but not for transport of fish seed as in USA or elsewhere. Now that the roads have been or are being widened and connectivity is

improving, we should also put such a transport system in place to economize on time and fuel costs. An Invention Award was given to the Extension Unit at Mandapam more than four decades ago for transporting about a lakh of fingerlings in a tanker but it has not found a field application till today! It is equally necessary to replace the kerosene oil tins with laminated card board cartons which do not rust and can be folded and stored in a much smaller space.

National Breeding Programme : It is a crying need of the hour but not an easy task. However, if there is a problem in developing a National Breeding Programme, can we think of it on a smaller scale and begin with a Breeding Programme for Odisha? Though it is a little late this year but soon after the current breeding season the scientists of the Institute and the Hatchery Mangers of select hatcheries can sit together and plan a programme.

It would be worthwhile to develop molecular genetic maps of Indian major carps and some other commercially important species such as sarana (*Puntius sarana*), bata (*Labeo bata*), goni (*Labeo gonius*) besides the two catfishes, singhi (*Heteropneustes fossilis*) and magur (*Clarias magur*) to identify genes involved in growth and disease resistance to facilitate marker-assisted breeding programmes. These are long-term programmes and cannot be solved in a day. Maybe molecular geneticists from every corner of the country could work together to hasten the solution! Canada, Chile, New Zealand and Norway are working together to study the salmon genomes.

In any case, it is better to understand the capacity of the indigenous species rather than jump at exotics for diversification.

Seed Certification

While the ICAR is at it for quite some time a solution to the problem has not been found as yet. Perhaps, CIFA, CIBA, CMFRI and DCFR could now work together and prepare a draft and send it to the Council for comments/suggestions of the Agriculture Seed Committee as its experience would be a valuable input and then after getting a legal opinion, circulate it amongst the States, to finalize it for presentation to the Parliament for enacting a Bill.

We as a large nation and said to be the second largest producer of inland fish in the world, half of which is from aquaculture, should take a lesson from other countries which have a seed certification programme in place. It is our requirement to ensure quality.

Best Practice Guidelines (BPGs)

A farmer needs to be told the Do's and Don'ts in simple and clear terms with illustrations wherever needed. It would be an immense service if CIFA undertakes this work to guide the farmers right from the security of brood stock to the fry production ponds, in methods of (i) raising the brood stock, its feed, disease diagnosis and control; (ii) how to avoid inbreeding and hybridization; and, (iii) all aspects of larviculture or nursery rearing. These could be in all the regional languages as well. The Western Orissa Rural Livelihood Project (WORLP) of the Orissa Watershed Development Mission in collaboration with nr international and STREAM (Support to Regional Aquatic Resources Management) had produced a series of BPGs which were immense popular with the farmers and NGOs.

FRP PORTABLE CARP HATCHERY

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Introduction

The technology of induced breeding through hypophysation has helped in mass production of quality seed under controlled condition. It has reduced the dependence on the natural seed collection. Quality seed production can be achieved through scientific brood stock management, establishment of hatcheries, and refinement of induced breeding techniques and rearing of seed across the country. The long way contribution of several researchers from hapa breeding to cemented eco-hatchery and then to portable carp hatchery has made easy in availability of stocking material for aquafarming. For easy accessibility and timely production of quality seed, "ICAR-AICRP on Application of Plastics in Agriculture" Center at CIFA has designed and developed fibreglass reinforced plastic (FRP) carp hatchery, which can be transported from place to place for the stated purpose (Mohapatra *et al.,* 2003; 2004; & 2008). The innovation of portable FRP carp hatchery has added a feather to the blue revolution in the country by producing fish seed at the farmers' field. The unit consists of four major parts *i.e.,* breeding-cum-spawning pool, hatching-cum-incubation pool, egg-cum-spawn collection chamber and overhead water storage tank. The system is so designed that it creates the environment suitable for fish breeding in the field conditions for 10-12 kg of carps in one operation. In one run, 1.0-1.2 million spawn can be produced from the system which is sufficient to stock water area of about 30 hectares. The "FRP hatchery for carp seed production" has been released as a technology package by CIFA in 2004, and ICAR in 2005. On 14 July 2006, the then Governor of Orissa, Hon'ble Shri Rameshwar Thakur has released this technology to the nation at CIFA, Bhubaneswar. The transportation of seeds from different far off places to the farm sites involving substantial cost is getting reduced by introduction of this hatchery. This hatchery unit has some benefits *viz*., it is portable, easy to install and operate, consumes less quantity of water during fish breeding and seed production, needs less space for installation and the product is durable for about fifteen years. In lean season, the system can be used for ornamental fish rearing in which village women may take part in leisure time. The unit can be operated by pretrained unemployed youth, progressive and resource-rich farmers, Gram Panchayat and Cooperative societies on self-operational or rental basis. In one cycle of operation a minimum quantity of 30 cu.m water is required for the hatchery (Mohanty *et al*., 2009)

The FRP Carp Hatchery System

The system (Fig. 1) consists of four major parts *i.e.,*

- Breeding/ spawning pool
- Hatching/ incubation pool
- Egg/ spawn collection chamber, and
- Overhead storage tank/ water supply system

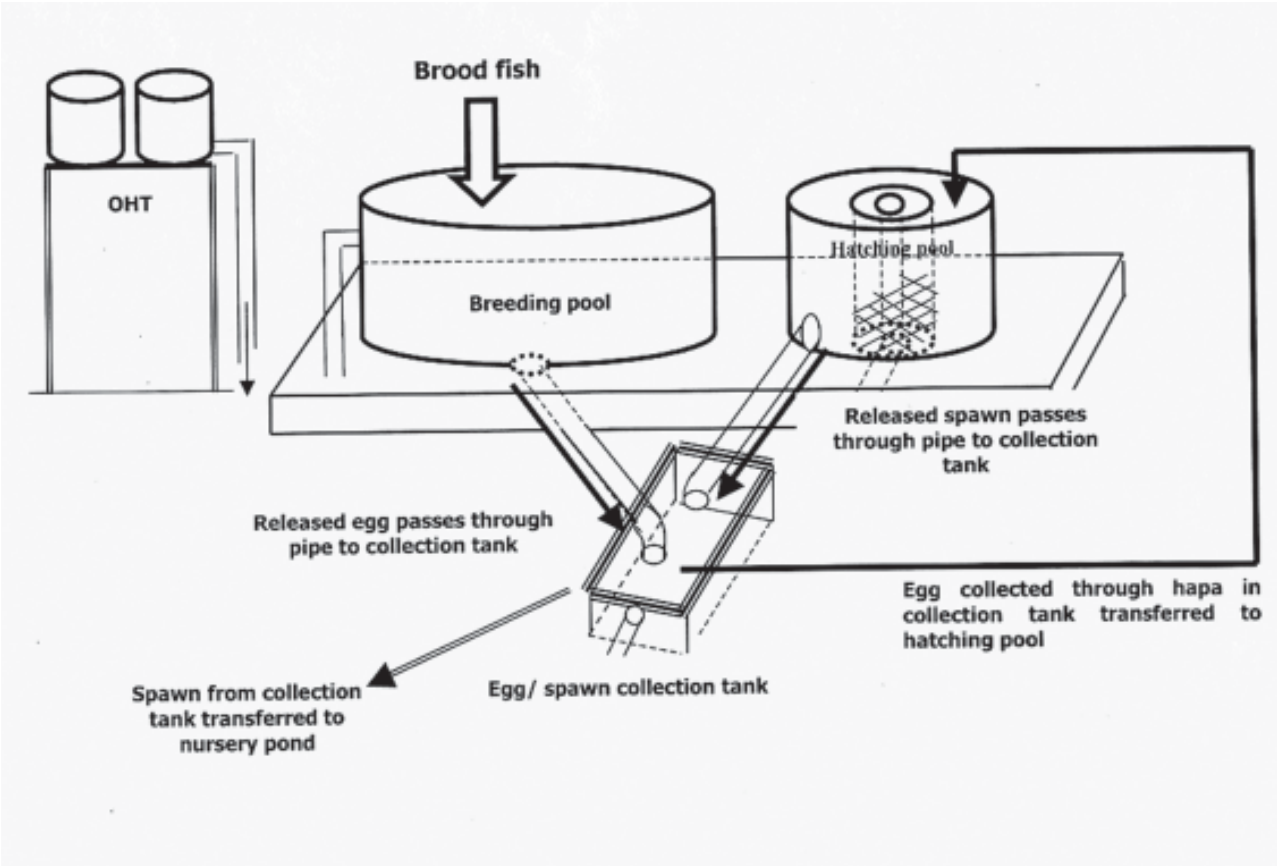

Fig. 1. Diagram of FRP Carp Hatchery

Breeding/ Spawning Pool

The breeding pool (Fig. 2) is cylindrical in shape with 2.15 m diameter, 0.9 m height and 3409 l capacity. The bottom is with uniform slope (1:22) towards outlet at the centre. The wall thickness varies 4.2–6.0 mm. To provide water circulation/flow, 5 numbers of 15 mm diameter rigid PVC elbows are fitted at the bottom of the sidewall at equal spacing. Five numbers of rigid PVC nipples 15 x 75 mm are fitted with elbows in the same direction. A single point water inlet of 25 mm diameter is also fitted at the sidewall of the bottom. All the water inlet pipes are interconnected and fitted with individual full-way valves to control the flow of water. One/two shower(s) is/are also provided at the top of the tank to sprinkle and aerate the water. The water supply to the pool comes from the overhead tank(s). If necessary the water supply to the system can be made with an electric pump of 0.5-1.0 HP capacity. The system is suitable for breeding 10-12 kg of carps in field conditions. The breeding success has been recorded at cent percent level in various carp species. The flow rate during egg collection is maintained in the pool at 1-1.5 l/sec. depending on species.

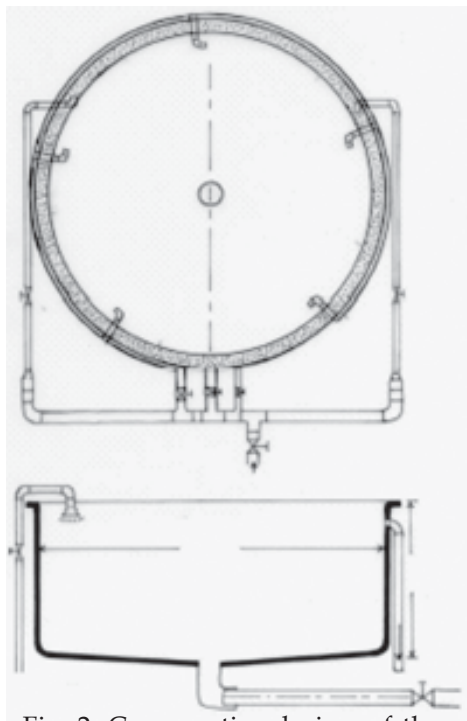

Fig. 2. Cross-sectional view of the FRP Breeding Pool

Hatching/ Incubation Pool

The pool (Fig. 3) is cylindrical in shape with 1.4 m diameter, 0.98 m height and 1200 l net egg incubation volume. It consists of egg incubation chamber, FRP inner chamber, water supply system and accessories. The FRP inner chamber of the tank is with 0.4 m diameter and 89 cm height, covered with nylon bolting cloth of 0.25 mm mesh to filter the excess water to the drain. Five numbers of RPVC (15 mm diameter) duck-mouths are fitted at the bottom of the hatchery at 45° in between outer and inner chamber at equal distances to get required water flow for the eggs. It also has drainage outlets fitted at the centre and at the outer chamber for draining and cleaning purposes. The carp eggs are introduced in the outer chamber of the system and water flows continuously through the duck-mouths. The excess water flows continuously through the cloth of the inner chamber to the outlet pipe. The eggs hatch out in 14-18 h and remain in the pool for 72 h. The spawn is collected from the hatching pool through PVC hose pipes/spawn collection tank. It has the capacity of hatching 1.0-1.2 million eggs per operation. The hatching percentage of the carp eggs in the system is found generally in the range of 80-99. The flow rate in the pool during operation is maintained at 0.3-0.4 l/ sec.

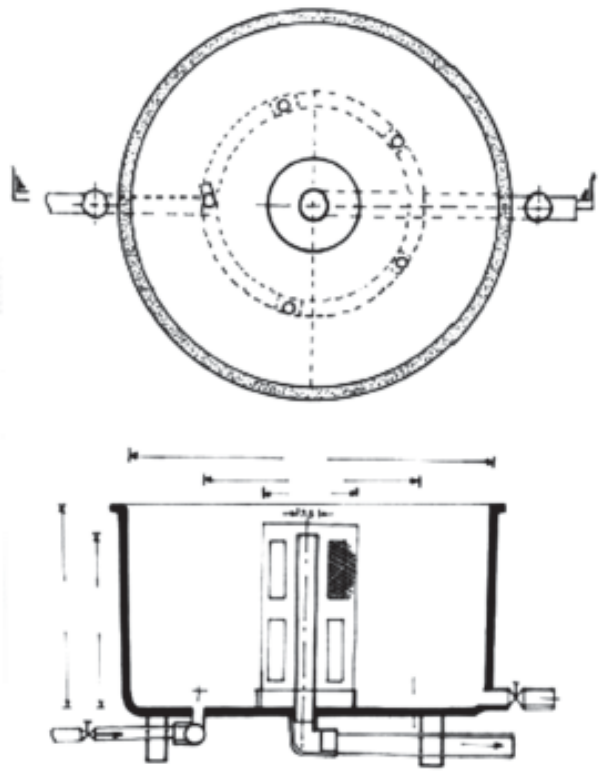

Fig. 3. Cross-sectional view of the FRP Hatching Pool

Eggs/ Spawn Collection Tank

This is a rectangular tank of size 1.0 × 0.5 × 0.5 m with capacity of 250 l. Its wall thickness is 3 mm and it is reinforced with MS angle of 25 × 25 × 5 mm at all sides from the bottom in a height of 0.35 m. The water level in the tank is maintained at a height of 0.45 m (net water volume 225 l). To drain the excess water, PVC pipe of 63 mm diameter and 150 mm length is fitted at a distance of 38.7 cm from the bottom. Cotton inner hapa of the tank size is fixed inside it to collect eggs/ spawn from breeding/ incubation pool, respectively.

Overhead Water Tank

Water storage tank of capacity 2000 l is required to operate the hatchery unit. As per the space availability, 2 tanks of 1000 l capacity each can solve the purpose. The breeding pool and hatching pool are connected to the water storage tank separately or together in the same water line. One 1.0 HP pump set is required to fill the storage tank periodically to supply water to hatchery continuously.

Species Suitable for Breeding

The system is suitable in field conditions for breeding of carps *viz.,*

- Rohu (*Labeo rohita*), Catla (*Catla catla*)
- Mrigal (*Cirrhinus mrigala*)

- Kalbasu (*Labeo calbasu*)
- Silver carp (*Hypothalmichthys molitrix*)
- Grass carp (*Ctenopharyngodon idella*)
- Common carp (*Cyprinus carpio*)
- Silver barb (*Puntius* sp.), etc.

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CAPTIVE BREEDING OF CARPS AND PORTABLE HATCHERY OPERATION

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Introduction

India is regarded as one of the leading contributors to world aquaculture. Freshwater aquaculture is now a farming activity in agriculture sector and is well known as a profitable farming system. Indian major carps are the potential species in Indian aquaculture besides other fish varieties. Initially fish culture was going on by stocking natural seed, collected from riverine system. But, gradually over fishing, pollution and human activities in different water bodies have contributed to the destruction of spawning ground resulting decreased seed collection. So, captive production of seed became important to satisfy the seed requirement for aquaculture. The initial success of captive breeding of carps during 1957 became a hope to get pure seed for aqua-farming. The long way of contribution of several researchers from hapa breeding to eco-hatchery and then to portable carp hatchery made easy in availability of stocking material for aqua-farming. The success of seed production depends on the brood status and management, practices during breeding and management involved in hatchery operation.

Brood Pond

The brood ponds usually vary in size from place to place and size ranges from 0.2-0.5 ha. Too big ponds should be avoided for management point of view. It is good to construct the brood pond in a place, which has good water retention capacity and free from flood. The ideal water depth in the pond is 1.5 m. The old pond can be utilized for brood rearing, but with prior preparation. These are to be dewatered for taking out the mud and exposed to sun drying. Before stocking, liming can be made depending on the pH level of the pond. Similarly the new ponds should be manured like carp nursery pond preparation before stocking the brood fish.

Brood stock management

Ideal management for brood fish is required for breeding success. Some factors like poor water quality, over crowding or poor nutrition for brood fish may lead to breeding failure. The water temperature is the most important factor influencing spawning success. It is difficult to control or modify the temperature in open pond system. But, it can be controlled to some extent by maintaining water flow as well as sprinkling of water in the brood pond. By the water in-flow and out-flow, the extra load of nutrient is washed out providing good environment to brood fish.

A relatively low standing crop is required in brood pond to provide optimal environmental conditions as well as to minimize the possibility of spawning failure by over crowding. The stocking of different carps in brood pond is considered ideal within 1.0-1.5 ton/ha. Large fish, which weighs more than 4 kg should be replaced every time with younger fish for better output in seed production. Segregation of brood as per the size and distribution of fish from one pond to another gives excellent exposure to brood in new pond environment during their rearing. But, it is not feasible in a bigger farm every time. Hence, it is

better to adopt this at least in one to two years succession. The maintenance of male and female brood at a ratio of 1:1 to 3:2 is acceptable as male is required in more numbers during breeding operation.

The brood fish must be provided with adequate and nutritionally balanced diet. They should be fed regularly with the feed containing 30-32% protein for better performance during the season. Insufficient and poor quality feed may result poor gamete quality. The fish manager should be confirmed that all fish get sufficient feeding. In pond condition, generally the dominant fish consume more feed, which deprive other smaller fish to eat. So, equal sized brood in pond as well as feed dispensing method should be considered an important aspect during brood raising programme. So it is advisable to offer feed in more places, so that all fish get opportunity to consume feed. The brood fish may be checked at regular intervals for their health status.

Hormones used in fish breeding

Captive broods do not breed in pond condition except few fish like tilapia. So they require hormonal induction for captive breeding. Captive breeding of fish is generally approached by two ways through hormone injection or by environmental manipulation. It is well known that environmental cues like temperature, photoperiod, rainfall, etc. are helpful for ovulation and spawning. But it is difficult to say which factor or combinations of factors are helpful in spawning for a particular fish. However, environmental stimulation for spawning of few fishes like milkfish is often talked about.

Induction of spawning using hormones has a direct control on the reproductive cycle of fish. Commercially important tropical fish are commonly spawned by pituitary homogenate, human chorionic gonadotropin (HCG), pregnant mare's serum, semi-purified fish gonadotropin, etc. These preparations are used in two split doses with a priming low dose followed by a higher resolving dose. Variable doses are even used for the same species. Always the spawning success depends on the potency of hormone, maturity status of fish, dose used, etc. The purified form of inducing agents like HCG is widely used by Asian fish breeders although it is expensive. But, the consecutive use of this inducing agent may result in the development of an immune response. Use of crude pituitary extract through intramuscular or intraperitoneal injection to fish is still widely acceptable during induced breeding operation. Fresh or preserved pituitary glands from same species (homoplastic) or other related species (heteroplastic) are used. Doses are given on the basis of body weight or ratio between the body weight of donor and recipient. The standardization of hypophysation is a great problem as pituitary extract depends on the age, sex and maturity of the donor. But, now researchers have developed synthetic forms of inducing agents like LHRHa, GnRHa, etc., which are less expensive and easy to use. Some synthetic inducing agents like Ovaprim, Ovatide, WOVA-FH, Ovopel, etc. are available in market in a ready to use form. These are not only less expensive, but also, effective in ovulation and spawning in a wide range of fish species.

Brood selection and breeding practice

The Indian major carps usually breed once in a year during monsoon months. The rainfall and low water temperature are believed to be the key factors for gonadal maturation in those fishes. During the breeding season, the females show bulging abdomen and red genital papilla, which show the readiness of female for breeding operation. The suitable males show free oozing condition. The stress factor should be avoided or minimized while transporting the broods to the hatchery. Too much stress in broods may lead to breeding failure.

The application of hypophysation technique is an age-old practice to breed this fish, which is also continued now by many fish breeders of Indian sub-continent. The pituitary gland of carps is collected during breeding season and is used in fresh or preserved form through one or two injections. The doses vary from 5-14 mg/kg body weight for both the sexes depending on the maturity status of breeders. Males require half the dose compared to female brood. Some fish breeders also inject 250 IU HCG along with 6 mg pituitary gland per kg body weight for effective spawning. Now the use of pituitary in fish breeding has been reduced to large extent after the entry of synthetic hormone like Ovaprim, Ovatide, Wova-FH, etc. in the market. These hormones are available in liquid form and the Indian major carps usually require 0.3-0.5 ml/kg body weight for successful spawning. Sometimes the dose range goes little higher or lowers depending on the maturity status of brood and temperature of the environment.

Steps of hatchery operation

The portable FRP hatchery is suitable for breeding of Indian major carps, minor carps and exotic carps. The operation is described here under.

Clean and wash the breeding and hatching pools by 5 ppm $KMnO_4$ solution before the hatchery operation.

↓

Close the outlet valve of breeding pool and then fill it with water. Fix a clean cotton hapa inside it.

↓

Collect the male and female brood at a ratio of 1:1 by weight, transport them to breeding pool, place them in hapa and run the shower(s) for conditioning. The maximum carrying capacity of brood fish in the breeding pool should be limited to 10-12 kg (3-4 kg/m^3 of water)

↓

After 1-2 hours of conditioning, inject the breeders with suitable inducing agents and dose, release them to the breeding pool, remove the hapa and run the shower(s).

↓

After 4-5 hours of injection, allow the flow/circulation of water in the breeding pool, open the outlet valve, allow the water to pass from breeding tank through the hapa of the eggs/spawn collection tank to the outside. The water current is created in the breeding pool by regulating the water flow through the inlets and outlet. If the eggs are released from the fishes, they are to be collected at regular intervals with renewal of hapa in the eggs/spawn collection tank.

↓

In hatching pool fix the screen on the FRP socket; fix the PVC drainpipe in the center of the tank to drain excess water. The height of the drainpipe in the pool is adjusted at 0.9 m so that the water level can be maintained. Provide water circulation in the egg incubation chamber through duck-mouths (inlets) for free floating of incubated eggs.

↓

Collect the released eggs from the egg/ spawn collection tank by hapa time to time, measure them and

release them in the egg incubation chamber of the hatching pool. The egg release generally stops within 8-10 hr from injection.

↓

Remove the breeders from breeding pool once the breeding is over. They may be released to the spent brood pond after dipping them in 5 ppm $KMnO_4$. Clean the breeding pool by $KMnO_4$ solution and water properly for other breeding operation.

↓

On release of eggs maintain the flow rate in the hatching pool in such a way that the eggs float in the water (can be checked by putting light from a torch from the top of water). Periodical check is required to get the present status of eggs/spawn. Periodical cleaning of the filtering mesh by a brush with long handle from the side of inner chamber is essential to avoid water choking.

↓

On 4th day, collect the spawn through hapa in the eggs/ spawn collection tank by opening the outlet valve connected to the outer wall of the hatching pool. These are ready to be stocked in nursery ponds for fry production.

↓

After spawn removal the hatching pool and the eggs/ spawn collection tank are cleaned by $KMnO_4$ solution and then by water.

↓

To avoid direct exposure of sun light to the pools and tank, a shed may be constructed.

Economics of FRP Carp Hatchery Operation

Hatchery unit of "one million spawn production per operation" consists of one breeding pool associated with one hatching pool. In this hatchery the spawn (final product from hatchery) is harvested on 4th day during operation. Fertilized eggs are kept in hatching pool for incubation and it takes 14-18 hours for hatching, and then after 72 hours for transformation to spawn. Thus, four days are required for spawn production from one million capacity unit. Similarly hatchery for "two million spawn capacity" means one breeding pool associated with two hatching pools and "three million capacities" includes one breeding pool with three hatching pools. In case of two million capacity hatchery, the eggs produced from two consecutive fish breeding operations can be incubated in two hatching pools, thus two times the seed can be harvested (totaling to two million seed production from two operations) *i.e.,* on 4th and 5th days from initial hatchery operation. Once one hatching pool is free after harvest, the next breeding programme can be taken up. In case of three million capacity hatchery, three times the seed can be harvested (totaling to three million seed production from three operations) *i.e.,* on 4th, 5th and 6th days from initiation of hatchery operation. Then after operations can continue with serial harvesting of spawn from hatching pools. The economics of FRP hatchery operation is given in table 1.

Table 1. Economics of FRP carp hatchery operation

(Current price in Rupees)

Sl. No.	*Items*	*1.0 million spawn capacity*	*2.0 million spawn capacity*	*3.0 million spawn capacity*
I.	***Expenditure***			
A.	***Fixed Capital***			
1.	*FRP Carp hatchery*	*1,00,000*	*1,45,000*	*1,90,000*
2.	*FRP water storage tank*	*15,000*	*22,000*	*30,000*
3.	*1 HP single phase mono block pump set (2 nos)*	*10,000*	*10,000*	*10,000*
4.	*Miscellaneous accessories*	*5,000*	*6,000*	*7,000*
	Sub-total	***1,30,000***	***1,63,000***	***2,33,000***
B.	***Variable Cost per Cycle***			
1.	*Brood fish (@ 50/kg)*	*1,000*	*2,000*	*3,000*
2.	*Electricity and fuel*	*200*	*300*	*400*
3.	*Inducing agent*	*325*	*650*	*975*
4.	*Wages (@ Rs. 100/day for 8 man-days per operation i.e., 4 days)*	*800*	*800*	*800*
5.	*Miscellaneous*	*175*	*250*	*350*
	Sub-total	***2,500***	***4,000***	***5,525***
C.	***Total Costs***			
1.	*Total variable costs (20 cycles)*	*50,000*	*80,000*	*1,10,500*
2.	*Depreciation cost on fixed capital @ 10% yearly*	*13,000*	*16,300*	*23,300*
3.	*Interest on fixed capital @10% per annum*	*13,000*	*16,300*	*13,000*
	Grand Total	***76,000***	***1,12,600***	***1,46,800***
II.	*Gross Income (per Cycle)*			
	Sale of spent brood (@ Rs. 40/kg)	*600*	*1,200*	*1,800*
	Sale of spawn (avg. @ Rs. 600/ lakh)	*6,000*	*12,000*	*18,000*
	Sub-total	*6,600*	*13,200*	*19,800*
	Gross Return (for 20 cycle)	***1,32,000***	***2,64,000***	***3,96,000***
III.	***Net Income (Gross income - Total costs)***	***56,000***	***1,51,400***	***2,49,200***

Conclusion

Now the availability of pure seed as well as the quantity of seed from natural resource has been reduced to a great extent. The easy in installation and management, and the effectiveness of fish breeding and spawn production in FRP portable hatchery may be one of the alternatives to get quality seed for aqua farming in coming years.

UTILIZATION OF MILT CRYOPRESERVATION TECHNOLOGY IN AQUACULTURE - A STRATEGY

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Introduction

Poor growth of hatchery bred seed has been a real concern in fish farming industry in India in spite of a remarkable growth in this sector. The quality of seed is an important consideration for commercial aquaculture. To improve the quality of the stock, the primary strategy has been to exchange the brood stock, but the cumbersome process of transport and subsequent mortality of brood fish has been an impediment. To overcome this, an effective strategy has been to preserve the milt of unrelated healthy fish stocks and use in different carp hatcheries.

Cryopreservation of gametes and embryos is an essential tool for germplasm conservation. This is also used as a tool in assisted reproductive technologies providing the possibility to preserve rare and valuable breeders (gene banking) and enabling semen and embryos to be marketed or to be exported. Long-term preservation of sperm is a common place in cattle breeding but has been limited in aquaculture. Creation of semen banks can also assist in selection programmes. The technology involves the principle of in vitro fertilization by stripping method. The technology targets at delivery of improved milt at the hatcheries. If this can be practiced commercially then hatchery managers need only to rear female fishes and thus the cost of raising males by each hatchery will be reduced because of the use of cryopreserved milt. By using males from distant places with unrelated pedigree large effective population size can be maintained with minimal cost. The technology can bring a qualitative change in the fish production by improvement of the basic genetic materials in the aquaculture. The change in the quality of the seed will improve performance at the hatchery, seed growers and fish farmers level .

Preservation of Milt (Short Term)

Short term preservation of fish gametes is a matter of convenience and is undertaken well in advance. Thus, at the time of stripping female fish, milt is at one disposal and less number of fishes is handled. The preservation of fish sperm is based on the principle that it reduces the metabolic activity of the cells so as to prolong their life span. It involves maintenance of fish milt on ice or in a refrigerator at temperature 0-10^{0}C and the period of storage may last a few days. The sperm may be stored either undiluted or diluted with extenders that correspond to ionic composition of seminal plasma. The storing of diluted milt is preferred as it keeps spermatozoa viable for a longer duration than undiluted. The success of short term storage of spermatozoa is influenced by number of factors such as collection technique and contamination, storage procedures such as storage temperature, composition of gamete diluting medium and gamete diluents ratio. Storage temperature is a major factor affecting the viability of gametes during in vitro storage. Viability can be prolonged by maintaining gametes at near zero temperature to reduce their metabolic burden. Saad *et al*., (1988) reported short term preservation at 4 ^{0}C temperature in *Cyprinus carpio* spermatozoa resulted in more than 80 % fertilization.

Cryogenic Preservation (Long Term)

Cryopreservation is defined as the preservation or storage of living or non living materials at liquid

nitrogen for a long period of time without affecting the original nature of the materials. Spermatozoa can be stored for years together in liquid nitrogen (-190^{0}C) where all the biochemical activities of a living cell ceases. Cryopreservation techniques involve mixing the milt sample with diluents, ampouling, rapid cooling and storage in cryogenic condition. The basic component of diluents is an extender that has the approximate osmotic properties of seminal plasma and a cryoprotective agent. Extenders are generally designed to be compatible with the physiochemical composition of the seminal plasma of the candidate species to maintain the sperm in a non motile but viable state (Stoss, 1983). The diluents must also contain a cryoprotective agent. Cryoprotectants are a chemical that minimizes damage to sperm cell during freezing and thawing process (Jamieson, 1991). Saad *et al*., (1988) (Stoss, 1983).

Protocol for Cryopreservation

Milt Collection

Matured males showing free oozing of semen upon gentle abdominal pressure are selected for semen collection. Milters are injected intraperitoneally with Ovaprim (Salmon GnRH+ Domperidone) at a rate of 0.2ml/kg. Semen collection is carried out 4-5h after the hormone injections. Milt samples are collected in ice cooled and sterilized test tubes. During the semen collection, attention is paid to prevent contaminations by faecal matter, urine, blood, or scales and to maintain the temperature of the collected semen at 4^0 C. Before cryopreservation, the milt quality is assessed.

Milt Quality Assessment

The capability of a milter can be assessed by evaluating the quantity and quality of the milt. Such evaluation parameters are milt yield by volume, viscosity by spermatocrit value, sperm density by total sperm count per unit volume and motility by activation. Milter in peak breeding season yields 1-2ml per kg body mass when pressed gently on its abdomen. A prospective milter can yield about 6- 10ml milt on hormonal induction with any standard inducing agent (Gupta and Rath, 1991, Verma *et al*. 2009). The colour of the milt is cream-white to milk-white depending upon the viscosity. Viscosity of the milt implies the total sperm packed cell found per unit volume and can be expressed as spermatocrit percentage. Spermatocrit value is ascertained by the help of haematocrit capillary and haematocrit centrifuge instrument. Non induced milter produces little milt but it will be of very high spermatocrit value ranging 90-95 percent. On induction milt volume increases but spermatocrit value range comes down to 70-90 %. The number of spermatozoa is estimated per unit volume with the help of a simple haemocytometer. Catla,Rohu and Mrigal count is estimated as 2.0-2.5 x 10^7 , 3.0 –3.5 x 10^7 and 2.0-2.5 x10^7 spermatozoa per cu.m respectively.

Equilibration with Diluents

For successful cryopreservation, it is essential to prevent any activation of spermatozoa during preservation. Undiluted sperm is unsuitable for storage at cryogenic temperatures, so it should be diluted with an appropriate medium (Scott and Baynes, 1980; Stoss, 1983). Because motility of fish spermatozoa is mostly a one-time event, this medium should not induce motility and at the same time must not interfere with the ability of the spermatozoa to be activated subsequently during utilization. Media that satisfies these conditions is called "Extender". The chemical components of extender are NaCl – 750 mg, KCl – 20 mg, CaCl2 – 20 mg, NaHCO3 – 20 mg added to 100 ml distilled water and adjust the osmolality in the range of 280-300 mOsm/kg. The extender may be prepared in advance and, immediately before use (Routray et al. 2002).

Cryoprotectants Used for Cryopreservation

To protect the cells from cryoinjuries, it is essential to protect them with the help of chemicals known as cryoprotective agents (CPAs) or cryoprotectants. The addition of cryoprotectants during sub-zero storage of fish gametes is important in protecting them from intercellular freezing and solute injury. Cryoprotectans are essential for the survival of spermatozoa during cryopreservation. Cryoprotectants are divided into two groups; those permeable to the cell membrane called permeating cryoprotectant and those not is known as non-permeating cryoprotectants. Commonly used permeating cryoprotectants are DMSO, glycerol, methanol and 1, 2-propanediol. Of these compounds, glycerol is the least toxic to most biological materials but also the least permeable to the cell membranes. Methanol is highly permeable to cell membranes but is generally considered to be most toxic. DMSO is fairly permeable to the cell membrane but its toxicity is intermediate between glycerol and methanol. Probably of these reasons, DMSO is the most widely used permeating cryoprotectant.

Freeing Protocol

A rapid freezing protocol is advocated for carp sperms as it minimizes the thermal shock and intracellular ice formation. The sealed visotubes are required to be cooled at -15^{0}C/minute by programmable cooling chamber. Similarly, manual method of freezing is also possible by manual vaporization over liquid nitrogen in thermocol chamber. The frozen milt samples in straws/visotubes are quickly plunged into liquid nitrogen and kept undisturbed. The evaporation loss of liquid nitrogen is compensated by regular filling of the container.

Thawing/Warming and Fertilization

Thawing is an important step in cryoprotocol; if optimum conditions are not followed, ice formation takes place due to recrystallization. In the case of carp spermatozoa, fast thawing is preferable, because slow thawing can recrystallize small intercellular crystals that may damage the cells. In the present protocol the cryomilt samples are thawed in warm water at 38±1°C. Visotubes and French straws take approximately 65–70 and 8–10 seconds, respectively, until slush formation. After slush formation, it is important to keep the milt decanted from the visotubes on to a fertilization plate for nearly 5 sec before mixing with the unfertilized eggs. This is done to bring both gametes to isothermal conditions at room temperature. Eggs fertilized with the cryomilt are washed thoroughly 5–10 times in freshwater and then placed in flow-through incubation chambers to wash out excess CPA and for hatching.

Sustainability of Technology

Protococol for cryopreservation of Indian major carp spermatozoa has been standardized and used for stock upgradation and seed production on a sustainable basis. Methods of carp milt cryopreservation were used for demonstration to fisheries personnel. Multilocational trial cum demonstration of cryopreserved milt and its utilization was carried out at different states of India. Regular training programme on "cryopreservation of male gametes of carp" is conducted at this Institute. For the purpose of stock upgradation and quality seed productions of Indian major carps (Catla catla, Labeo rohita, Cirrhinus mrigala) fish semen cryobank (2 in Andhra Pradesh and 2 in Orissa) have been established recently. Cryosemen from these banks were used for stock upgradation in hatcheries. This has changed the germplasm of the farms for future brood stock development. Moreover, the genetic upgradations at the seed growers levels will have multiplier effect on the sector as the impact will be carried to the fish culturist and ultimately to the consumers of the country. Similar strategies have revolutionized the livestock sector in many countries. By doing this, the hatchery managers can be assured about the quality of seed.

Conclusion

This is a completely user friendly technology and can be applied on the farm site of the farmers and fish seed producers. It involves very few chemicals and the cost of stock upgradation in the farm becomes less expensive when compared to the live seed or brood stock transportation.

Applications of Cryomilt in Aquaculture

- Solve the asynchronous spawning time between female and male.
- Easy selective breeding or hybridization.
- Potential for year-round fish seedling production.
- Preservation of decreasing indigenous species.
- Set up the fish sperm bank.
- Synchronization of gamete availability of both sexes, sperm economy.
- Simplification of broodstock management.
- Transport of gametes and embryos between different fish farms instead of breeders.
- Germplasm storage for genetic selection programs or conservation of species.
- Marketing of well-characterized and standard quality sperm (genetics as a business).

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FISH SEED QUALITY ASSURANCE AND CERTIFICATION

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Introduction

Fish production in India has grown tremendously from a meager 0.75 million t in 1950-51 to 7.13 million t in 2008-09, with substantial contribution from freshwater aquaculture (about 3.37 million t). With the impressive annual growth rate of about 6% during the last three decades, there is no doubt that aquaculture holds great promise to produce high quality, large volumes of fish. Carps contribute to over 80% of national aquaculture production. Quantity of carp seed production in India has increased from 6,321 million in 1985-86 to about 1,85,000-2,10,000 million during 2004-2005. Dependence on wild seed collections for fish aquaculture declined rapidly with the success of fish seed production through artificial breeding techniques and establishment of the hatcheries in the public sector, which also acted as centers of technology transfer. For example, the dependence on wild collected carp fish seed in India has been reduced to negligible levels (5 percent).

Against this background, it is evident that quality of fish seed produced in hatchery would be the major constraint for expansion of aquaculture industry; poor quality seed can have deleterious effect on fish production and broodstock development. In this article we are attempting to go to the fundamentals of fish seed quality assurance and status of seed certification.

What is Seed Quality ?

"Seed" (eggs, milt, fry, fingerlings or nursed animals) quality is that which optimizes the potential for aquaculture production and is related to the quality of the broodstock used and the seed produced. The quality considerations are those which meet the expectations and demands of the producer (grow-out operations) and the final consumer of the end product.

The parameters for quality assurance may include the following:

(i) Conforming to market needs, e.g.

- colour
- body shape (meat yield)
- safety (free of human disease causing organisms)

(ii) Meeting producers' needs and expectations, e.g.

- uniformity of size and age
- fast growing
- consistency
- genetic potential

- purity
- minimal risk to the farmer, e.g. high survival, disease resistance, healthy (nutritionally fit and free of disease), etc.

How to Achieve Quality in Fish Seeds ?

This can be achieved in three ways:

(i) Genetic management of domesticated stocks and broodstock – issues, such as inbreeding, effective population size, base populations, etc.

(ii) BMPs (Better Management Practices) of broodstock – good nutrition, good record keeping, bio-security, disease control, standardization of protocols & techniques, HRD and documentation.

(iii) Seed Certification – assurance of the genetic status of seed, production of seed under proper husbandry conditions, proper handling & transportation and final measurable quality at POS (Point of Sale).

Genetic Management

Inbreeding pressure in carp hatcheries is high because the operators do not (a) maintain an effective population size and (b) exchange broodfish with unrelated or wild fish. High rates of inbreeding and inter-specific hybridization in both endemic and exotic carps resulted in low growth rate, high mortality, deformities of fish seed and less fecundity. Inbreeding of carps in some hatcheries has gone up to even 17%. Effective population size (N_e) is the critical parameter deciding inbreeding level and it is inversely related to the latter. Any seed production unit should follow certain norms by giving importance to the genetic status (genetic variation) of the brood fish population and the effective numbers (N_e) required for the production of the seed. Then only it is possible to preserve the genetic superiority of the successive progeny of a given species by avoiding inbreeding. Therefore, to improve the genetic status of any population and thus assure seed quality, hatchery managers should decrease inbreeding rate and increase effective population size. Selective breeding plays an important role to improve genetic status of fish in a positive direction by which quality seed can be produced. The development of GIFT (Genetically Improved Farmed Tilapia) in the Philippines and Jayanti rohu in India has clearly demonstrated that rapid genetic improvement of farmed tilapia and rohu through selective breeding is possible. Similarly the base population should have a broader gene base with genetic variability, in order to maximize genetic gain in both short and long terms.

Better Management Practices (BMPs)

Better broodstock management will lead to improved breeding responses and increased fecundity, fertilization, hatching and larval survival rates and more viable fish seed. The process can be divided into two broad categories:

(a) the pre-spawning process and (b) the post-spawning process. The pre-spawning process includes procedures for broodstock selection and procurement, maintenance, broodstock handling, maturation, acclimatization and spawning. The post-spawning process includes facility maintenance, water quality management,; washing, selection, holding and transfer/transport of spawn, rearing of spawn, maintenance, health management, assessment of condition, selection and risk assessment for stocking, documentation and record keeping.

After the segregation of putative brood fishes from the communal rearing ponds, the fishes are stocked in brood fish rearing ponds @ 1500-2000 kg/ha fish biomass. The brood fishes are fed with a formulated diet, starting at least 3 months before the breeding initiated, to attain the optimum level of sexual maturity. The mixture consists of groundnut oil cake, rice bran and vitamin supplement. During maturing stage, the rate of feeding has to reduce to 2% of the body weight of the fish to enable proper development of gonads. To keep the rate of inbreeding at an acceptable level, the number of male and female breeders is restricted to not more than eight animals from each full-sib family.

Success of fish seed nursing is critical as the fish seed production of a country is measured by the quality output from fry nurseries. Nursery operation can be carried out in two ways: (1) single-stage operation where hatchlings are raised until fingerling stage and (2) two-stage operation such as: (i) raising hatchlings to fry and (ii) raising fry to fingerlings. Concept of gene banking has not quite caught up with fish, notwithstanding the case of GIFT; descendants of these fish remain available from this gene bank for national, regional and international breeding purposes.

Causes for Poor Quality of Seeds

The reasons for the gradual deterioration in fish yield and individual weight of many farmed fish are not very clear. Improper production and delivery of seed to farmers or poor management of fish seed by farmers once stocked, may lead to decline in fish production.

Poor pond hygiene

Mass mortality of seed in ponds is attributed mainly to prevalence of protozoan parasites, particularly in ponds which are not dried properly prior to stocking. Pond drying followed by liming is known to reduce mortality considerably and improve seed quality.

Presence of pests

The presence of pests in carp nurseries is known to hamper its growth and survival by competing with fry for food, space and oxygen. Presence of weed fishes in nursery ponds also could affect production of carp seed.

Inbreeding

Since carps are highly fecund, hatchery operators tend to maintain a low effective population size (number of broodstock that contributes genetic material to the next progeny) and do not exchange broodfish with unrelated or wild fish. Poor performance of the resultant seed had been linked to inbreeding of carps in India. A communal or mixed spawning system for major carps in some parts of India is being practiced and is known to produce approximately 10 percent hybrids. This technique may lead to loss of genetic purity of important major carps. Fish farmers often complain about poor growth of fish procured from particular hatcheries (seed farms) and feel that such fish do not reach marketable size within the stipulated period. This is also attributed to inbreeding.

Poor management of brood fish and Seed

Competition among fish seed producers to meet demand sometimes leads to poor management of broodfish and fish seed which may negatively affect seed quality. Substandard quality seed are frequently observed as a result of high stocking density in nurseries. Most fish hatcheries in India are concerned more about the quantity rather than the quality of fish seed and produce them without following any

selection norms. Consequently, seed suffer from high rates of mortality, poor growth and high susceptibility to diseases and parasites.

Transportation stress

During transportation, fish seed are subjected to confined environment, higher metabolic load, stress, strain and exhaustion. As a result, seed becomes susceptible to diseases and parasites.

Seed Certification

The seed demand for aquaculture is almost exclusively met from hatcheries. To ensure the quality of seed, it is essential that production units use broodstock, breeding and husbandry practices as per scientific norms. There is a growing need to develop standard norms for hatcheries and accreditation of hatcheries based on these norms will be essential to maintain the supply of quality seed. In some of the Asian countries, the purposes of seed certification include certification of genetically improved varieties, certification of hatchery production processes, food safety and traceability. In India, National Bureau of Fish Genetic Research, Lucknow has been recognized as the nodal agency for formulating legislation on aquatic animal health certification and quarantine. Table 1 provides information on modes of fish certification is some Asian countries.

Table 1. Modes of fish seed certification in Asia

Country	System	Mode
Bangladesh	National Committee	Preparing a policy for seed certification
India	NBFGR, at Lucknow, Uttar Pradesh	Recognized nodal agency for formulating legislation on aquatic animal health certification and quarantine
China	National Certification Committee on Aquatic Wild and Bred Varieties (NCCA-WBV)	Certification of genetically improved varieties
Indonesia	Director General of Aquaculture	Certifies the hatchery management & production process, food safety and traceability
Philippines	Bureau of Fisheries and Aquatic Resources (BFAR)	Certifies and distributes improved tilapia strains
Thailand	Department of Fisheries	Guidelines and codes developed on aquaculture

A sound seed certification system for seed quality control for the crop plants (Indian Seed Act, 1966) is available, but there are no definite guidelines to ensure proper accreditation of hatcheries in fishery sector. Therefore, policy guidelines for quality seed production are urgently needed in the fisheries sector.

Seed certification process through accreditation of hatcheries

Accreditation of hatcheries to produce certified seed could be more practical approach than certification of seed batches. In other words, process certification i.e. certification of hatchery management practices is

considered a better way than the product certification alone. Testing of seed for compliance to the norms, could be part of the of hatchery accreditation procedures.

Requisites

The necessary requisites for the certification process are: Identification of fish that are cultured with hatchery bred seed; appropriate guidelines and criteria of standards for certification of seed producing centres; designated agency/authority for accreditation of hatcheries with well equipped technical manpower, diagnostic and analytical capabilities.

Role of ICAR

The ICAR institutes will play a crucial role towards developing Disease/pathogen diagnostic capabilities, guidelines for certification, start-up diagnostic and analytical facilities, technical backstopping to resolve emerging issues. The ICAR institutes will also provide consultancies to help in establishing technical expertise and infrastructure with the designated certification authorities of the Govt. of India.

General procedures for accreditation of hatchery

Procedures for hatchery accreditation include: registration of hatcheries with the designated agency for accreditation, necessary verifications and evaluation of prescribed field and production standards by the agency, evaluation at various stages of harvesting, packing and transportation, certification by the accredited hatcheries for compliance of specific norms or quality standards for production of their produce, separate accreditation for hatcheries for various types of species, hybrids and improved varieties and different and stringent norms for verification of hatcheries producing improved varieties and hybrids, printing of test certificate and sealing tags as per approved format by accredited hatcheries after grant of certificate of accreditation.

Recommendations

Technical

- Number of brood fishes used for production of seed purpose may be increased by the hatchery managers.
- It is better to stock own hatchery breeding seeds from different days of breeding rather than from a single day. It will increase the genetic variability in the hatchery stock.
- Replenishment of brood fishes periodically at least partially may be done from other sources such as rivers and genetically improved stock. Enhancement of heterozygosity in the broodfish is important.
- With proper care and knowledge on brood fish / hatchery management can improve the quality of fish seed.
- The pedigree record should be maintained to avoid the mating of close relatives. Use the same brood fishes up to a certain generation.
- Broodstock of different age groups should be bred together. This helps in reducing the chance of loss of some valuable alleles due to genetic drift.
- Crossing of different lines of fishes would increase heterozygosity. Separate lines of fish can be maintained by keeping the record of the families of different strains bred in the hatchery.

- Indian major carps should be spawned separately in the breeding pool to avoid inadvertent hybridization between these species and for purity of strains.

Policy-related

- A live gene bank for producing and supplying pure seed of IMCs and exotic carps may be established since the quality of carp seed produced in several hatcheries are reportedly not satisfactory due to continuous inbreeding.
- Fish hatchery operators should be trained on better broodfish management, hatchery management and nursery management to produce quality fish seed.
- Government or financial institutions should sponsor setting up of field laboratories for assessing and monitoring fish seed quality.
- Greater support (technical as well as financial) from government agencies is needed for sustainable fish seed production.
- Apart from the routine production of carp seed, emphasis needs to be given also to produce seed of valuable species like catfish and murrels, which command a good price in several parts of the country.
- Attempts should be made for efficient marketing and distribution of fish seed from surplus states to maximum deficit states.
- The Government of India should explore the possibility of having a uniform fish seed grading system and pricing for the entire country.

For Further Reading

- Assessment of freshwater fish seed resources for sustainable aquaculture, Edited by Melba G. Bondad-Reantaso, *FAO Technical Paper* 501, FAO, 2007.

GENETIC TOOLS FOR STOCK IMPROVEMENT IN AQUACULTURE

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Introduction

Systematic and scientific research in aquaculture was initiated in India during the late 1940s. Till then, aquaculture practices were based only on empirical methods. One of the major constraints for aquaculture was the availability of seed in both quantity and quality, particularly of the commercially important fish species such as the Indian major carps, *viz*., catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). However, success in induced breeding of these carps during mid to late 1950s through the administration of pituitary hormones under controlled conditions and the gradual development of this technique has paved the way and there after, adequate quantity of pure seed of these carps is available for large scale culture purposes. Second step in the progress of Indian aquaculture is the development of different packages of suitable and effective culture technologies. These multispecies intensive and extensive culture technologies have demonstrated production levels in the culture sector ranging from 10-15 t/ha/yr., while the average fish production in the country was mere 0.6 t/ha/yr.

Beside these culture technologies, which are mainly based on the compatible and complementary food habits of these carps and judicious species-ratio manipulations and management practices, research to exploit the genetic potential has also been initiated with the success of induced breeding of Indian carps. Several interspecific and intergeneric hybrids have been produced and evaluated for their culturable traits. Simultaneously, cytological and biochemical genetic studies were also carried out, not only in Indian major carps but also in other commercially important species.

It was in early 1980s that research on modern genome manipulation (chromosomal engineering) has been taken up, and standard protocols have been developed for Asiatic carps to induce gynogenesis and produce inbred lines of gynogens and also polyploids (triploids/tetraploids).

Selection work in carps (Indian major carps) has been initiated for the first time from early 1990s in collaboration with the Institute of Aquaculture Research (AKVAFORSK), Norway and is being continued. Genome manipulation by gene transfer (genetic engineering) in fishes had its relatively recent beginning in India.

India possesses rich fish germplasm resources, accounting for about one-tenth of the 20,000 and odd species of fish known in the world. The Ganga network of rivers in the North, the Brahmaputra in the East, the Sutlej, the Narmada & the Tapti in the West and the Mahanadi, the Godavari, the Krishna and the Cauvery in the South are very rich sources, harbouring bulk of the important fish fauna (Jhingran, 1982).

The major carps of India which are also referred to as Gangetic carps are the most important among the commercial fish species and form the major component of the aquaculture system in the country (Jhingran, 1982; Reddy, 1999). Since the last two to two and a half decades there was a steady progress in carp farming in India due to the availability of seed of the major carps and the development of different packages of culture technologies (Chaudhuri *et al*., 1975,1978).

Apart from the already existing different aquaculture practices in the country such as extensive, intensive and semi-intensive farming systems, the availability of huge quantities of organic wastes from plants and animals gives scope for integrated fish farming.

Stock improvement through genetic means is a novel approach and highly essential in the present context. Exploitation of genetic potentials of the carps has been initiated seriously from early 1980s particularly through genome manipulations and later through selective breeding from 1990s, to add to the already developed culture technologies, for further enhancement of fish production in the country through quality improvement of stock.

Genetic Research for Aquaculture Development

Genetics have to play a greater role in aquaculture too in the coming years. Sustainability in aquaculture calls for the attention of the aquaculturists for improvement in every aspect involved in the system or enterprise, *i.e.*, right from the production of quality fish seed with high survival, better growth performance, the ability to resist diseases and unfavourable environment. All these traits can possibly be built in an organism through genetic improvement or modifications.

There are several genetic improvement methods, starting from simple hybridization to sustainable prolonged selective breeding and from modern genome manipulation techniques, to gene transfer technique, which are useful tools for improving the quality and quantity of aquaculture products as in agriculture and veterinary animals.

Hybridization

In India, some work on hybridization has been done and some useful interspecific and intergeneric hybrids have been produced among the different major carp species within and between different genera. Though almost all the hybrids exhibited intermediate traits, some interspecific hybrids like *L. rohita* X *L. calbasu* & the reciprocal hybrids and intergeneric hybrids like *L. rohita* X *C. catla*, *C. mrigala* X *C. catla* and *L. fimbriatus* X *C. catla* have shown certain useful characteristics in terms of higher quantity of meat, broader feeding spectrum etc. Some of these hybrids were recommended for culture in reservoirs based on their feeding habits (Chaudhuri, 1971; Ibrahim, 1977; Natarajan *et al*., 1976; Bhowmick *et al*., 1981; Basavaraju *et al*., 1995).

Table 1. Modes of fish seed certification in Asia

Intra-specific	Inter-specific	Inter-generic
Among the rohu of : The Ganga, The Yamuna, The Sutlej, The Gomati, The Brahmaputra & Farm Stock	*L. rohita* X *L. bata* *L. rohita* X *L. gonius* *L. rohita* X *L. calbasu* *L. rohita* X *L. fimbriatus* *L. calbasu* X *L. bata* *L. calbasu* X *L. rohita* *L. gonius* X *L. calbasu*	*L. rohita* X *C. reba* *L. rohita* X *C. catla* *L. rohita* X *C. mrigala* *L. calbasu* X *C. catla* *L. calbasu* X *C. mrigala* *L. calbasu* X *C. reba* *C. catla* X *L. fimbriatus* *C. catla* X *L. rohita* *C. catla* X *L. calbasu* *C. catla* X *C. mrigala* *C. mrigala* X *L. rohita* *C. mrigala* X *C. catla* *L. fimbriatus* X *C. catla*

Table2: INTER-GENERIC HYBRIDIZATION

Among Chinese carps	Between Indian & Chinese carps	Between Indian carps & Common carp
H. molitrix X *C. idella*	*L. rohita* X *H. molitrix*	*C. carpio* X *C. catla*
A. nobilis X *H. molitrix*	*C. catla* X *H. molitrix*	*C. carpio* X *L. rohita*
	H. molitrix X *C. catla*	*C. carpio* X *C. mrigala*
	L. rohita X *C. idella*	*L. rohita* X *C. carpio*
	C. idella X *L. rohita*	*C. mrigala* X *C. carpio*
	L. mrigala X *C. idella*	
	C. idella X *C. catla*	
	A. nobilis X *L. rohita*	
	A. nobilis X *C. catla*	

Cytogenetics

Cytogenetic studies were carried out, mostly dealing with karyomorphological studies, covering over 200 species. Beside these, some investigations on comparative karyomorphological studies were also carried out with regard to hybrids and parent species, particularly Indian and Chinese major carps in relation to hybrid viability and fertility/sterility (Manna and Khuda–Bukhsh, 1977a, b; Reddy *et al.*, 1990; Reddy, 1991; Zhang and Reddy, 1991).

Biochemical genetic studies were carried out mainly to understand the genetic pattern and closeness among Indian carps and the inheritance pattern in hybrids of these carps.

Genome Manipulations

Beside these classical approaches, modern genetic improvement methods like genome manipulations such as chromosomal engineering and genetic engineering, though still at experimental stage, appear to be promising tools in the development of modern aquaculture. Chromosomal engineering usually gives rise to gynogenesis or androgenesis and polyploidy (triploids/tetraploids). Gynogenesis and androgenesis are effective shorter routes to produce highly inbred lines for intraspecific hybridization through topcrossing to get heterosis effect and to produce monosex individuals. Polyploidy helps in producing sterile individuals. Monosex or sterile populations have several applied values in aquaculture. Genome refers to the set of chromosome complement of a given individual. Through genome / chromosome manipulation a new genetic status can be attributed to an individual by altering set (s) of chromosome. Chromosome manipulation involve addition of extra set (s) of chromosome to the existing set of chromosome, resulting in triploid or tetraploids individual or replacement with a duplicate set of chromosome from the same individual, the resultant product being either gynogens with maternal inheritance or androgens with paternal inheritance.

Gynogenesis

Gynogenesis is the process of embryonic development with solely maternal genome and without paternal genetic input. It is a specialized form of parthenogenesis wherein embryos develop after activation of egg by the genetically inactivated sperm but there is no genetic contribution from the paternal genome.

However, the resulting zygotes are haploid. Restoration of diploidy may occur spontaneously in natural gynogenesis or artificial gynogenesis can be induced through shock treatment (thermal / pressure).

Natural Gynogenesis

In some fish species of family Poecilidae i.e. *Poecilia formosa* and Cyprinidae i.e. *Carassius auratus gibelio* gynogenesis has been the method of reproduction (Gold. 1979). Natural gynogenesis has also been reported among members of Pleuronectidae family. Crosses between grass carp and silver carp also resultedin gynogenetic offsprings (Mantelman, 1973 and Reddy, 1995)

Induced Gynogenesis

Eliminating can artificially induce gynogenesis / denaturing the genetic material (DNA) of the sperm through irradiation either by UV or Gamma rays and activating the eggs with irradiated milt. Giving thermal (cold/ heat) or hydrostatic pressure shock can restore diploidy. Artificial gynogenesis has been successfully induced in many species of dish including carps (Purdom, 1969, Stanley *et al*., 1975, Chourrout D, 1980, John *et al*., 1984 and 1988 and Reddy *et al*., 1993)

Types of Gynogenesis

Restoration of diploidy in a haploid gynogen egg can be achieved in two ways. In the first case it can be achieved by suppressing metaphase-II in the second meiotic division in other words by preventing the extrusion of the second polar body (Fig:). This type of gynogen induction is known as meiotic gynogenesis.

In the second case gynogenesis can be achieved by blocking the first cleavage (Fig.) and they are termed as mitotic gynogenesis.

Both meiotic and mitotic gynogenesis was successfully induced in *Catla catla, Labeo rohita, Cirrhinus mrigala* and *L calbasu*. Meiotic gynigenesis was successfully induced in Indian Major Carps for the first time in *L.rohita* and *C. catla* (John *et al*., 1984) and in Cirrhinus mrigala (John *et al*., 1988). Reddy et al., 1993 for inducing C.catla and L.rohita with the help of milt from common carp and mrigal respectively, reported the first report on successful induction of mitotic gynogenesis. The yield of mitotic gynogens as reported by Reddy *et al*., 1993 was 15-30% up to fry stage and 0.66-10% up to fingerling stage with heat shock and 3.0-4.3% up to fry and fingerling stage respectively through cold shock treatment. The average survival rate ranged from 1.13% with heat shock to 4.3% with cold shock. Success of induction of gynogenesis is species specific to type of shock treatment. In case of Rohu, yield of gynogens is better in cold shock than heat shock. However, yield of meiotic gynogens in Indian Major Carps is higher than mitotic gynogens (John *et al*., 1984 and Reddy *et al*., 1993)

Qualitatively, meiotic gynogens requires about 4-5 generations achieving complete homozygosity (Nagy *et al*., 1984). Where as same result can be achieved with one generation with mitotic gynogens, as blocking of mitotic division before first cleavage results in retention of two identical replicated mitotic products (Mair *et al*., 1986).

Top Crossing of Gynogenetic Line

Once the induction of gynogenesis is over, the gynogen population may be reared separately. Because of their high homozygocity, proper feed and aeration is required for growth and maturity. The resulting gynogenetic offspring may all develop to female where homogamety exists.

One group of gynogens may be treated with Methyltestosterone (MST) for reversal of sex from female to male. MST has to be provided along with feed to the gynogenetic larvae from the day of yolk sac absorption for varying period (2-3 weeks or more) depending on the species. This will result in production of genetic female with physiological male. This can be crossed with gynogenetic female to produce next generation offspring. The highly homozygous gynogens can be top crossed with heterozygous stock to realise heterosis effect.

Table3: Details of induced Gynogenesis in Indian Major carps.

Species	Type of gynogenesis		Shock treatment			Result
			Nature	Intensity	Duration	Diploid Gynogens
C.catla	Meiotic	Mitotic	C.S	12^0C	10 min.	Diploid Gynogens
C.catla	Meiotic	Mitotic	H.S.	39^0C	1 min.	Diploid Gynogens
L.rohita	Meiotic	Mitotic	C.S.	12^0C	10 min	Diploid Gynogens
L.rohita	Meiotic	Mitotic	H.S.	39^0C	1 min	Diploid Gynogens
C.mrigala	Meiotic	Mitotic	C.S.	12^0C	10 min	Diploid Gynogens
C.mrigala	Meiotic	Mitotic	H.S.	39^0C	1 min	Diploid Gynogens
L.calbasu	Meiotic	Mitotic	C.S.	12^0C	10 min	Diploid Gynogens
L.calbasu	Meiotic	Mitotic	H.S.	40^0 C	1 min	Diploid Gynogens

C.S : Cold shock
H.S.: Heat shock

Androgenesis

Androgenesis is a process which, results in all paternal inheritance. Like gynogenesis, androgenesis also occurs in nature and can be induced. Induction of androgenesis is difficult than gynogenesis.

Natural Androgenesis

Natural or spontaneous Androgenesis has been observed in certain hybrid-related individuals or those with remotely related individuals or those with not so compatible genome as in the cross between *C. carpio* female and grass carp male. Indian carp being highly compatible among them, no such instances were ever reported in any of the hybrid crosses.

Induced Androgenesis

Eliminating maternal genome in a similar way as is done for gynogenesis can induce Androgenesis. The process of inducing androgenesis involves the genetic inactivation of egg and its activation with normal sperm of the corresponding species. Shock treatment has to be administered to restore diploidy. But the mechanism of restoring diplody in androgenesis is quite different from that gynogenesis. The process probably involves dispermy or other mechanism.

Attempts of inducing androgenesis in Indian Major Carps have been made earlier but were unsuccessful mainly due to the difficulties in the effective irradiation of the egg. The egg consists of huge mass of yolk that prevent the proper exposure of the DNA to UV rays in the nucleus, which specially in carps is

oriented towards one side of the cytoplasm and usually facing downwards covered by cytoplasm and yolk. UV irradiation of egg may need a longer duration of exposure which may need a longer duration and that may be lethal.

Utility of Gynogens and Androgens

Gynogenesis and Androgenesis provide shorter routes and are effective methods to build homozygous inbred line in a faster way. By top crossing these inbred lines with heterozygous stocks, progeny with higher growth rates 30-40% over normal ones can be expected. Production of monosex population is also possible through gynogenesis and Androgenesis.

Polyploidy

Polyploidy is a process in which there will be addition of one or more set (s) of chromosomes to the original diploid complement. Like Gynogenesis and Androgenesis, Polyploidy also occurs in nature and can be induced. In nature, polyploidy occurs when very distantly related fish species are crossbred. For example cross between grass carp and big head carp. The hybrids of this cross are reported to be triploid. However, none of the inter-specific or inter-generic hybrid crosses among Indian carps have been reported to produce such triploids. Polyploid is induced in the same way as diploid gynogenesis (fig.3). However, unlike the latter the former is induced by subjecting the fertilized egg (by normal sperm) to the usual shock treatments Triplody can be induced by preventing the extrusion of second polar body, while tetraploidy is induced by blocking the first cleavage in the zygote (fig. 3).

Artificial Induction of Polyploidy

Reddy *et al*., 1987 made the first attempt of inducing polyploidy in Rohu, *Labeo rohita* by using colchicine. They could induce only tetraploids and mosaics. However, Reddy *et al*, 1990 successfully induced triploidy in Rohu, tetraploidy in Rohu and Catla by using thermal shock. Triploidy was induced in Rohu by administering heat shocks to the zygotes, seven minutes after fertilization at 42± 0.5 ^{0}C exposed for a duration of 1-2 minutes. However, the incidence of triploidy was only 12 %. Rohu zygotes exposed to heat shock, prior to first cleavage at 39±0.5 ^{0}C for two minutes yield 70% tetraploids and those exposed to cold shocks of 10-15 ^{0}C for 10 minutes yield only 30-55% tetraploids. In catla, heat shock to the zygote at 40 ^{0}C for two minutes prior to first cleavage yielded 30-65% tetraploids.

Zhang, 1990 induced tetraploidy in *C.mrigala* for the first time. It was reported that heat shock at 39-40^{0}C for two minutes to the embryo after 22-25 minutes of fertilization could induce tetraploidy in mrigal as well as in Rohu. However, the percentage of tetraploidy ranged from only 10-40% and 60% triploidy could induce by applying heat shock at 40 ^{0}C for two minutes after 4 minutes of fertilization.

Utility in Aquaculture Practices

Sterility is one of the great advantages in modern fish culture, as energy spent for maturation of gonadal development may possibly be diverted or utilized for increased somatic growth, especially in species like common carp, which have shorter maturity cycle. Triploid common carp have shown significantly higher growth rate than its normal diploid counter part, Reddy *et al*., 1998. Because of its sterility, overpopulation is also checked as the species has pond- breeding habit.

Sterile triploid grass carps can be safely released in open water systems to check the aquatic weeds without fear of its establishment through reproduction or its influence on the indigenous fauna.

Allopolyploidy

Allopolyploidy is a process in which there will be addition of set (s) of chromosomes to the diploid hybrid genome. Here male and female of different species are used. Allotriploidy can be achieved by preventing the extrusion of second polar body so here female genome contribution is 2n and male contribution is n. Allotetraploidy can be achieved by blocking the first cleavage in the developing hybrid zygote.

Allopolyploids may be possible to attribute some additional traits to the hybrids such as faster growth rate and disease resistance.

Genome manipulations at molecular level, leading to gene transfer technology appears to hold a great promise for the development of aquaculture. Isolation and cloning of genes of specific interest and production of transgenic individuals through the introduction of such cloned genes of preference seems to go a long way in future aquaculture programmes. It seems that transgenic fish might be the first transgenic animal that would be marketed for human consumption. Growth enhancement from 1.1 in common carp to 11.0 folds in the Pacific salmon has been reported. Trangenics of common carp, crucian carp, catfish, loach, tilapia, pike, Atlantic salmon and Pacific salmon have been produced (Hew and Fletcher, 1997

Selective Breeding

Role of selective breeding in increasing production level is well established in Agriculture and animal husbandry. Today the high yielding crops and land animals are totally depending on genetically improved domesticated breeds. This has not been true for aquaculture. Proper exploitation and utilization of genetic potential is lacking in aquaculture. Less than 5% of the total output of the aquaculture production is coming from improved breeding progamme. Aquaculture species are thus genetically much closer to their wild counter part than the land animals and plant species. During the last few years it has been well documented that high selection response can be obtained in fish as well as in shell fish for economic important traits like growth, disease resistance, flesh quality etc.

Before success of induced breeding through hypophysation in late fifties rivers are the main source for seed collection of Indian major Carps. With the introduction of induced breeding technique, hatcheries have been able to produce enough quantity of carp seed. The hatcheries in India hardly follow any genetic norms to produce carp seed. A limited number of brood fishes are used repeatedly for successive generations. As a result the quality of carp seed is showing negative effect of inbreeding i.e. slow growth rate, disease proneness etc. The potentials of genetics have already exhibited promising trends in aquaculture too. The correct breeding procedures followed through selective breeding in the case of Atlantic salmon and rainbow trout in Norway, Channel catfish in USA and Nile tilapia in Philippines are the standing examples in this regard (Gjedrem, 1997). The recent selective breeding programme of rohu (*Labeo rohita*) in India too is another example of the kind (Reddy *et al*., 2001).

Natural Selection

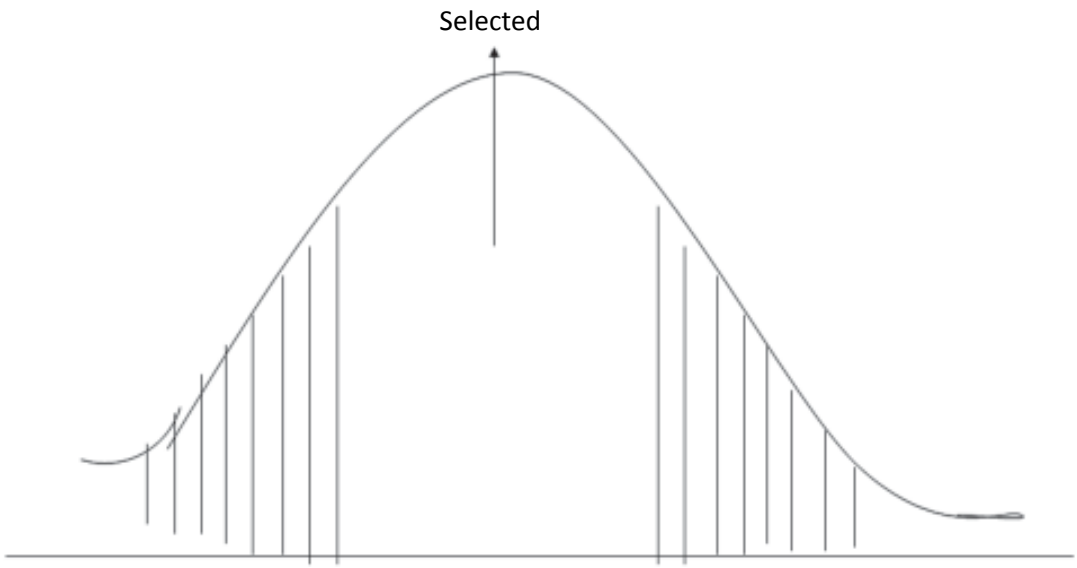
Fitness of an individual can be determined by its contribution to the next generation. This is also known as adaptive value or selective value. Natural selection selects the fitness as the character. This fitness also changes with change of environment. The animal with highest fitness in the changed environment, will produce at a higher level and have a higher survival rate than less fit animal. The effect of natural selection

over generation is to establish a population adapted to the new environmental condition. Thus adoptability is a response of a population rather than of individual. If the change in the environment condition represent large changes and take place rapidly then a population may be lost or destroyed due to non-adaptiveness of the population to the changed environment and new condition.

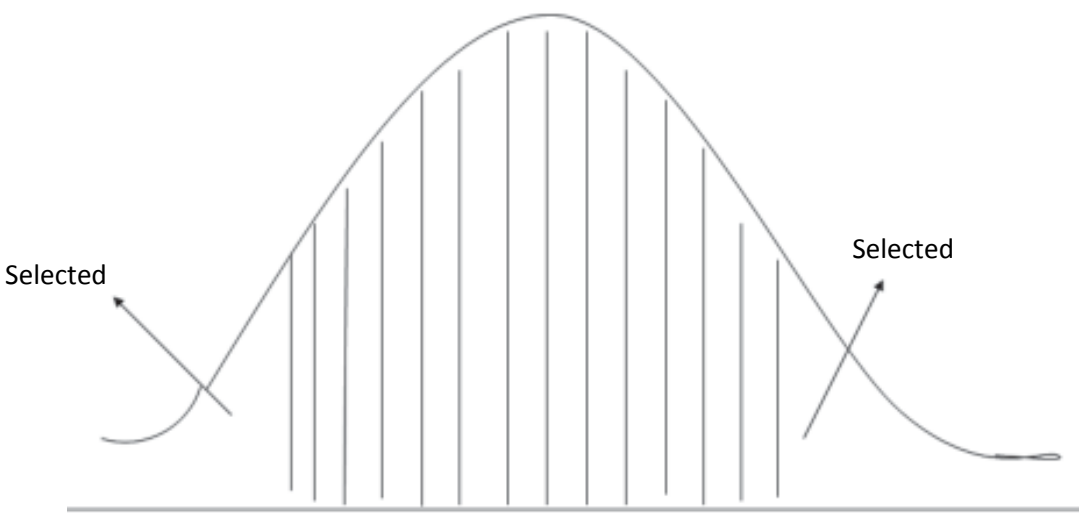
Artificial Selection

Artificial selection was created by man to improve genetic status of a population. Objectives of a selective breeding programme is to change the average performance of the targeted trait i.e. growth rate, disease resistance, better flesh quality, feed conversion efficiency etc. of the population in a favorable direction. Artificial selection can be performed in several ways.

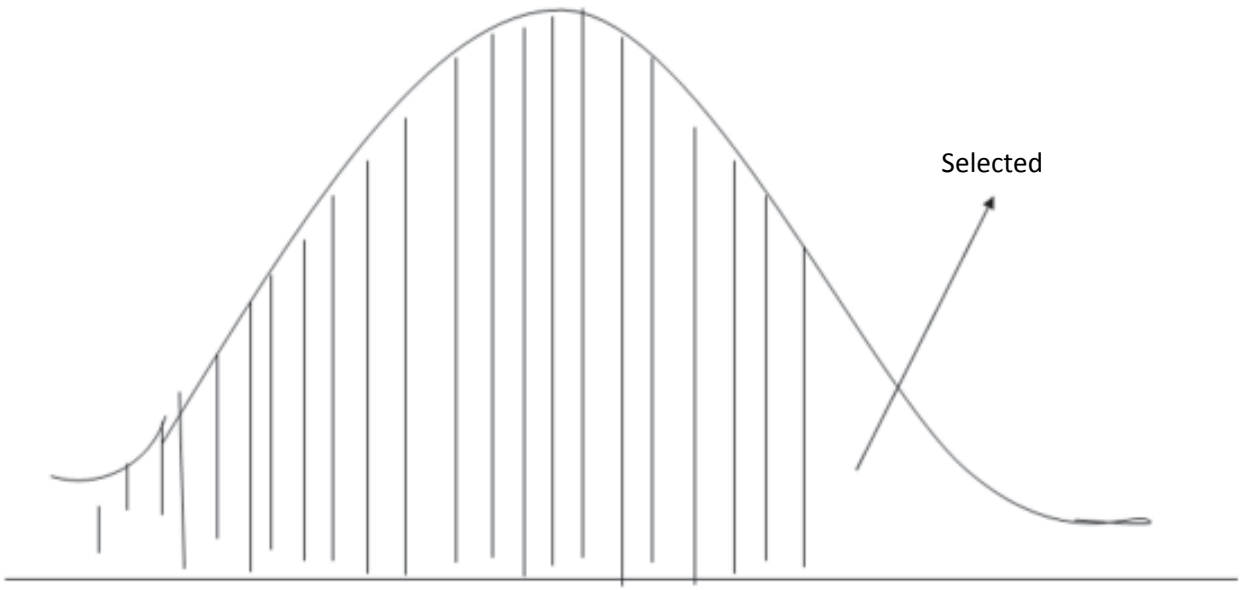
1. **Stabilizing selection** where selected phenotype is around the mean and both the extremes are discarded. Example: fat content of a fish where high and low fat content are less desirable.



2. **In the diversifying selection** both the extremes are selected through which subpopulation could emerge. It is rarely used in animal breeding.



Directional Selection is the most common type of selection form used in aquaculture sector. Selected individuals are taken from positive direction with high-ranking animals to produce better offspring every generation (Gjedrem, 2005).



Assuming no change in the in environmental condition the average phenotypic value of progenies of selected parents is increased.

Inbreeding

Inbreeding occurs due to mating of closely related individuals. Genetically inbreeding leads to homozygosity. Almost all individuals carry deleterious recessive genes, which are hidden in heterozygous state. Related individuals are likely to share common genes and probability of pairing of deleterious recessive genes gets enhanced with the increase of closeness between the parents. Due to which inbreeding depression occurs to the population with decrease growth efficiency, disease resistance and survival.

Effective Population Size

Effective population size is one of the most important concepts in the management of a population in that it gives an indication about the genetic stability of the population. It depends upon several factors such as total number of breeding individuals, sex ratio, mating system and variance of family size. The effective population size can be calculated by following formula,

$$N_e = 4N_f X N_m / N_f + N_m$$

Where N_e = Effective population size

N_f = Number of female brood fishes used for seed production

N_m = Number of male brood fishes used for seed production

Effective population size is inversely related to inbreeding

$$\triangle F = 1/2N_e$$

So $\triangle F = 1/8N_f + 1/8N_m$

Where $\triangle F$= Rate of inbreeding per generation

N_e= Effective population size

N_f = Number of female brood fishes used for seed production

N_m= Number of male brood fishes used for seed production

So to improve the genetic status of any population, hatchery managers should decrease inbreeding rate and increase effective population size.

Selective breeding plays vital role to improve genetic status of fish in a positive direction, which has already been demonstrated in case of Salmon at Norway, Tilapia at Philippines and Rohu at CIFA, India.

Objectives of Selective Breeding

Objectives of a selective breeding programme is to change the average performance of the targeted trait i.e. growth rate, disease resistance, better flesh quality, feed conversion efficiency etc. of the population in a favorable direction.

Selection Process

Selection is an age-old process in nature. Fittest organism survives and other eliminated. Selection also can be achieved artificially. In this process best individuals are selected as parents so that parents pass on their superior genes to their progeny and better progeny can be obtained. Selective breeding is based on principle of quantitative genetics, which indicated that that phenotype of an individual, which can be measured or scored, could be partitioned in to two components. One attributable to the influence of genotype i.e. the particular assemblage of genes possessed by the individual and other one attributes to the influence of environment i.e. all non-genetic components.

So $P = G + E$

Where P = Phenotype of an individual

G = Genotype

E = Environmental (Non-genetic) component

Quantitative phenotype exhibit continuous variation, the only way to study them is to analyze the variance that exists in a population. The phenotypic variance (V_P) that is observed for a quantitative trait is the sum of the genetic variance (V_G) and (V_E) and the interaction that exists between the genetic and environmental variance (V_{G+E}).

So $V_P = V_G + V_E + V_{G+E}$

Genetic variance is the component of interest in selective breeding program. V_G is further subdivided in to three component i.e. additive genetic variance (V_A), dominance genetic variance (V_D) and the epistatic genetic variance (V_I).

$V_G = V_A + V_D + V_I$

V_A, V_D and V_I differ from each other according to their mode of inheritance. Dominance genetic variance is the variance that is due to the interaction of the alleles at each locus. Because of this, V_D cannot be

inherited; it is created a new in each generation. Since it is the interaction between alleles at each locus so V_D is a function of the diploid state as alleles occur in pairs. During meiosis homologous chromosomes and allelic pairs are separated during reduction division and the chromosome complement reduced to half. So V_D is not transmitted to next generation.

Epistatic genetic variance (V_I) is due to interaction of alleles between two or more loci. Epistatic interaction occurs across loci so it is also not transmitted from parents to offspring. This also created a new in each generation.

V_A or additive genetic variance is the additive effect of genes. It is the sum of the effects of each allele that is responsible for phenotype. It does not depend on specific interaction or combination of alleles so it is not disrupted due to meiosis so additive genetic variance transmitted from parents to offspring. It is transmitted in a reliable and predictable manner. V_A is also called the variance of breeding value.

Heritability

Heritability describes genetic component that is not disrupted by meiosis. The proportion amount of phenotypic variance (V_P) that is controlled by V_A is called heritability (h^2).

$$h^2 = V_A / V_P$$

Once you know the heritability response of selection can be predicted as

$$R = S * h^2$$

Where R= response to selection,

S = selection differential (difference between offspring and parent generation)

h^2 = heritability of the trait

Selection Methods

Several selection methods are available for obtaining additive genetic improvement. The methods differ with respect to which type of relatives that provide information used for the selection decisions. The objective of all the methods is to maximize the probability of correct ranking of animals with respect to their breeding value, an estimate of each individual ability for producing high / low performing offspring. The breeding value of an individual cannot be estimated on basis of the phenotypic value of the trait (s). In fish such records are usually obtained from the individual itself (Individual selection), full and half sibs (family selection) or from all three sources of information (combined selection)

Constraints to Breeding Programs

Inbreeding Accumulation

Due to high fecundity in a selective breeding program, rapid accumulation of inbreeding is very common for fishes. When individual selection method is followed without identification of animals, it may be difficult to avoid inbreeding. By using tagged individuals with known pedigree, it is possible to avoid relative mating thus secure a slow build up of inbreeding. However, it is possible to reduce inbreeding by dividing the breeding population in to sub populations. After certain generation crossing of subpopulation can be made to avoid inbreeding. By introduction of unrelated stocks is another efficient way of reducing inbreeding.

Negative Correlated Effects

When several traits are included in the breeding goal, genetic correlation between traits is very important. Some important traits like disease resistance and growth may be negatively correlated. Then care should be taken while selecting the fishes. When negative effects are detected the breeding program must be changed and action should be taken to repair the damage already done.

Natural Calamities

Some times in breeding nucleus due to natural calamities a great damage may occur due to loss of animals. In that case second nucleus may be considered so that protection of selected animals can be made. Safeguard of selected stock should be given priority in a breeding program.

Genotype- Environment Interaction

Genotype-environment interaction plays a significant role, as it needs to develop more than one strain. However, there is possibility that strains over time may become more sensitive to environmental variations. So periodically investigation on genotype-environment interaction should be studied by testing breeding value under common farming conditions and on several private farms.

Experiences in Selective Breeding of Rohu in India

For the first time in India, selective breeding was carried out to genetically improve one of the most preferred carp species (Rohu). Under the program a range of selective breeding techniques (production of fullsib groups, individual identification by PIT tags, communal pond rearing, estimation of breeding value and ranking of individuals in different year classes) were standardized for rohu. In five generations of selection for greater harvest weight an average 17 % genetic gain per generation was obtained. On-farm trials have proven the strain's superiority and it is being disseminated to farmers.

Base Population and Mating Procedure

For the selective breeding program Rohu fry or fingerlings were obtained from five rivers of India, the Ganga, the Yamuna, the Brahmaputra, the Gomati and the Sutlej and raised at CIFA for 2 to 3 years until they were sexually mature (Reddy *et al*, 2002). A CIFA farm (local) rohu was also added to the base population. The fry or fingerlings collected were under quarantine for about two weeks in cement cisterns. After quarantine, combinations of both marked by fin clipping, M-procaine blue dye marking or fingerlings. They were stocked in communal ponds for rearing until sexual maturity. Genetic characterization of the six base population stocks indicated a wide variation within each stock. The variation within stocks was greater than that between stocks (Reddy *et al*., 2002).

The technique of breeding followed for ovulation of females and sperm collection (milting) from males. A synthetic hormone (Ovaprim was used) to obtain the gametes. To date 17-year classes of fullsib and half sib families have been produced with seven complete generation's growth evaluated. Eighth generation's offspring is being reared for further study. A nested mating design (two males nested within a female or vice versa) was used. Approximately 60 full sib families were produced in each year class.

In order to estimate the magnitude of heterosis for harvest body weight two 3 by 3 diallel crosses were made as described in Table 1. The local stock was common to both diallel crosses (Gjerde *et al,* 2002).

Table 5 Rohu stocks included for two diallele crosses

Male parent	Female parent				
	Ganga	Yamuna	Local	Brahmaputra	Sutlej
Ganga	X	X	X		
Yamuna	X	X	X		
Local	X	X	X	X	X
Brahmaputra			X	X	X
Sutlej			X	X	X

However, negative to very low heterosis effect could be achieved indicating pure breeding to be the selection method for genetic improvement in rohu.

Tagging Passive

Integrated Transponder (PIT) tags were used to identify fingerlings from different families individually. Ten to 15g fingerlings were found to be quite suitable for tagging (Das Mahapatra et al., 2001). However, smaller fishes (4-5g) are also tagged subsequently with minor modification for tagging procedure.

Test Environment for Rearing

Tagged fish were stocked in three communal ponds of 0.1ha each under monoculture and two 0.4 ha ponds under poly-culture practice. In poly-culture, rohu was stocked along with Catla and Mrigal in the ratio of 1.2: 1: 1, respectively. This practice was continued until 1997. After 1997, only monoculture was practiced, as a high correlation between the performance in mono and poly-culture was observed.

Statistical Analysis

Editing of the data and basic statistical analysis were performed using SAS (SAS Institute Inc., 1990). For each year class full sib, half sib and individual data were considered for breeding value estimation purposes. Individuals with average breeding value were chosen as controls and in every generation they were compared with the selected (higher breeding value) individuals.

Field Testing

Field trials were arranged in several parts of India, namely: 1.Rahara, West Bengal; 2.Ludhiana, Punjab; 3. Vijayawada, Andhra Pradesh; and 4. State Fisheries Department, Orissa. In 2005 and 2006 demonstrations were also arranged at farmers' ponds in different states of India. A comparison of improved rohu was made with local rohu and with the control group from the research center.

Dissemination of Improved Rohu

Initially dissemination of improved rohu was carried out in three states (Andhra Pradesh, Orissa and West Bengal). CIFA, the research center, is where the nucleus resides, and provides improved rohu seed to the multiplier units. Multiplier units are raising the brood fishes, producing seed and distributing the seed to the fish farmers. (Gjerde *et. al*, 2005)

Estimation of Genetic Parameters

Total heterosis for each of the six crosses was low or negative, whereas average heterosis was low and mostly not significantly different from zero. It was concluded that genetic improvement of rohu by crossbreeding would be futile (Gjerde *et al*., 2002).

At tagging, the heritability (h^2) for body weight was very low whereas the environmental effect common to full sib families other than additive genetics very high For sampling and final sampling the heritability was moderate (0.23 ± 0.08)

The phenotypic and genetic correlations between sampling and final sampling weights were 0.92 (± 0.01) and 0.98 (±0.01), respectively, indicating that they were virtually the same trait.

Realized Selection Response

Each generation mating average individuals created a control. The progeny of these was compared with that of selected parents in the selection line. Over seven generations the average response to selection per generation in final body weight was 17 per cent.

Field Trials

During field trials in different parts of India, the improved rohu showed significantly greater growth rate in comparison to the control and to the local rohu. A growth rate superiority of up to 75 per cent was observed by improved rohu over local rohu. In farmers' fields, the evaluation of the fifth generation of improved rohu showed 98 to 117 per cent greater growth rate than the local rohu.

Selective Breeding of Rohu for Disease Resistance *i.e.* Aeromoniasis

Apart form growth, disease resistance against *A. hydrophila* was also included in the rohu-breeding program from the year 2004.

A reliable challenge test has been developed to aeromoniasis after collecting the bacterial isolates from different regions of India and testing their pathogenicity through a series of challenge tests. Ten different pathogenic isolates of *Aeromonas hydrophila* were collected from different regions of India. One of these isolates (Ah #4) was found most suitable based on pathogenicity, and thus selected for all the further challenge studies.

In order to develop a challenge model for rohu, an experiment investigating the portal of entry of *A. hydrophila* was conducted. Fish were challenged by various routes viz. immersion, scale removal (5 scales) + immersion, abrasion (1 cm) + immersion, high stocking density (10 g fish/L with aeration)+ immersion, immunosuppression (after 3 days of cyclophosphamide 0.1mg/0.1ml ip/100 g fish)+ immersion, scale removal + high stocking + immersion, and abrasion + high stocking + immersion.

Most of the challenge methods produced nil or little mortality except the abrasion + high stocking + immersion method where necrosis, sloughing of tail (erosion), development of deep ulcers beyond the abrasion region exposing vertebral column, ventral congestion, congested operculum, secondary contamination like saprolegniasis were noted. Since none of the above methods was found to be much useful for challenge test in rohu, intraperitoneal route was then investigated. The LD_{50} dose was calculated to be 5 ´ 10^6 CFU/g fish. Thus intraperitoneal challenge method was selected for mass challenge study.

Fish from as many as 40, 47 and 51 families from 2003, 2004 and 2005 year classes, respectively, were challenged with *Aeromonas hydrophila* at 5 x 10^6 CFU/g fish along with the control families from respective year classes. All challenge tests were performed in duplicate. A wide variation in percent survival among the families was observed in all the three-year classes. The ranges of percent survival were 17.39 – 75, 33.33 – 90 and 20 – 70.37 for 2003, 2004 and 2005 year classes, respectively. Coding of dead and survival animals were done as 0 and 1, respectively. Apart from that, time intervals for mortality was also noted

during the experiments. Hourly mortality recorded during the challenge. Tests showed that most of the fish died within 24 hours of challenge. The fish were watched for 30 days for mortality. The cause of mortality was confirmed by reisolating bacteria from the kidney of 10 % dead fish.

Based on the results of a binary threshold model analysis, the heritability (± SE) for survival in the controlled challenge test was estimated to 0.11 ± 0.04, indicating low but significant additive genetic variability. These results, further substantiated by the considerable difference in mean survival between offspring produced from HR and LR breeders in the divergent selection experiment clearly suggest that significant improvements can be obtained for innate resistance to aeromoniasis in rohu carp through systematic selection. Variation in innate immune response in different families was also studied. A wide range of variation was observed in different immune parameters under different year classes.

During the year 2006, offspring were produced from susceptible and resistant families. From each group 20 brood fishes (10 males and 10 females) taken, and spawn was produced. One-generation selection has been completed and two extreme lines (resistant and susceptible) were produced. The offspring of both the lines were challenged and the realized response to selection was found to be 31.1%. Correlation among growth and survival against aeromoniasis was observed to be positively correlated in 2009-year class families.

Guidelines/ Tips to the Hatchery Managers

Main aim should be to increase effective population number and reduction of inbreeding to improve the quality of carp seed.

- Maintenance of record of the hatchery stocks
- Give importance to own brooder raising program of the hatchery
- Seed from different days of breeding may be taken for own stocking rather than from same day spawn for own brooder rising.
- Maintain 50:50 sex ratio and use the same ratio in breeding
- Replenishment of brood stock from other sources and crossing may be done. Net- working of hatcheries can be made and exchange of fish among hatcheries may be done and cross breeding of different hatchery stock will improve the quality.
- Avoid same yearclass or parent offspring mating
- Use breeder 3-5 years of age for female and 2-5 years for male
- Repeated use of same breeder should be avoided.
- Fin clipping can be done to mark different year classes or groups
- Cohort breeding procedure to improve the quality of carp seed
- Cryopreserved milt may be used to reduce space for male brooder raising
- Water, Feed and disease management

Conclusion

Sustainability is the slogan in the present time in any venture, with no exception of aquaculture. An assured way to sustainability in aquaculture is the systematic exploitation of genetic resources of the economically important species of fish & shellfish. Exploitation of genetic resources should include identification of different populations within the species, if any, conservation and exploitation of the potentials of each species in question right from the production of quality seed by following correct breeding procedures, with high survival and better growth performance, the ability to resist disease attacks and unfavourable environmental conditions. All these traits can possibly be built in an organism by genetic improvement methods.

Genetics, thus from the classical selection methods to the modern genetic engineering techniques, have a much greater role to play in stock improvement and development of aquaculture in the coming years to obtain sustainable yields.

USE OF PORTABLE FRP HATCHERY BY APPL IN TEA GARDEN AREAS IN ASSAM

Amalgamated Plantations Pvt Ltd (A Tata Enterprise)
Guwahati,Assam

We, at the Amalgamated Plantations Pvt Ltd (A Tata Enterprise) have developed low lying areas inside the Tea Garden areas for doing aquaculture in the State of Assam. Since 2007-08 vigorous experiments have been conducted at various locations on grow ability of fish in highly acidic soil and different agro-climatic conditions. With a determined effort to stay focused in this sector, APPL had already developed 150 ha. of ponds in 15 tea gardens in 8 districts of Assam. APPL's foray into developing a localized sustainable aquaculture model was assisted by CIFA with lot of technical knowledge base support and guidance since 2007-08.

One of the major constraints faced by APPL in this sector was the availability of good quality fish seed at the right time and in right quantity. So to improve the productivity levels and build sustainability, the Company has started to set up its own hatcheries. One concrete hatchery was set up at Hathikuli T.E in 2008. APPL's ponds are located in remote locations and getting the fry/fingerlings to these locations posed lot of logistical challenge. To avoid the risk it was conceptualized in 2010 to use the portable FRP hatchery developed by CIFA, Bhubaneswar. Initially two units were set up at two locations *viz.* Nonoi T.E. and Powai T.E in the Nagaon and Tinsukia districts respectively, but we had some doubts over its results in our condition both in terms of its operational economics and production efficiency. But it gave us convincing results in both the ways. Observing its efficiency; in the current year *i.e.*2011 we have procured five more units and installed at different tea gardens *viz*. Nonoi T.E., Nahorani T.E., Namroop T.E., Chubwa T.E. and Powai T.E. in the districts namely Nagaon, Sonitpur, Dibrugarh, and Tinsukia respectively all in the state of Assam. The main deliverables of these hatcheries will be to produce good quality fish seed for own use as well as for commercial sales.

It convinces us by the following advantages.

- Portable in nature. We can change the locations as per our requirement with minimum transportation cost.
- Easy to install and less space requirement.
- Very easy to operate. Can have full attention and control over each point and steps of operation with minimum time like cleaning, etc.
- Economic in terms of labour, fuel and water requirements.
- Gives good results in breeding.

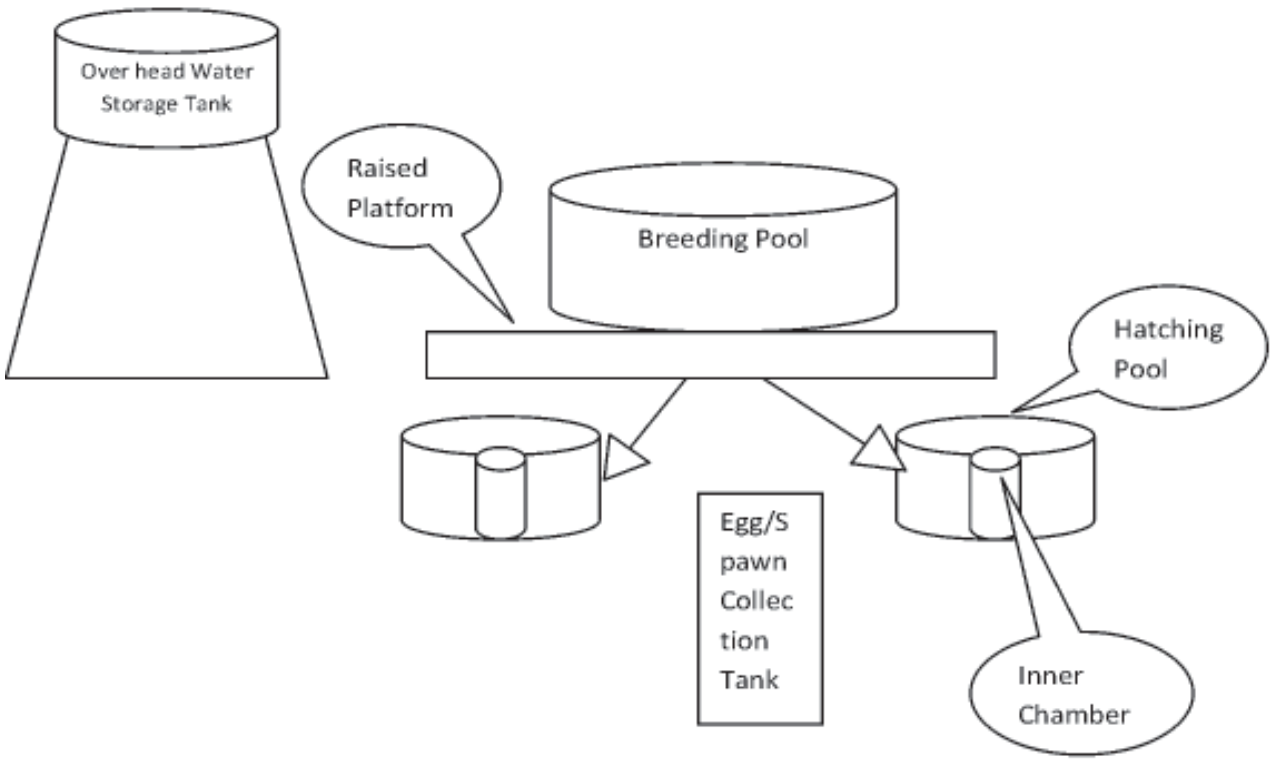
From the farmers level, this structure will be very beneficial particularly to the rural farmers of remote areas of the North East Region, where they can have the facility to breed fishes as per their requirement at relatively low cost.

Seeing the potential advantages associated with this hatchery in our farms; local farmers have started taking lot of interest. Even the College of Fisheries, AAU, Raha , Nagaon have been conducting exposure

trips for the BFSc students to have a first hand experience on its operational aspects. So it has become an area of academic interest also.

However, from our practical experience we feel that there is an opportunity for improvement. If the egg collection system is modified in such a way that the eggs automatically go to the hatching pool from the breeding pool (as shown in the diagram below), this will help to minimize the stress to the eggs during collection and will also save labour and time.

Finally we thank CIFA team for developing such a wonderful hatchery. It is really a gift to the aquaculture industry of the Nation.



PORTABLE CARP HATCHERY FOR WATERSHED PROJECTS: EXPERIENCES FROM WESTERN ORISSA RURAL LIVELIHOODS PROJECT (WORLP)

Niranjan Sahu and G B Reddy
Orissa Watershed Development Mission, Bhubaneswar

Introduction

WORLP is a Government of Orissa (GoO) initiative managed by the Orissa Watershed Development Mission (OWDM) funded by the Department for International Development – India (DFID-I), UK. It is implemented in 290 micro-watersheds of 4 four western Odidha districts namely Bolangir, Nuapada, Kalahandi and Bargarh over a 10 year period (2000-2010).

The Project follows a Sustainable Rural Livelihoods Approach in a watershed platform. Watershed plus is an additional component under WORLP to strengthen and improve the livelihoods asset base of the poorest. Under the Watershed component various interventions viz. Soil and Moisture Conservation measures, Land Development, Plantation activities etc are undertaken to improve the soil and moisture regime. Various livelihoods interventions include Cropping Systems Strategy, Pisciculture, Livestock, Development of Commons, NTFP and promoting various Non-Land Based Income generating Activities. Emphasis is also given to improve the 'Quality of Life' through improved sanitation, health interventions, providing food security, addressing the issues of migration etc.

The purpose of WORLP is to develop more effective approaches to sustainable rural livelihoods which could be adopted by government agencies and other stakeholders in KBK districts and elsewhere and for promoting these approaches in 4 project districts in replicable ways by 2010. Different strategies were developed based on the needs of the community which emerged during the participatory planning process of watershed projects to contribute towards achieving the project purpose.

A study was conducted by the project to understand the issues, problems and gap in promoting Aquaculture. The study revealed that there is substantial potential for aquaculture in Western Orissa to contribute towards improved livelihoods for resource poor and disadvantaged people. It is a highly suitable activity for SHGs and lucrative income generating activity; it helps food security and improves diets, especially children and mothers.

Accordingly, strategy for aquaculture development was designed with the following programme objectives,

- Enhance diversity of livelihood options in watersheds through aquaculture.
- Support income generation and food security through aquaculture for poor.
- Contribute to doubling inland fish production (the vision of Orissa Fisheries policy).
- Support and increase seed production capacity at PIA level by establishing new FRP hatchery
- Develop nursing networks of SHGs associated with each hatchery and increase fingerling supply availability at village level.

The Key Aquaculture Strategies

- Enhance productivity by increasing area under improved aquaculture practices
- Boost up and ensure supply of quality fingerling to SHG dwellers involved in aquaculture activities
- Capacitate primary as well as secondary stakeholders through training and exposure
- Strengthen management and planning process

The Partnership Process

The project identified aquaculture sub sector as most under utilized and one of the important livelihoods options for many poor families in Western Orissa. It has been observed that the problem is access to information and technology. WORLP found out the way forward through building partnership with agencies like Central institute for Freshwater Aquaculture (CIFA), Directorate of Fisheries (DoF), Support to Regional Aquatic Resource Management (STREAM) etc.

CIFA based in Bhubaneswar has developed low cost technologies suitable for poor and marginal communities. Scientists from CIFA are always keen to test the technology in remote parts of Orissa for its replication and wide adoptability.

Directorate of Fisheries - Orissa working extensively to strengthen cultural practices on fish farming at community level. They formulate policies and practices for promotion of aquaculture in the state. They have also a wide network of field functionaries with technical know how on fishery promotion.

STREAM is affiliated to FAO and is promoting pro poor aquaculture policies & practices in south & south-east Asian countries. The organization has technical expertise to identify suitable technologies for the poor and have documented some better practices in aquaculture for the poor. STREAM in particular has expertise in adopting technology to the socio-economic & institutional context of the rural areas.

WORLP identified and exploited expertise of local agencies who are working for numbers of years in the same areas and have acquired knowledge and skill to effectively monitor and replicate new technologies. Such civil society organisations are considered as local implementing partners who also invest financial, human and physical resources to sustain such effort beyond the project period.

WORLP brought together all above organization into a single platform of Orissa Watershed Development Mission (OWDM) and used expertise of all such agencies to get the best output for the benefit of the poor. The outcome of the project partnership has been increased access to information, technology & infrastructure in a sustainable manner for longer term.

Promotion of Fibre Reinforced Plastic (FRP) Hatchery

A small project fund (SPF) was created under WORLP to test innovations by implementing them through small local civil society organisations. So, the promotion of FRP hatchery came in the ambit of small project fund.

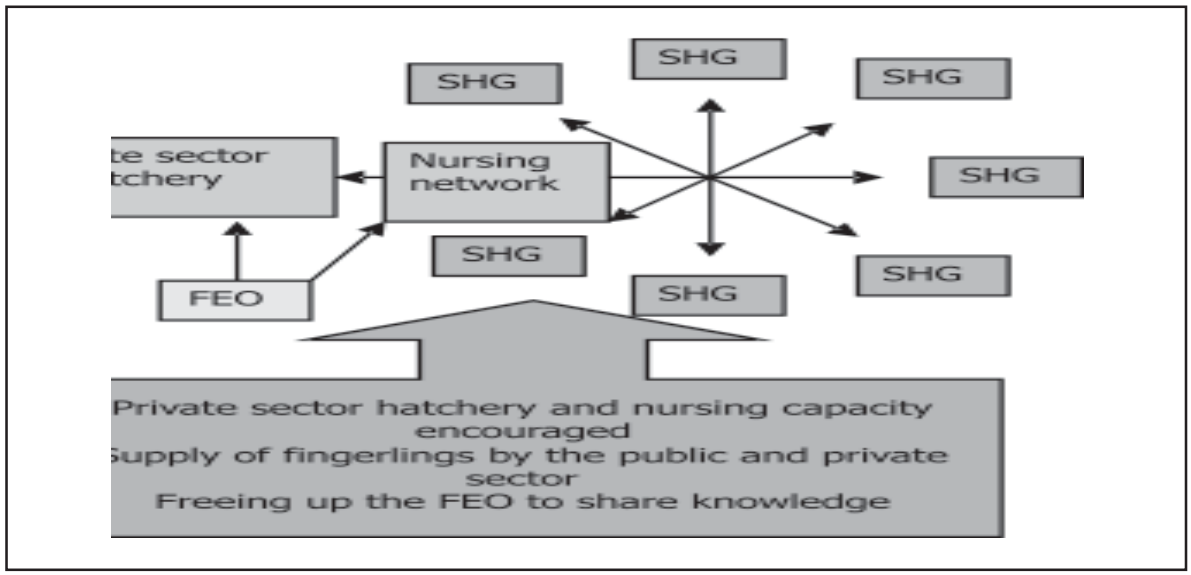
Whilst the SPF in WORLP was looking for organizations to implement its idea of producing good quality advanced fingerlings for supply to fish farmers, two civil society organisations namely Sahabhagi Vikas Abhiyan (SVA) and West Utkal Agriculture Centre (WUAC) were chosen as the most suitable agencies. The existing infrastructure, the latent demand for fingerlings in the area, the experience of the organization with fish rearing and the interest of its key staff in promoting fish culture led to the project being established in these centres.

Two FRP hatcheries have been installed in Billenjore, Komna, Nuapda and Diptipur, Bargarh in the campuses of partener NGOs Sahabhagi Vikas Abhiyan (SVA) and West Utkal Agriculture Centre (WUAC) during 2005 and 2007 respectively.

CIFA provided technical and capacity building support in successfully establishing the FRP hatcheries in both the places.

A Nursing Network of SHGs was promoted by the NGOs working in close contact with a hatchery for raising fingerlings. SHGs taking on nursing can overcome limitations in nursery facilities, and make a rapid return on a small investment.

Supporting fingerling supply – with hatcheries and 'nursing networks' of SHGs



Outcomes/Impacts of the FRP Hatcheries so far

- Network of nursery ponds established through women self help groups
- A fish farmer co-operative registered in Diptipur for promotion of fish farming
- The farmers who had used 'advanced fingerlings' and 'yearlings' as fish seed found significant increase in fish yield in their ponds. Traditionally, the average weight of the fish at the time of harvest during February-March is around 500-600 grams. With 'advanced fingerlings' a fish farmer is able to grow fishes weighing around 1 Kg, doubling the total yield.
- A fish farmer having a two-acre pond can hope to earn around Rs. 50,000 in a season i.e. in six months by using the 'advanced fingerlings'. This is equal to the average net earning from two seasons of agriculture in 15 acres of land or from vegetable in two acres but with much lesser input of time and resources.
- The consumption of fish in the household has also increased. Earlier, people would eat fish only on particular occasions or when special guests arrived. These occasions numbered around 15-20 times in a year. Now, with fish available in their ponds people eat fish more frequently. Moreover, the quality of fish consumed now is much superior than earlier.

Lessons Learned

- Building partnerships among civil society, development and resource organisation is important to translate innovations into actions for the rural community
- Capacity of the civil society organisation is critical for sustainability of the FRP hatchery
- Securing supply of good quality and sufficient quantity of brood fish several months in advance is very critical for optimal hatchery operation.
- Having more number of smaller nursery ponds rather than a few large ones is better from management point of view.
- Catla is the most difficult among the IMC to breed.
- Breeding early in May-June will give better result than in July-August. Early spawning will allow the hatchery to start supplying fish seeds to farmers at the start of the monsoon and thus making the most of the limited availability of water.
- Access to water bodies by SHGs through long term lease has enabled poor families to participate in fish farming
- Support services have been effectively provided through the cooperative

ROLE OF FRP PORTABLE CARP HATCHERY IN AQUACULTURE DEVELOPMENT OF SOUTHERN ORISSA

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Introduction

Indian Major Carps *viz*., Catla, Rohu, Mrigal and Exotic carps (Silver carp and Grass carp) even though attain sexual maturity in the confined water, but fail to spawn in the same environments. However, all these species spawn freely in the natural flowing water systems like rivers, canals etc.

In due course of time during late fifties, induced breeding technique through hypophysation was tried through administration of crude pituitary gland extract. The first success in induced breeding of carps in India was achieved at Angul in Odisha State by the esteemed pioneers like Hiralal Choudhury and K.H. Alikhuni. Successively, synthetic hormones like Ovaprim, Ovatide and Ova-FH are developed for use in induced breeding of carps. Now, almost all commercial carp hatcheries of India are using this synthetic hormone for carp seed production.

The major constraint in the way of popularization of carp culture in India is the non-availability of required quantity and quality of seed at the appropriate time and location. Today, the quantity of seed for stocking in the farmers' pond is mostly produced from the Chinese circular hatchery, which is not self sufficient to mitigate the seed demand for carp culture. So, attempt should be made to fill the gap between demand and supply and establishment of FRP portable carp hatchery technology is a feasible option in this endeavor.

Concerned to southern region of Odisha, which constitutes 10 districts, is dominated by tribal population. The region supports a plenty of natural water resources like river, reservoirs, MIPs, ponds and tanks, etc. which can be scientifically utilized to enhance the freshwater aquaculture. Its high mountains and remote terrains discourage the infrastructure facility for producing quality seed for the expansion of aquaculture activity. To expand and spread the technology of seed production for producing more fish to support the livelihood and nutritional security, intervention like technology transfer, capacity building and infrastructure development are the need of the hour. One of the proven technologies like FRP portable carp hatchery could play a major role in changing the aquaculture scenario of the region through high quality seed production and income generation.

Portable FRP Carp Hatchery: An Overview

With the advent of the hatchery technology for commercial carp seed production, the role of Chinese circular hatchery is inevitable even though it has certain inherent problems like stationary massive cement and concrete structure with requirement of huge water for its successful operation. Hence, attempts were made to develop portable FRP carp hatchery for production of carp seed by the farmers in the rural fronts. The portable carp hatchery is designed by the scientists of ICAR-AICRP on Application of Plastics in Agriculture, CIFA centre by considering the principles of circular hatchery. Due to the untiring efforts of the scientists of CIFA, the portable FRP carp hatchery was installed first for seed production during the year 2003. Like that of the Chinese circular hatchery, the portable FRP hatchery comprises of different components like spawning pool, incubation pool, spawn collection chamber and over head tank. The

working principles of portable FRP hatchery are at par with that of Chinese circular hatchery.

The technology has been disseminated to the rural farmers to take up carp seed production. More than 125 numbers of portable FRP hatchery units has been distributed all over India. The end user of this particular hatchery includes the organizations, SC-ST farmers, self help groups, and rural youths for additional income generation.

In this context, it is noteworthy to inform that, Orissa University of Agriculture and Technology, Bhubaneswar is taking special interest in popularization and dissemination of carp seed production technology by the use of portable FRP hatchery among the rural farmers of Southern Odisha. Out of 28 Krishi Vigyan Kendra's working under OUAT, portable FRP hatchery units have been supplied and installed in six KVKs. The subject matter specialists working under these KVKs are well experienced and capable enough to take up carp seed production for the benefit of farmers. It is expected that, during the ensuing monsoon months, the need based skill oriented trainings shall be imparted at the Kendra to the rural farmers to upgrade their knowledge and skill to undertake carp seed production independently. No doubt, if implemented properly, the activity will certainly open up the avenues for income generation as well as entrepreneurship development among rural farmers of Southern Odisha for up-liftment of their socio-economic status. A proposal for constructing water harvesting structure at high altitude for drawing water for hatchery operation Government intervention

Interventions Suggested for Aquaculture Development

A very elaborative table has been put to know the important information regarding fisheries scenario of Southern Odisha. From the table, it is seen that the average productivity of the south zone is 2.38 t/ha, which includes productivity from both extensive (1.94 t/ha) and semi-intensive/ intensive (2.83 t/ha) systems. The total aquaculture production of the region is 50676.27 tonnes, which is mostly dominated by three districts namely, Ganjam, Kalahandi and Nawrangpur, at the same time, the total existing area under aquaculture is 29360.3 ha, and out of which 8916.7 ha is un-utilized. Ganjam, Kalahandi and Nuapada Districts possess the major share in area under aquaculture leaving Ganjam, Nuapada and Boudh Districts having most un-utilized water area.

With the proposal of the state government for new excavation of ponds and tanks during 2016-17, the un-utilized area will be reduced to half of the existing aquaculture area (during 2007-08). So, the newly constructed ponds and tanks coming under aquaculture practices will require more number of seeds for stocking. To fulfill the demand, the pressure will shift towards the seed production system, which will be compensated by the establishment of more number of portable FRP carp hatcheries in this region.

The hatchery could be established by selected shelf help groups (SHGs), small and marginal farmers, and un-employed rural youth by the technical guidance of scientists of CIFA, SMS of KVKs and State Fisheries officials. In hilly, remote, high terrain and disadvantageous villages of Southern Odisha, where road communication is very poor for transportation of seeds, introduction of FRP carp hatchery in suitable locations can be a viable and encouraging step in this direction. Considering the local topography and socio-economic status of the people of this region, where electricity and water supply is poor, establishment of light weight, durable and easy repairable FRP portable carp hatchery for production of carp seed is a welcome step toward the expansion of rural aquaculture.

In this regard, a proposal may be suggested to government for construction of water harvesting structures at high altitude for operation of a number of portable FRP carp hatcheries in the vicinity taking the advantage of natural slope is a welcome venture. By visualizing the above suggestions concerned to FRP carp hatchery, it can be presumed that, achieving the target for blue revolution is not far away.

District (South zone)	Aquaculture production (ponds/tanks), 2007-08			Existing Aquaculture area(ha), 2007-08				Proposed Aquaculture area(ha) during 2016-17				
	Semi-intensive/ intensive	extensive	total	Semi-intensive /intensive	extensive	Un-utilised	total	Semi-intensive/ intensive	extensive	New excavation	total	Un-utilied
Boudh	1480.10	1222.4	2702.5	473.1	266.1	1399.4	2138.6	686.0	1102.8	50.0	1838.7	699.7
Gajapati	1277.28	98.71	1375.99	520.2	169.9	567.9	1258.0	656.1	459.9	20.0	1136.0	142.0
Ganjam	15544.31	5588.77	21133.08	4505.5	3403.6	2567.9	10477.0	7228.4	2606.6	300.0	10135.0	1284.0
Kalahandi	8524.62	3264.85	11789.47	3390.8	1553.4	871.4	5815.6	4633.5	964.2	100.0	5697.8	435.7
Kandhamal	215.03	306.88	521.91	50.7	113.5	780.5	944.7	141.5	608.1	120.0	869.6	390.2
Koraput	1084.22	1715.99	2800.21	372.0	825.0	0.0	1197.0	1032.0	165.0	50.0	1247.0	0.0
Malkangiri	2569.30	1932.20	4501.50	739.7	419.8	263.3	1422.8	1075.5	281.4	600.0	1957.0	131.7
Nawrangpur	2195.80	441.05	2636.85	1487.8	352.1	23.3	1863.2	1769.5	87.9	70.0	1927.4	11.7
Nuapada	1289.28	1044.44	2333.72	454.2	782.6	1696.3	2933.1	1080.3	1428.7	80.0	2589.0	848.2
Rayagada	483.02	398.01	881.03	218.6	344.9	746.7	1310.3	494.6	629.0	70.0	1193.6	373.4
Total	**34662.96**	**16013.30**	**50676.27**	**12212.6**	**8230.9**	**8916.7**	**29360.3**	**18797.4**	**8333.6**	**1460**	**28591.1**	**4316.6**

Source: Directorate of Fisheries, Cuttack

MANAGEMENT PRACTICES FOR CARP FRY PRODUCTION

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Introduction

Availability of seed of desired species and size at appropriate time is one of the most important aspects for the success of fish culture. In carp culture, fingerlings of about 10 cm (Hd 10 g) are considered as the appropriate size for stocking in grow-out ponds. Seed of such size are obtained through two phase rearing, i.e. rearing spawn to fry in nursery and fry to fingerling in rearing ponds. Due to the tiny size and delicate nature of the spawn, nursery phase warrants skilful management to maximise the seed survival. Ponds of smaller size are generally preferred for seed nursery due to easiness of management. Though low survival in nursery has been a perpetual problem, R&D over the years has led to development of several standardised simple packages of practices making use of the resources available with the farmers.

Seed rearing in small and marginal ponds offers greater scope for their effective utilisation and ensures higher return within a short period. The seasonal ponds, which often remain unutilisedalso form important resource for such seed rearing activity. Fry rearing is a short-term activity of only 15-20 days and requires lower water depth of about 1 m. Small earthen ponds of 0.02-0.10 ha are used for small-scale fry production, while areas up to 0.5 ha are preferred for large-scale commercial production. Use of concrete nursery tanks has also been advocated in recent years for high density seed rearing and for raising 4-5 crops in the same season.

Pre-Stocking Pond Preparation

The tender carp spawn are susceptible to the environmental condition and food availability. Thus, ensuring congenial condition and adequate natural fish food organisms prior to their release in nursery pond forms important aspects for higher spawn survival. Such requirements are accomplished through a series of preparation measures. While seasonal ponds can be used effectively with minimum preparatory measures, perennial ponds require specific steps prior to seed stocking. Removal of terrestrial grasses, if any, followed by ploughing, liming, filling of water, fertilisation and control of aquatic insects in that order are some common steps involved for preparation of seasonal ponds. Similarly, the perennial ponds require steps like removal of aquatic vegetation and control of predatory and weed-fishes prior to liming, fertilisation and aquatic insect control. Some of the common methods followed for each of these preparatory phases are discussed.

Aquatic Weed Control

Poorly managed ponds often are infested with luxuriant growth of floating, submerged, emergent and marginal weeds. Such infestation causes several problems:

- restricts plankton production
- limits the living space for fish
- upsets the equilibrium of physico-chemical qualities of water
- causes imbalance in dissolved oxygen budget
- increases siltation
- provides shelter to predatory and weed fishes
- harbours aquatic insects and obstructs netting operations

Common aquatic weeds

Eichhornea
Salvenia
Pistia
Spirodella
Ipomea
Trapa
Hydrilla
Nechamandra
Potamogeton
Nymphoides
Sagittaria
Valisneria

Control of aquatic weeds

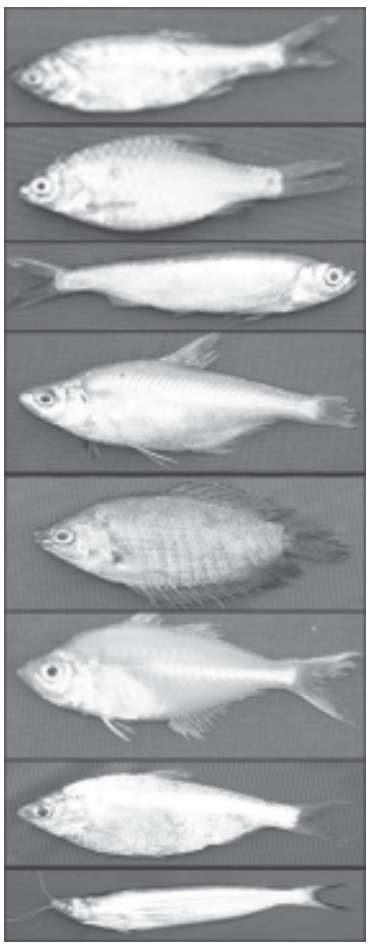
Physical	Chemical	Biological
•Manual (Sickle, Hoe) •Winch •Conoe-weeder •Mechanical weeder •Polythene shading •Turbidity	•Anhydrous ammonia @ 20 ppm N •Glyphosate @ 3 kg/ha •2, 4-D @ 7-10 kg/ha •Simazine/Diuron @ 0.30.5 ppm	•Plankton bloom •Floating weed •Macrophagus fish like grass carp & silver barb •Snail

Though, a wide range of manual, mechanical, chemical and biological methods are available for control of these weeds, the manual method is advocated for nursery due to easiness.

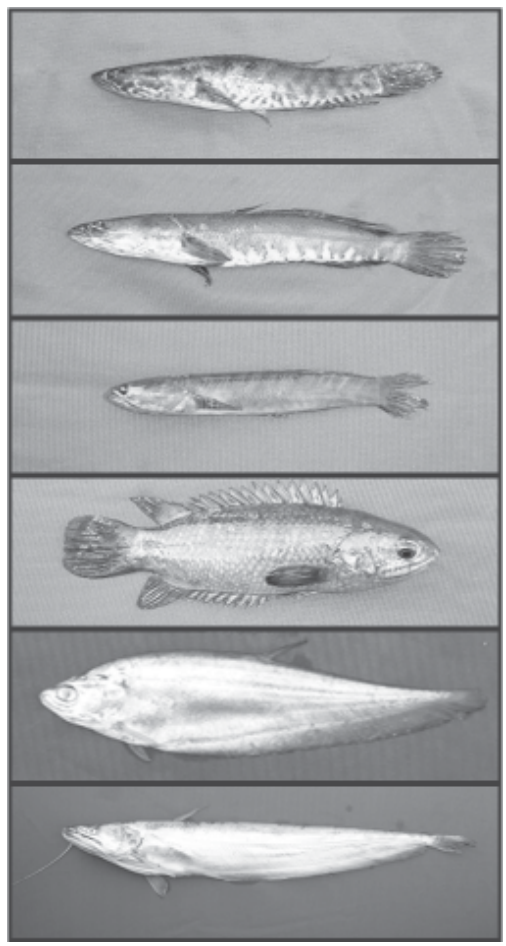
Eradication of Predatory and Weed Fishes

Presence of predatory and weed-fishes in nursery can cause extensive damage to spawn survival. These fishes normally breed prior to onset of carp spawning season and increase their population in the pond. Besides predation of spawn, these fishes and their larvae compete with the carp seed for space and oxygen, affecting their growth and survival. Thus, eradication of these species is a pre-requisite which can be achieved through dewatering and sun drying. In undrainable ponds, eradication of these unwanted fishes is done through application of piscicides.

Common predatory and weed fishes



Weedfishes
*Amblypharyngodon, Puntius,*Oxygaster, Colisa, Ambasis, Gadusia, Ailia, Esomus, Barilius



Predatory fishes
Channa, Anabas, Notopterus, Clarias, Ompok, Wallago, Silonia, Ailia, Mystus, Glossogobius, Heteropneustes

Control of Predatory and Weed-Fishes

Control methods	Dose/ha	Detoxification time
Physical		
Drying/ Hooks and line/ Repeated netting	-	-
Plant derivatives		
Mahua oil cake (saponin)	2500 kg	3 weeks
Tea seed cake (saponin)	200 kg	2 weeks
Derris/Cube root powder (rotenone)	25 kg	2 weeks
Chemical		
Bleaching powder	350 kg/ha	1 week
Urea + Bleaching powder	100 kg+175 kg after 18 h	1 week
Anhydrous ammonia	10 mg N/l	2 weeks

Soil Correction

The pond soil plays important role in the mineralisation of organic matter and supply of nutrients to the overlaying water coloumn. Slightly acidic to neutral soil with pH 6.5-7.0 is productive. Since low soil pH always associated with low productivity, ponds in acid sulphate region need attention for soil correction thus require heavy liming. The effectiveness of lime used for soil correction also depends on the type of lime. Liming is also done as a disinfecting agent in pond with a neutral soil pH and for correction of water pH or control of turbidity in subsequent period of culture operation. A brief account of the lime requirement in a pond is given as following.

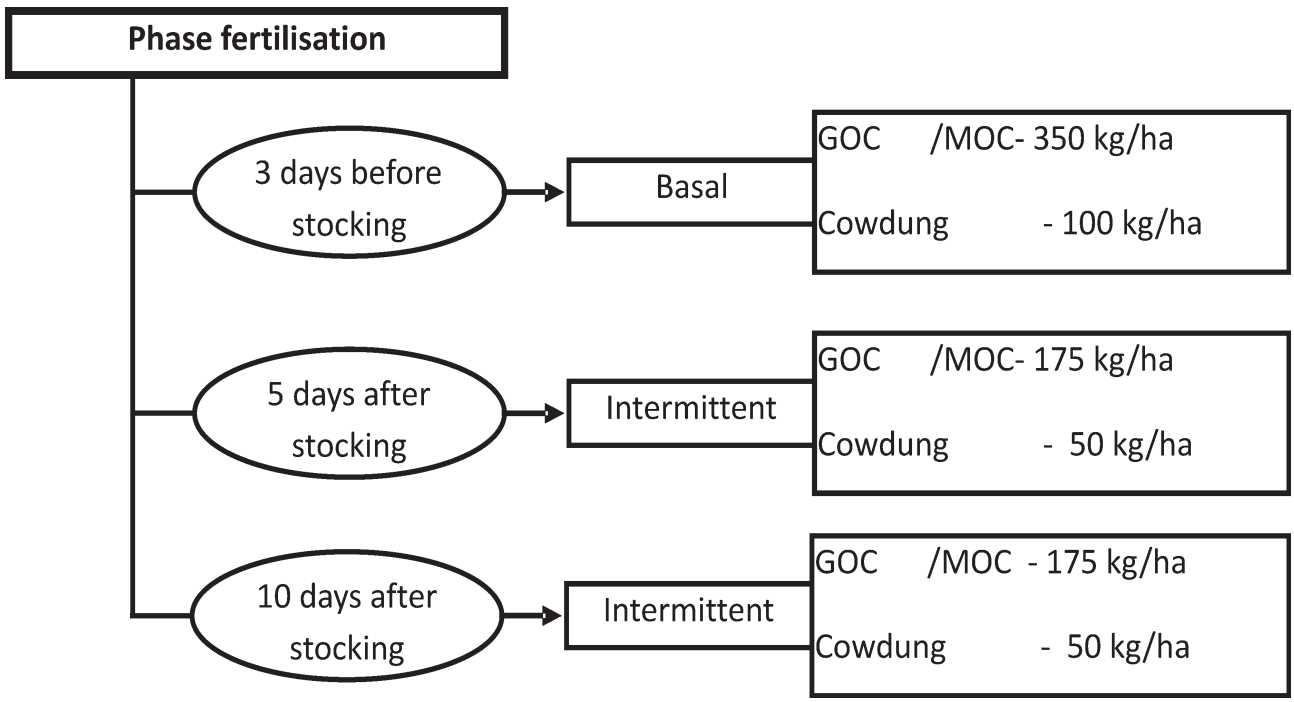
Lime requirement for soil treatment during pond preparation

Soil pH	Pure $CaCO_3$	Amount of lime substances required (t/ha)						
		Agricultural lime	Calcite	Dolomite	Hydrated lime	Hydrated granules	Quick lime	Shell powder
6.5	2.5	2.8	2.8	2.8	4.2	3.9	2.3	3.2
6.0	5.0	5.5	5.6	5.7	8.5	7.7	4.6	6.4
5.5	7.5	8.3	8.4	8.5	12.7	11.6	6.9	9.6
5.0	10.0	11.1	11.1	11.3	17.0	15.5	9.2	12.8
4.5	12.5	13.9	13.9	14.2	21.2	19.3	11.5	16.0
4.0	15.0	16.6	16.7	17.0	25.5	23.2	13.8	19.2
Efficiency percent	100	90.2	89.7	88.3	58.9	64.6	108.5	78.2

Source: Gupta *et al.* (1997)

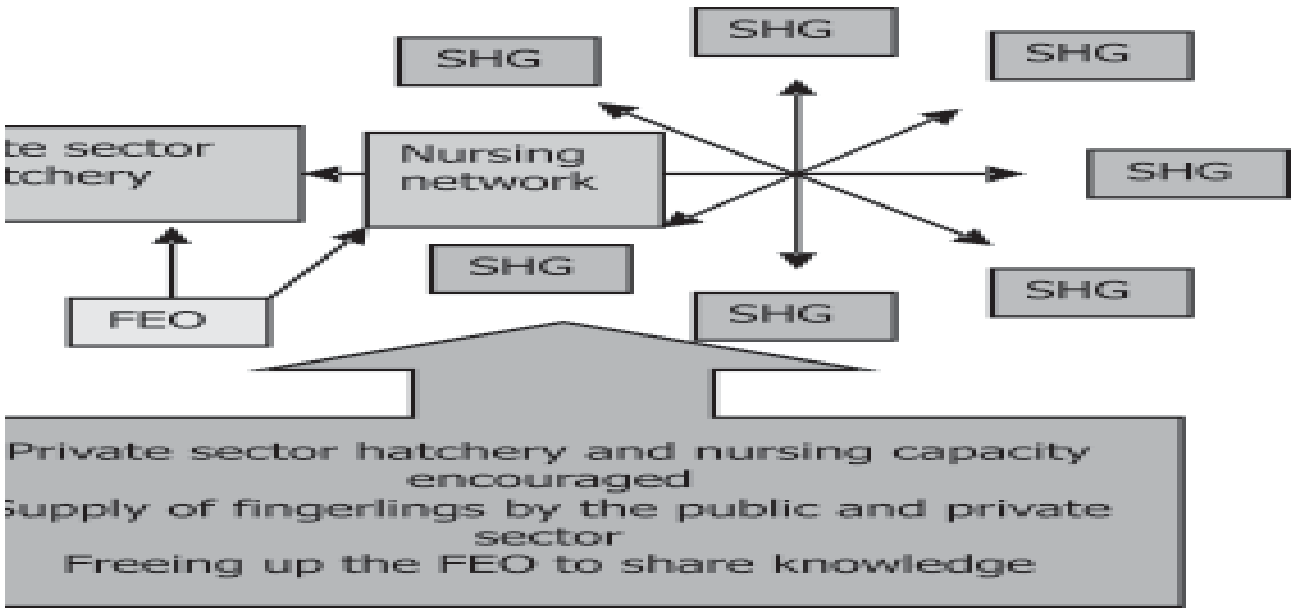
Pond Fertilization

To increase the availability of plankton in the pond, which are the preferred foods for the early stages of fishes, fertilization is carried out with both organic manures and inorganic fertilisers. The ponds are first applied with lime depending on the soil pH. Use of cowdung @5-6 tonnes/ha or poultry dropping @2-3 tonnes/ha, fortnight before stocking helps in improving the natural productivity. However, phased manuring schedule with combination of 750 kg groundnut/mustard oil cake, 200 kg cowdung, and 50 kg single super phosphate per hectare in following split doses helps in maintaining desired plankton population.



Aquatic Insect Control

Aquatic insects and their larvae often prey upon the carp larvae and sometimes kill them through pricking their body. They also compete for food with the fish seed leading to poor survival and growth. The population of these insects increases tremendously just after pond fertilization. The shorter multiplication time and flying ability of these insects often pose problem for their control.



Seed Stocking

The spawn are transferred from the hatchery and stocked in nurseries during cool hours, preferably in morning, after due acclimatization to the new environment. The optimum stocking density of spawn recommended for earthen nursery is 3-5 million/ha. However, higher densities of 10-20 million/ha can be followed for nursery rearing in cement tanks. While mono-species culture of carp is usually recommended, multi-species rearing can be taken up in case of non-availability of sufficient number of ponds.

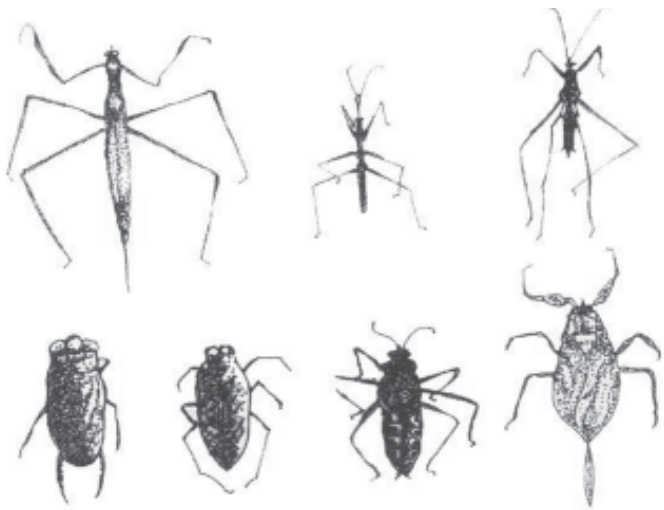
Post-stocking Management

Supplementary Feeding and Other Pond Management

The available natural food in heavily stocked nursery pond even with regular manuring may not be sufficient to meet the food requirement of the stocked spawn, thus supplementary feeding is necessary in the pond. The most commonly used supplementary feed in carp nursery has been the powdered mixture of groundnut oil cake and rice bran at 1:1 ratio by weight. Alternatively, other oil cakes and bran available locally can also be used after studying their efficiency. The dry feed mixture is normally supplied in nurseries @ 6 kg/million/day for the first 5 days and 12 kg/million/day during the subsequent days. The daily ration may be supplied once during morning hours or divided into two equal rations during morning and evening hours. Rearing period of 15-20 days is normally advocated in nurseries to get optimum survival and growth. Prolonged retention of seed in the nursery drastically reduce the survival, thus should be avoided by harvesting or thinning out the population. Fry attain the size of about 25 mm during 15 days of rearing which is the ideal size for fingerling rearing pond. Harvesting is done by repeated netting with dragnet of 1/8" mesh and the quantity harvested is measured with a perforated cup. Survival levels of 40-50% are normally achieved in well-managed ponds. During a season from June to September at least 2-3 crops of fry can be raised in earthen ponds and 4-5 crops in cements tanks.

Common aquatic insects

Water stick insect (*Ranatra)*
Water measurer (Hydrometra)
Pond skater (Gerris)
Water boatman (Corixa)
Back swimmer (Anisops)
Water cricket (Velia)
Water scorpion (Nepa)
Diving beetle (Cybister)
Dragon fly nymph (Odonata)



Economics of Fry Rearing

Sl. no.	Items	Amount (in Rupees)
I.	**Expenditure**	
A.	**Variable Cost**	
1.	Pond lease value	5,000
2.	Bleaching powder (10 ppm chloride)/other toxicants	5,000
3.	Manures and fertilizers	8,000
4.	Spawn (5 million @ Rs 5,000/million)	25,000
5.	Supplementary feed (750 kg @ Rs 10/kg)	7,500
6.	Labours for management and harvesting (100 man-days @ Rs 50/man-day)	5,000
7.	Miscellaneous expenditure	2,500
	Sub-total	**58,000**
B.	**Total Cost**	
1.	Variable cost	58,000
2.	Interest on variable cost (@ 15% per year for one month)	0.725
	Grand Total	**58,725**
II.	**Gross Income**	
	Fromsale of fry (15 lakhs fry @ Rs 7,000/ lakh fry)	**1,05,000**
III.	Net Income **(Gross Return - Total Cost)**	**46,275**

At least two crops can be raised during one monsoon season (June-August). Thus, net income from two crops in one hectare water area will be Rs 92,000.

Conclusion

Carp seed rearing is a short-term activity and can be adopted in small and marginal water bodies. The high economic return within short period also offers greater opportunity for the farmers for its large-scale commercial adoption.

PRACTICES FOR CARP FINGERLING PRODUCTION

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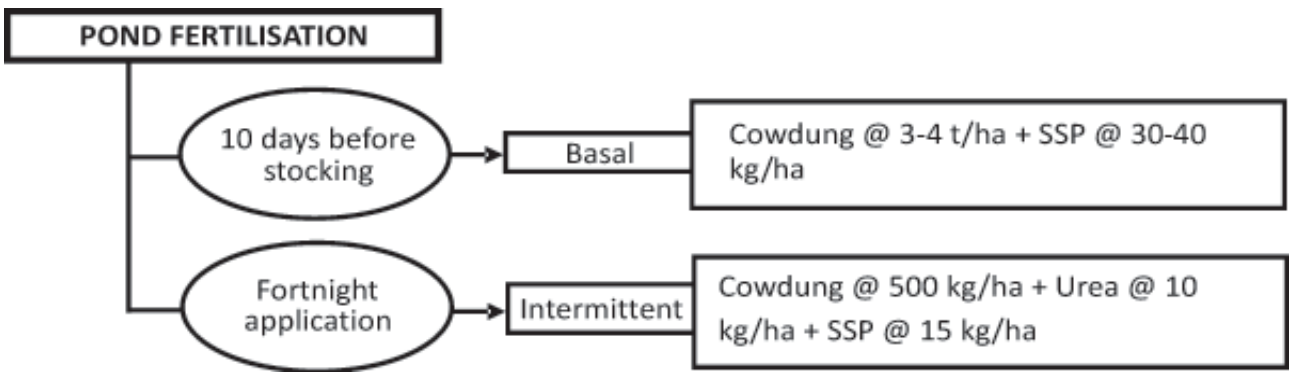
Introduction

Fingerlings are the desired size for stocking in grow-out culture ponds. Though higher size of 50-100 g often recommended for stocking for higher survival, it is always difficult to get such size in adequate quantity due to requirement of long term rearing and larger rearing space. In this context, rearing of fry up to 80-100 mm fingerlings (8-10 g) may be considered ideal for stocking. Fifteen days old fry of 20-25 mm in size are raised for two to three months to attain this size in a relatively larger rearing ponds of 0.05-0.1 ha area with 1.2 to 1.5 m water depth. As breeding season lasts for 3-4 months *viz.*, June-September normally one crop is taken from a rearing pond. However, two crops can also raised with proper planning.

Pond Preparation

Like nursery ponds, the ponds for fingerling rearing also need specialized basic management such as soil correction, clearance of aquatic weeds, soil correction, and control of predatory and weed fishes are similar to the ones discussed for the nursery pond. The aspect of aquatic insect control in this case is not required. The other aspects of management like manuring, fertilization and water quality management of the rearing ponds are discussed.



In case of use of poultry droppings, the dose may be reduced to one third to half of the amount of cattle dung. Biogas slurry at 30-45 tonnes/ha in bimonthly split doses is also found to be more effective over raw cattle dung application.

Fry Stocking

Normally fingerling-rearing practice involves culture of multiple carp species based on their feeding niche distribution. Some species of locally important medium carps can also be raised along with carps depending on their compatibility and demand. Long distance transport of fry requires proper acclimatization to the pond environment prior to their release.

Stocking aspects

- **Size:** 25 mm fry (15 days old)
- **Species:** Catla, Rohu, Mrigal, Silver carp, Grass carp, Common carp and other medium carps
- **Density:** 0.1-0.3 million/ha
  0.5-0.6 million/ha with aeration
- **SSpecies ratio**
  - Catla : Rohu : Mrigal : 1:1:1 or 1:2:2 or 3:4:3
  - Silver carp : Grass carp : Common carp : 4:3:3 or 6:5:5 or 1:1:1
  - Catla : Rohu : Mrigal : Silver carp : Grass carp : Common carp :: 1:1:1:1:1:1

Supplementary Feeding

All carps at their fry stage are planktophagic with preference for zooplankton and no species-specific management is required except providing some duckweed like Spirodela, Lemna, Wolffia, etc. when grass carp is stocked. Food requirements is met through available natural fish food and provision of supplementary feed of mixture of groundnut/mustard oil cake and rice bran/wheat bran at 1.1 ratio by weight. Other ingredients such as fish meal, soybean flour, vitamin-mineral mixture, etc. are also suggested to be incorporated for improving the feed quality. Fortnight samplings of the fry are done for biomass estimation.

Days of culture	Feed	Daily feed as % biomass	Forms of feed	Feeding frequency
First month	GOC & rice bran at 1:1 ratio	8-10	Powdered mixture/ Crumbled pellet	Morning (50%) Evening (50%)
Second & third month	GOC & rice bran at 1:1 ratio	6-8	Powdered mixture/ Crumbled pellet	Morning (50%) Evening (50%)

Water Management and Health Care

The water level of 1.2-1.5 m should always be maintained in rearing system through periodically compensating the evaporation and seepage loss. Water quality parameters and plankton concentration during rearing phase are maintained within the desirable levels (pH-7.5-8.5, dissolved oxygen >4 mg/l,

total alkalinity 80-100 mg as CaCO3/l) through periodical liming and fertilization. In high density rearing system, aeration and/or water exchange is given to keep the overall water quality parameters, particularly the dissolved oxygen content within optimum ranges. Health of fry is assessed particularly for any parasitic or microbial infections during sampling and suitable preventive/curative measures are taken accordingly. Parasitic infections like Mixoboliosis, Trichodinasis, etc. are common problems encountered in rearing system which may be treated with due consultation with aquaculture expert.

Harvesting of Fingerlings

Harvesting of fingerlings is done after 2-3 months of rearing during which they attain about 80-100 mm length. Rearing period can be further extended when bigger size fingerlings are required. Fingerlings are effectively harvested by using a closed-meshed drag net. If the fingerlings are to be transported, feeding is usually stopped one day prior to harvesting so as to improve their conditioning. Morning hours with low water temperature is the most preferred time for harvesting. Survival levels of 60-70% are usually achieved in well-managed rearing ponds.

Economics of Fingerling Rearing

Sl. No.	Items	Amount (in Rupees)
I.	**Expenditure**	
A.	**Variable Cost**	
1.	Pond lease value	10,000
2.	Bleaching powder (10 ppm chloride)/other toxicants	5,000
3.	Manures and fertilizers	3,500
4.	Fry (3 lakhs fry @ Rs7,000/lakh)	21,000
5.	Supplementary feed (5 tonnes @ Rs 7,000/tonne)	35,000
6.	Wages (100 man-days @ Rs 50/man-day for management and harvesting)	5,000
7.	Miscellaneous expenditure	2,500
	Sub-total	**82,000**
B.	**Total Cost**	
1.	Variable cost	82,000
2.	Interest on recurring expenditure 15% per year for three months	3,000
	Grand Total	**85,000**
II.	**Gross Income**	
	Fromsale of 2.1 lakh fingerlings @ 500/1000 fingerlings	**1,05,000**
III.	**Net Income** (Gross income - Total cost)	**20,000**

Transportation and Marketing

Long distance transportation of fry and fingerlings can be done in polythene bags filled with oxygen. The number of seeds to be packed in each bag would depend on the size of fry/fingerling, duration of transport, quality of water and environmental temperature. Conditioning of the seed is an important aspect that needs to be given due attention for reducing the transportation stress. Depending on the distance and mode of transportation, the polythene bags are supported by suitable tin containers, bamboo baskets, paper cartons or nylon bags to prevent damage during transportation.

Conclusion

Supply of fingerlings of desired size has been a limitation, which often force the farmers to resort for stocking of undersized seed, i.e. fry, thus resulting in low survival in pond. Limited resource availability in terms of water area, difficulty in long distance transportation of fingerlings, low profit margin compared to that of nursery rearing and longer duration are few factors responsible for such low adoption of fingerlings rearing practice. Such constraint in availability of fingerlings can be overcome through encouraging the practice of fingerling rearing among farmers and entrepreneurs.

NUTRITION AND FEEDING OF LARVAE AND BROOD CARPS

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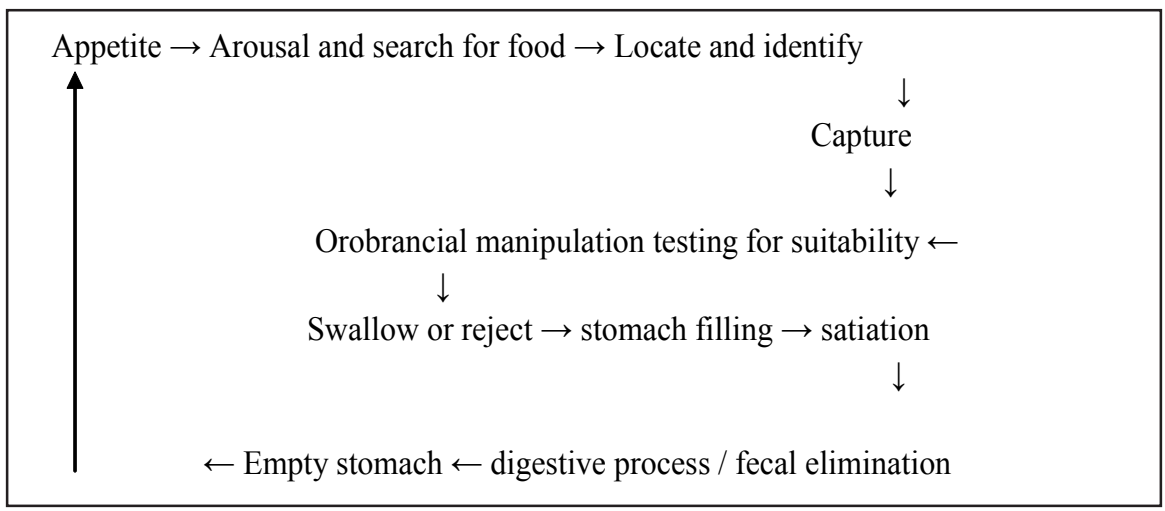
Introduction

In India carp is grown in semi-intensive polyculture system. In this culture system three Indian major carps, catla, rohu mrigal are reared in ponds. Some times grass carp silver carp and common carp are cultivated together. Natural food such as plankton, peryphyton, benthic organisms, and aquatic plants supplement a part of the nutrition and supplementary feed is fed to meet the rest. Carps eat both living and nonliving maters as their food. In the aquatic ecosystem different carp species relish these four categories of live food. In wild culture or extensive culture, fish production entirely depends upon the live food availability in that water body. In semi-intensive and intensive culture live food serve a part of the diet where as prepared feed compensate the rest. Prepared feed or artificial diets may be either complete or supplemental. Complete diets supply all the required nutrient components viz. protein, carbohydrates, fats, vitamins, and minerals for the optimal growth, health and reproduction. In contrast, supplemental (incomplete or partial or compensatory) diets are intended only to help and support the live food available in pond environment. Supplemental diets do not exactly provides all requirements of vitamins and minerals, but append the naturally available diet with extra protein, carbohydrate and lipid.

Nutrition in fish as a whole includes food, feeds, feeding system and biological phenomena of their acceptance and utilization. Raising of brood as well as nursery rearing of larvae are two essential component in carp aquaculture where nutrition plays important role.



Source: De Silva and Anderson (1995)

Appetite and Satiation

Appetite is the desire for food and satiation is the fulfillment of the desire. So one is complementary to the other.

A fish culturist should have adequate knowledge about appetite and satiation of cultivable species. Appetite is a physiological phenomenon controlled by metabolic and hormonal mechanism regulated by specific hypothalamic centers. As it is understood by the above schematic expression that the emptying of the gut is one of the factors for the food ingestion so there is directly relation of length of digestive tract with the frequency of food intake. The digestive tract of carp species is a long tubular coiled structure. The food after ingestion through mouth takes a considerable time to pass out of the anal aperture. So feeding to the brood carp once or twice a day solves the purpose. In case of larvae or juveniles the length of gut is relatively small therefore the frequency of feed application needs to be manipulated as fish grows from larvae to juveniles and to adult.

Gustatory Stimulant

Larvae of all cultivable carps feed on plankton as well as fine particle of formulated feed, at initial stages. As they grow bigger their individual food choice is varied from each other. This diversification on food choice is prominent at family level of the individuals. Although the cultivable carps belong to family cyprinedae the food diversification exists among species. For example the preference of food of grass carp seed and adult is different than that of catla seed and adult. This is because of the chemical stimulant known as gustatory stimulant. Such chemical stimulant for one species may not be same for other species. Therefore, there is a relation between the gustatory stimulant and food habit of the species. Accordingly, the food is the formulated for different stages or phases of the carp culture system.

Nutritional Requirement

In brood raising and nursery rearing system carp may get ad libitum food but of no use if the food does not satisfy their nutritional requirement. Therefore thorough knowledge on nutritional requirement is necessary to prepare a working diet for the carp brood and larvae. Protein, lipids, carbohydrates minerals and vitamins are the chief constituents of the fish feed, which are required for survival and growth of the larvae in nursery pond and to improve spawning efficiency and breeding response in brood.

Proteins

Protein is an essential component in the fish feed which is directly responsible for tissue building and growth. The dietary protein requirement of the carp broods is 30-35%, The formulated feed is superior than the traditional ones, which contains low protein (20-25 %) consisting of GOC & RB (1:1 by wt). Protein requirement of carp spawn is 35-40%. About 10 amino acids viz. Arginine, Histidine, Isoleucine, Leucine,Lysine, Methionine, and Phenylalanine Threonine, Tryptophan and Valine are considered as essential amino acids which cannot be synthesized in the body of fish. So incorporation of these amino acids through diet is essential. Requirement of Methionine and Phenyleanalyne, depends upon the amount of cysteines and Tyrosines respectively present in the diet. The level of incorporation of such amino acids varies in different species of Indian major carps and in different stages of their life such as larvae, postlarvae, juveniles and adults are given bellow.

Essential Amino Acids Requirement Of Indaian Major Carps

Amino acid	Requirement range (g / 100g protein)
Arginine	4.80-5.75
Histidine	2.13-2.45
Isoleucine	2.35-3.00
Leucine	3.70-4.63
Lysine	5.58-6.23
Methionine	2.88-3.55
Phenylalanine	3.70-4.00
Threonine	4.13-4.95
Tryptophan	0.951.13
Valine	3.50-3.75

Lipids

Lipids are the source of energy, essential fatty acids, and phospholipids. It provides a vehicle for absorption of fat-soluble sterols and vitamins. These also play a vital role in the structure of cell and cellular membrane and serve as the precursors of several hormones, in addition to their function for prostaglandin synthesis. Lipids are classified as fats, phospholipids, spingomyelins, waxes and steroids. It also provides essential fatty acids. Like essential amino acids, certain fatty acids, which play important physiological role, are not biosynthesized in the tissue of the fish. These are named as essential fatty acids and are to be incorporated from external feed sources. About 8-10 % and 4-6% of lipids is required in the carp brood and larval diets respectively.

The Indian major carps have requirement of phospholipids to the tune of 4% for enhancing larval growth and survival rates. Supplementation of n-3 and n-6 PUFA is also required for broodstock diet which is done by providing vegetable oil and fish oil of marine source and this greatly influences gonadal maturation, breeding efficiency and spawn recovery of Indian major carps.

Carbohydrate

Unlike terrestrial animals, fish require less amount of carbohydrate. The requirement carbohydrate in carp is in the range of 22-26% in different species and in different life cycle stages. The incorporation of carbohydrate in feed reduces the protein flow for energy purposes and thus reduces the cost of the feed. The excess incorporation of carbohydrate as food not only reduces the feed efficacy but also affects the digestibility. More carbohydrate supplementation causes deposition of glycogen in liver and muscle and accumulation of lipid in the viscera, which in turn results the poor gonadal development and breeding response. Especially grass carp and common carp brood perform considerably less under the influence of carbohydrate rich feed.

Energy

Energy is not a nutrient, but is the property of nutrients, which is released during metabolic oxidation of proteins, lipids and carbohydrates. Fish do have a low energy requirement because no energy expenditure is involved for maintenance of body temperature and due to its neutral buoyancy. Other explanations for low energy requirement are less muscle activity to maintain their position in aquatic ecosystem as

many fishes have swim bladders, and less energy expenditure for excretion of ammonia, which is 85% of metabolic wastes that are excreted directly through gills into surrounding water. Physical activities like swimming, escaping from predators and stress, temperature, size, growth rate, species and food are some of the factors that affect energy requirements of fish. Proteins, lipid and carbohydrates contain 5.6, 9.4 and 4.1 kcal of GE/g respectively. Carp brood requires gross energy of 4,000Kcal/kg feed

Protein-Energy Ratio

The condition where energy intake is inadequate, energy is drawn from protein sources. Excess protein is not only wasteful and uneconomical but also causes stress to fish and aquatic pollution as well. Diets containing excess energy leads to lipid accumulation resulting in fatty fish. Therefore, a balance between protein and energy is considered important in fish diet, so that energy spares protein for growth. The optimum protein and energy (P:E) ratio is known to be size-related and is higher in small fishes. Few information is available for P: E ratio in carps which are given bellow.

Dietary P:E ratio for optimum growth of carps in different species and life cycle

Species	P:E ratio (mg/kcal)
Catla fingerlings	97.3 (40% dietary protein)
	109 (45.8% dietary protein)
Rohu fry	113 (40% dietary protein)
Rohu fingerlings	95 (38% dietary protein)
Common carp	108
Grass carp	110

Minerals

Certain minerals like calcium and phosphorus are required in greater amount, as these are required for scale and bone formation. Calcium is also needed for other physiological process such as blood clotting; muscle functioning and nerve impulse transmission etc. phosphorus is involved in energy transformation, membrane permeability, genetic coding etc. Apart from these two other minerals are chlorine, magnesium, sodium, potassium, cobalt, copper, selenium, zinc, aluminum, chromium and vanadium, required in varied quantity.

Vitamins

Vitamins plays important role in body metabolism. Fish requires at least eleven water soluble vitamin such as thiamin, riboflavin, pyridoxine, niacin, pantothenic acid, inositol, folic acid, choline, biotin, ascorbic acid and cynocobalmin. It also required at least four fat soluble vitamins such as A, D, E and K. the vitamin requirement of common carp is more or less applicable for IMC diet which are as follows per kg of diet. Riboflavin-4-10 mg, pyridoxine- 4mg, pantothenic acid-25mg, biotin-1-1.5mg, inositol - 200-440mg, ascorbic acid-30-50mg, vit-A (retinol)-1000-2000 IU and Vit. E- 80-300mg

Ration size

Ration size or the feeding rate defines the amount of feed or diet available to the cultivated species. The optimum ration is that ration which gives best growth, health and breeding performance in brood and better growth and survival in case of nursery rearing. Under feeding causes poor gonadal growth, disease appearance and poor survival. Whereas, over feeding causes water quality deterioration and

uneconomical too. Ration size is different for fry, fingerling, yearling and brood carps. The fry, fingerling, yearling requires more energy for metabolism per unit weight. They have the potential to grow faster than the adult fish therefore they need higher ration than that of the grow-out brood fish. Again the fry, fingerling, and yearling have their own ration size depending upon duration of culture and marketing strategy. In general the ration size of carp nursery is 400 % of the initial body weight of the spawn for first 5 days and 800 % for subsequent days. For an example one lakh spawn weigh about 150-160g. So one million spawn need about 6 kg feed for first 5 days and 12 kg for subsequent days. The spawn are reared in the nurseries for 15-20 days to get fry about 25 mm in length. The nutritional requirement of carp spawn have been evaluated over the years as 35-40% protein , 4-6 % fat, 22-26 % carbohydrate, 0.1 % vitamin B complex, 600 mg/kg vitamin C and 200 IU vitamin -A per kg feed. Feeding rate of 5-10 % and 3-5% of the bodyweight are recommended for fingerling and juvenile rearing respectively. In brood rearing system feed at 1-2% of the biomass is recommended. The ration size also depend open the water temperature. For an example the ration size of a given crop is not same during winter and summer.

Ration type

Ration can be applied as powdered, finely granule, or pelleted forms. The pellet size and quality of the pellet such as floating, semi-floating and sinking etc. can be decided as per the requirement of the crops. Pelletization reduces the wastage (qualitative and quantitative) of food in the pond. Crumble feeding to fry or early fingerling is always considered better than powder broadcast feeding.

Weaning

In carp culture system weaning means the transformation of food habit of spawn from natural food (plankton) to the formulated external food (supplementary feed). Spawn and early fry stages of the carp are crucial as there is no parental care. These are the stages where high mortality is encountered needs special attention. Several factors operate for infant mortality in carps. The yolk reserve of the carp larvae exists for a limited period. Neither mouth nor the digestive system is well developed to accept and digest the external food particles. At the early spawn stage the digestive enzymes are not all operative. The most important factor is particle size of the food irrespective of its nature such as natural or supplementary. Spawn and early fry prefer food particle smaller than that their mouth size and smaller than that of physically capable of ingesting. Keeping this in view the pond fertilization programme and timing of base manuring should be decided to get small plankton or suitable supplementary feed is to be supplied soon after the stocking of spawn. Some information on feed particle and pellet size is given bellow.

Crop	Particle/Pellet size
Spawn	< 50-80 µm
Fry	0.5 mm dia crumbled pellet
Fingerlings (3-4g)	up to 2.0 mm dia crumbles
Growout / brood	up to 3.0 mm dia pellet

Feed formulations for Indian major carp spawn

Feed	Ingredients	Composition (%)
1	Fresh liver	50
	Bioboost forte (1robiotics supplement)	30
	Starch	13
	Cod-liver oil	5
	Mineral premix	1
	Vitamin premix	1
2	Finely powered soybean meal	10
	Finely powdered groundnut oilcake	32
	Finely powdered fish meal	20
	Finely powdered rice-bran	30
	Vitamin and mineral premix	2
	Phospholipid (as soya lecithin)	4
	Veg. Oil : fish oil (1:1)	2
3	Groundnut oilcake	40
	Roasted soybean meal	20
	Rice-bran	10
	Fish meal	20
	Vegetable oil	4
	Fish oil	3
	Vitamin+mineral premix	2
	Bioboost forte	1

Some feed formulations for fry and fingerlings of Indian major carps

Feed	Fry		Fingerlings and growers	
	Ingredients	Composition (%)	Ingredients	Composition (%)
1	Azolla powder	60.0	Rice-bran	35.0
	Soybean meal	19.0	Groundnut oilcake	25.0
	Groundnut oilcake	13.9	Roasted soybean meal	25.0
	Sesame oilcake	4.0	Fish meal	7.0
	Rice-bran	2.0	Vegetable oil	5.0
	Vitamin mineral mix	1.0	Fish oil	2.0
	Attractant (seeds of Trigonella and Murraya)	0.1	Vitamin-mineral premix	1.0
2	Groundnut oilcake	26.0	Groundnut oilcake	28.0
	Soybean meal	23.0	Soybean meal	20.0
	Rice-bran	33.0	Rice-bran	30.0
	Fish meal	16.0	Meat-cum-bone meal	20.0
	Vitamin mineral mix	2.0	Vitamin-mineral premix	2.0
3	Groundnut oilcake	28.0	Soybean meal	7.0
	Soybean meal	20.0	Groundnut oilcake	30.0
	Rice-bran	30.0	Mustard oilcake	35.0
	Meat meal	20.0	Rice-bran	26.0
	Vitamin mineral mix	2.0	Vitamin-mineral premix	2.0

4			Groundnut oilcake Soybean meal Fish meal Rice-bran Vitamin-mineral premix Vegetable oil	40.0 20.0 8.0 30.0 1.5 0.5
5			Fermented silkworm pupae Rice-bran Groundnut oilcake Groundnut oil Binder (tapioca flour, maida and rice flour in 6:3:1 ratio) Vitamin-mineral premix	6.7 19.3 62.0 5.0 5.0 2.0

Some feed formulations for Indian major carp brood fish

Feed	Ingredient	Composition (%)
1	Fish meal Groundnut oilcake Soybean oilcake Wheat-flour Rice-bran Trace elements Vitamin mixture	10.0 35.0 20.0 10.0 24.8 0.1 0.1
2	Fish meal Groundnut oilcake Roasted soybean meal Rice-bran Mineral mixture Vitamin mixture Fish oil Vegetable oil (soybean oil) Fish meal	10.0 38.0 20.0 30.0 2.0 0.2 0.3 2.7 10.0
3	Fish meal Groundnut oilcake Maize Broken rice Horsegram Blackgram Vitamin and mineral mix	25.0 25.0 10.0 10.0 10.0 10.0 <1.0

Practical diets

The traditional supplementary feed used in carp culture generally consists of rice-bran and groundnut oilcake which are compounded in 1:1 and some farmers use mustard oilcake in place of groundnut oilcake. Cake-bran mixture in conjunction with natural fish-food organisms is still a practice for brood rearing in India. This mixture is not nutritionally balanced, and is normally used to supplement protein and energy. Some of the practical diets for rearing of carp spawn, fry and brood are given bellow.

A Formulation For Grass Carp Brood:

Grass carp brood when reared with foliage feed shows very poor gonadal development and breeding performance. In contrast those fed with a formulated diet bred luxuriantly. The formulated diet contains soybean 50 kg, ground nut oil cake 25 kg, rice bran 20 kg and fish meal 5 kg in 100 kg feed. The proximate composition of the above feed was evaluated as crude protein 36.75 %; crude fat 6.80 %; crude fibre 14.25 %, total ash 13. %, nitrogen free extracts (NFE) 29. 20 % and energy was 3.252 K cal/ g.

DISEASES IN CARP SEED AND ITS MANAGEMENT

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Introduction

Traditional freshwater aquaculture in India has a long history and comprised mainly of Indian Major Carp cultivation. Since 1980's, commercial carp culture expanded slowly and steadily to different parts of the country particularly Andhra Pradesh, Punjab, Haryana, West Bengal, Orissa and Karnataka. The primary goal of commercial aquaculture is to boost production from a unit area. The Indian major carps mature in confined freshwater but fail to breed spontaneously in confinement. With the aid of pituitary extracts and synthetic hormones, the Indian Major carps can now be induced bred successfully. Circular eco-hatchery is by far the most common hatchery systems adopted all over the country.

The most important criteria for successful fish culture practice are the availability of healthy fish seeds. Availability of required quantity of seeds of the desired species at the appropriate time is also a guiding factor that leads to success of aquaculture operation. The nursery rearing involves nurturing of the 72-96 hour old hatchery-produced spawn, which has just begun to eat. Nursery rearing continues for a period of 15-20- days, during which they grow to fry of about 25-30 mm. It has been observed that in drainable/ undrainable earthen ponds, the spawns attain this desired size within a 3-week period but with a survivability of only 40-45%, even after following scientific management practices with utmost care. High losses are incurred during the early development of cyprinids. Rearing of spawns in cemented rectangular cisterns can increase the survivability rate to about 65%, but the resource-poor aqua-farmers in villages cannot afford to construct a cemented nursery chamber. They own earthen ponds of assorted sizes.

Even when the fry-staged IMC are reared for a period of 90 days to obtain the fingerlings (80-100 mm size), a maximum of 70% survivability is obtained in well-prepared earthen rearing ponds. Mortality of fish seeds occurs due to stress, infection or diseases. The etiology and the particular cause of such fish seed mortality must be properly diagnosed, so that the survivability rate increases in earthen ponds and farmers get a satisfactory production with higher profit margin. The need for adopting suitable health management measures to reduce the loss is being increasingly felt by fish seed producers.

General Cause of Diseases

In nature, there exist a delicate balance between the host, pathogen and the environment. Disease outbreak occurs when this delicate balance is upset. Diseases caused by bacteria and parasites are quite common in nursery and rearing ponds; non-infectious diseases due to pollution, algal toxins, feed contamination and water quality also occasionally lead to crop loss.

A pathogen cause a clinical disease only when it can establish in or on the host, proliferate, overcome the non-specific and specific defence barriers of the host, produce the pathogenic factors, cause cellular and tissue damage, produce significant pathological changes, impair the function of the target tissue and

cause mortality. Stress can accelerate this process. Stress is caused by environmental or other factors, which disturbs the normal function of the animal to such an extent, that the chances of survival are significantly reduced. Common husbandry practices like handling, netting, transportation and other factors like suspended solids, low oxygen, high organic matter, overcrowding, high ammonia can cause stress to IMC and other fishes in their early life stages.

The egg stage appears to be less tolerant and is particularly susceptible to small changes in environmental conditions. It has been reported that intense algal photosynthesis release large amount of oxygen into water. If this gas-supersaturated water is used for the hatchery operations, it may cause gas emboli to develop within the fertilized eggs, resulting in decreased hatching yields. It has harmful impact on fry-staged fishes also. In terms of infectious disease risk, newly developed fry are disadvantaged as compared to older stages by not having a fully mature immune system. They will not have developed any acquired immunity to specific infectious diseases. High mortalities among fry are likely since even low infection levels may be lethal to small fish. Fry of Indian major carps are particularly susceptible to gas bubble disease. The freshly consumed phytoplankton is capable of photosynthesizing within the gut of fry and can produce oxygen gas. Affected fry exhibit gas distended abdomen and unusual swimming posture with their ventral surface uppermost.

Bacterial and Viral Infections

Bacteria like *Aeromonas hydrophila, Edwardsiella tarda* and *Pseudomonas sp*. can cause infection in fry-staged fishes and fingerlings. Majority of the bacterial fish pathogens in tropical waters are ubiquitous and can cause disease as primary pathogens or as secondary opportunist under stressful condition of the host. Major clinical signs of *Pseudomonas sp.* infection include body reddening, skin lesions, protruding belly and eyes, loss of natural colour and progressive disintegration of fin and tail tissue. Same for *Aeromonas hydrophila* infection are skin lesion with blood, sluggishness, anorexia, eroded fins and ulcers on the roof of mouth.

For the external surface ulcerative type of bacterial diseases caused by *Aeromonas hydrophila* and *Pseudomonas sp*., a dip bath treatment of the infected fishes in Copper sulphate solution at 500 ppm concentration for 60 seconds has been found to very effective. Strict sanitation of hatchery equipments, elimination of carrier fish from the water supply, use of Calcium oxide at regular intervals in ponds may prevent the diseases to a considerable extent. The best preventive measures for bacterial diseases like fin rot and tail rot are the maintenance of favourable environment and good sanitation. Application of Oxytetracycline hydrochloride along with supplementary feed at the rate 75 mg per kg fish for three weeks may help to get rid of *Aeromonas* and *Pseudomonas* infections.

Few bacteria, *e.g.,* Mycobacteria and viral fish pathogens get transmitted from parents to progeny via eggs or possibly sperm that the offspring are infected before hatching. This vertical transmission is suspected in case of viral infection caused by some Rhabdoviruses, which affect cyprinids.

Fungal Infections

The fungi *Saprolegnia sp.* has been reported to cause infection in spawn and fry of Indian Major Carps.

Often it infects as external fungi on fish eggs. The fungus first establishes on dead and unfertilized eggs and gradually spread to healthy developing eggs destroying the entire batch of incubated eggs. The fungus manifests itself as white to grey cotton wool-like growth smothering the eggs. Egg washing and removal of necrotic substances such as unfertilized and damaged eggs helps to minimize fungal infection to hatcheries. The fertilized eggs before releasing into the incubation-cum-hatching chamber are given a dip treatment in Malachite Green (Zinc-free) at 2-5 ppm concentration for one hour. This duration of egg exposure to Malachite Green should not be extended.

Saprolegnia sp. infected fry-staged IMC can be given a bath treatment in formalin at concentrations 1:500 or 1:1000 for 15 mins. In order to cause disinfection of fertilized eggs, it can be treated with pure iodine at a concentration of 50-100 ppm for 10-15 mins. Acriflavin and commercially available iodophors may also be used as egg disinfectants.

Parasitic Infections

The ciliated protozoan ectoparasite *Ichthyophthirius multifilis* often infect the fry and fingerlings of Indian Major Carps. This parasite (0.03-0.4 mm) is visible as white grit-like spots on skin, gills and fins. Affected fishes show erratic swimming movements, mucus secretion occurs and they gasp for air. Certain ectocommensal ciliates (Epistylis, Vorticella and Zoothamnium) often attach to the external surface of the fish leading to fouling. They are often associated with mortalities of younger stages of cultured fish.

Monogenetic trematodes like *Dactylogyrus sp.*(gill fluke) and *Gyrodactylus sp.* (skin fluke) with their well-developed attachment haptor and feeding apparatus can cause extensive pathology and mortality in early developmental stages of fishes. Fishes become restless, gasp for air; they appear anaemic with opened operculum. Proliferation and hyperplasia of respiratory epithelial cells and skin epithelial cells occur in cases of gill fluke and skin fluke infection respectively. *Myxobolus sp.* is a Myxosporidian protozoan endoparasite reported to infect immature IMCs. Affected fishes exhibit loss of balance, typical whirling movements; malformation of jaw and vertebral column takes place.

Prolonged bath of the *Ichthyophthirius multifilis*-infected fishes in Malachite Green oxalate at a concentration of 0.15-0.20 ppm for 4-6 hours will be useful. Such a treatment must be repeated four times at intervals of 1-2 days. In order to control the existence of monogenetic trematodes, a permanent bath treatment of affected fishes in Dipterex at 0.5 ppm concentration at water temperature between 27-31° C can be very effective. A bath treatment in 5-10 ppm Potassium permanganate solution for 1-2 hours helps to get rid of these infestations. The non-toxic antibiotic Furazolidone has been found to be effective against *Myxobolus* infections. Application of the same with supplementary feed at concentrations 152-194 mg per kg fish is recommended. Formalin @ 5-15 ppm is also recommended for control of such parasitic infections in early stages.

Conclusion

For the larvae of fishes, which are much tinier than the adult, the period between first feeding and metamorphosis is a crucial one in which many larvae die. This is a serious constraint for the fish farmers. We understand that different stress factors such as inadequate physico-chemical and microbial quality

of culture water, poor nutritional status and high stocking density can cause infection by opportunistic pathogens. Acute level of pollutants and suspended solids can directly bring about abnormalities and mortalities in seed fishes. Supplementary feeds stored under improper and humid conditions can lead to deterioration of its quality. It may prove harmful for the spawn, fry and fingerlings. Algal blooms in small fishponds may contribute to crop loss. Application of Ammonium sulphate at 10 ppm concentration over pond surface can be useful in this regard. Considering some of the environmental requirements, dissolved oxygen concentration may be less than 5ppm for a period not to exceed 8 hours within a 24-hour period, but at no time shall the concentration be lower than 2 ppm. Pond waters with pH values ranging from about 6.5 to 8.5 at daybreak are most suitable for fish production. Water supporting good seed fish population must contain less than 5 ppm of free carbon dioxide. Total ammonia concentrations must only be in trace amounts. A 30-45 cm Secchi Disc reading in pond water indicates that it is in good condition and phytoplankton production is neither excessive nor scarce. Presence of such congenial conditions in nursery and rearing ponds must be monitored frequently so that the delicate early stages of IMC and other fishes may grow in a non-stressful environment.

WATER QUALITY MANAGEMENT FOR OPTIMUM PRODUCTION IN FISH PONDS

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Introduction

Physical, chemical and biological aspects of water influence the ability of fish to perform physiological functions, including growth, disease resistance, reproduction and tolerance to extreme temperatures. Aquaculture species are in more intimate contact with their own waste than terrestrial species, because the water in which they live also is, necessarily, self-contaminated. The consequences of pond management to improve water quality are site specific, and procedures that are successful at one site may fail at another. This chapter therefore presents those aspects of the general 'state-of-the-art' concerning pond water and soil quality, and its management for the purpose of improving pond water quality.

Water Quality Management

There are three basic types of water quality problems in ponds. The first involves undesirable characteristics in the water supply. The second type of problem concerns events that develop in ponds as a result of the culture system. High natural productivity is usually a result of feeding to enhance prawn production, and it causes a high abundance of phytoplankton, a low concentration of dissolved oxygen (DO), thermal and chemical stratification, high pH and excessive concentrations of metabolites such as ammonia, carbon dioxide and nitrite. The third aspect of water quality in aquaculture that may become a problem relates to the influence of production practices on the outside environment. The most important consideration probably is the possible eutrophication of natural waters caused by pond effluent discharge. It is therefore, very important to know something of the water quality parameters and their management that have influence on growth and survival of fish.

pH

pH is a measure of the hydrogen ion concentration in water and indicates how much acidic or basic the water is. Water pH affects metabolism and physiological process of fish. pH also exerts considerable influence on toxicity of ammonia and hydrogen sulphide as well as solubility of nutrients and thereby water fertility. Guidelines for pH value in fish health management are given in Table 1 below:

Table 1. Effects of different pH levels

pH	Effect
4	Acid death point
4–6	Slow growth
6–9	Best for growth
9–11	Slow growth, lethal to fish over long period of time
11	Alkaline death point

Calcium carbonate (calcite) CaCO3, Dolomite-CaMg (CO3)2, Calcium hydroxide (slaked lime)-Ca(OH) and Calcium Oxide (quick lime)-CaO are the liming materials generally used. Liming should be carried out a few weeks before addition of fertilizers and stocking of fish. Agricultural gypsum (CaSO4) is applied, to correct total hardness without affecting total alkalinity when total hardness is low and total alkalinity is high to control very high afternoon pH. It may also be applied to correct alkaline pH.

Dissolved Oxygen

Respiration by fish requires oxygen, which is acquired from the water by diffusion across the gills. The amount of oxygen required by aquatic animals is variable, and depends primarily upon size, food intake, activity, water temperature and dissolved oxygen (DO) concentration. The optimum dissolved oxygen (DO) content of pond waters should be in the range of 5 mg/l to saturation level for good growth of fish. Guidelines for dissolved oxygen level in fish health management are mentioned in following table.

Concentration	Effects
5.0 mg/l	Optimum for normal growth and reproduction in tropical waters
1.0–5.0 mg/l	May have sub–lethal effects on growth, feed conversion and tolerance to disease
0.3–0.8 mg/l	Lethal to many species if sustained for a long period

Oxygen depletion in water is rectified by the following aeration methods:

- **Manual:** In this method, water surface is splashed with bamboo sticks. This helps in dissolving atmospheric oxygen in water.
- **Mechanical:** Water is pumped out by a diesel water pump and simultaneously sprayed it again into the water body. This helps in dissolution of atmospheric oxygen.
- **Aerators:** Aerators are mechanical floating devices. Their rotating blades churn the water helping in dissolution of atmospheric oxygen in water. Depending upon the concentration of oxygen in waters, the number and placement of such aerators are determined.

Other steps taken to control the oxygen level are as follows:

- Care should be taken to feed fish in the afternoon or evening in heavily stocked pond systems as oxygen requirement in fish after feeding increases and dissolved oxygen is minimum in pond during early morning.
- Organic manure application in a water area should be done carefully as organic material consumes oxygen during decomposition. Therefore, the quality of manure to be applied without the risk of oxygen depletion can be calculated taking into consideration the availability of dissolved oxygen during the 24 hr period.
- During collapse of phytoplankton bloom, decomposition occurs and in the process oxygen requirements of micro-organisms increase. Thus, special care has to be taken during this time.
- Special care has to be taken as fish require more oxygen with increasing temperature.

Temperature

Temperature sets the pace of metabolism by controlling molecular dynamics (diffusibility, solubility, fluidity) and biochemical reaction rates. Under favorable conditions, the optimum temperature range

for many coldwater and warm water fishes are 14-18°C and 24-30°C, respectively. Water temperatures can be adjusted to optimum levels in controlled system such as hatcheries. It is difficult to adjust water temperature in large water bodies. Operation of aerator during calm and warm afternoon helps to break thermal stratification by mixing warm surface water with cool subsurface water. Planting of trees on pond banks to give shade will reduce stratification but at the same time, reduces the beneficial effects of wind mixing and restricts solar energy for photosynthesis.

Turbidity

Turbidity in cultural water is the resultant effect of several factors like suspended soil particles, planktonic organisms, humus substances produced through decomposition of organic matter, etc. Turbidity is measured by secchi disk visibility. Optimum secchi disk visibility in fish ponds is considered to be 40-60 cm. Turbidity resulting from plankton is generally desirable. Guidelines for suspended soil particles value in fish health management are:

Up to 10 000 mg/l freshwater carps, Tilapia sp. and catfishes are tolerant to this level, however, the effect will depend upon the nature of the suspended particles.

Pond waters turbid with suspended soil particles can be controlled by application of 500-1000kg/ha organic manure, 250-500 kg/ha gypsum or 25-50 kg/ha alum

Alkalinity

Total alkalinity or acid combining capacity of water is a measure of carbonate, bicarbonate and hydroxyl concentration in water and expressed as Calcium carbonate ($CaCO_3$) mg /l equivalent. Guidelines for alkalinity in fish health management are:

- 300 mg/l - create stress to fish;
- 20-300 mg/l - ideal for fish;
- < 20 mg/l - create stress to fish.

Alkalinity can be improved or raised by the application of lime of any form.

Total Hardness

Contents of alkali earth metals; mainly calcium and magnesium constitute the total hardness of a water body. As a general rule, hardness is derived from the dissolution of lime stone. If a quantity of limestone dissolves, it gives equal amounts of hardness and alkalinity. Guidelines for hardness value in fish health management are given below:

- 20 mg/l - satisfactory for pond productivity and helps protect fish against harmful effects of pH fluctuations and metal ions;
- <20 mg/l - creates stress to fish.

Measures for rectification of low hardness:

- Ponds with low hardness can be treated with lime for rectification.

Carbon Dioxide

Carbon dioxide is present in the atmosphere in very small quantity. For this reason, in spite of its high solubility in water, its concentration in most water bodies is low. It occurs in water in three closely

related forms, namely: (a) free carbon dioxide, (b) bicarbonate ion (HCO3-), and (c) carbonate ion (CO32-). The amount of each form presents, depends on the pH of water. For example, in neutral or acidic waters high concentrations of free carbon dioxide, i.e. the toxic form is frequently found. Guidelines for carbon dioxide value in fish health management are:

- 12-50 mg/l - sub-lethal effects include respiratory stress and development of kidney stones (nephrocalcinosis) in some species;
- 50-60 mg/l - lethal to many fish species with prolonged exposure.

Measures for controlling high carbon dioxide concentration include:

- Repeated aeration of water;
- Increasing the pH of water by hydrated lime can control high carbon-dioxide
- concentration. Experiments have shown that 1.0 mg/l of hydrated lime can remove 1.68 mg/l of free CO2; and
- Phytoplankton population and the organic loading in a water body should be regulated by correct stocking, feeding and fertilization.

Ammonia

Fish are very sensitive to ammonia (NH3) and the total ammonia concentration in water comprises two forms, viz:

NH3 = unionized ammonia (Free ammonia) and NH4+ = Ionized ammonia

They maintain equilibrium as per the equation: NH3 + H2O ? NH4+ + OH-

The un-ionized ammonia fraction is more toxic to fish and the amount of the total ammonia in this form depends on the pH and temperature of the water. As a general rule, the higher the pH and temperature, the higher is the percentage of the total ammonia present in the toxic un-ionized form.

Guidelines for un–ionized ammonia level in fish health management:

Concentration	Effects
0.02–0.05 mg/l	Safe concentration for many tropical fish species
0.05–0.4 mg/l	Sub–lethal effects depending on the species
0.4–2.5 mg/l	Lethal to many fish species.

There are a number of measures to maintain safe ammonia concentration in pond water. Normally at high dissolved oxygen and high carbon dioxide concentration, the toxicity of ammonia to fish is reduced. Some recommended measures to reduce the effects of ammonia are:

- Aeration will increase the dissolved oxygen concentration and decrease the increasing pH thereby reducing toxicity.
- Healthy phytoplankton populations remove ammonia from water. Care should be taken while using fresh manure with high ammonia content. The manure should be dried to allow ammonia gas to escape before application to the pond.
- Biological filters may be used to treat water for converting ammonia to nitrite and then to harmless nitrate through nitrification process.

- A high quality feed that contains no more nitrogen (crude protein) and phosphorus than actually needed by fish should be used in ponds and also over-feeding should be avoided.
- Excessive liming should be avoided as it raises pH and high pH favors ammonia toxicity to aquatic animals.
- Water exchange can reduce ammonia concentrations in fish and prawn ponds. From both economic and environmental perspectives, water exchange should only be used when necessary.
- Formalin can be used to remove ammonia from fishponds.

Nitrite

Nitrite is an intermediate product in the biological oxidation of ammonia to nitrate, a process called nitrification. Under normal conditions the nitrite concentration of fish ponds is negligible as the ponds are kept well oxygenated. In water bodies with high organic pollution and low oxygen concentration, nitrite concentration may increase.

Guidelines for nitrite-N level in fish health management:

Concentration	Effects
0.02–1.0 mg/l	Sub–lethal effects depending on the species
1.0-10.0mg/l	Lethal to many fish species

Measures to maintain safe nitrite level in water are:

- Effective removal of organic wastes, adequate aeration, and correct application of fertilizers are the methods to prevent the accumulation of nitrite to toxic levels in water.

Hydrogen Sulphide

Freshwater fishponds should be free from hydrogen sulphide (H_2S). Hydrogen sulphide is produced by chemical reduction of organic matter that accumulates and forms a thick layer of organic deposit at the bottom. Unionised hydrogen sulphide is toxic to fish, but the ions resulting from its dissociation are not very toxic.

Guidelines for hydrogen sulphide level in fish health management:

Concentration	Effects
0.01–0.5 mg/l	Lethal to fish and any detectable concentration of hydrogen sulphide in water creates stress to fish
0.01–0.5 mg/l	Prawn lose their equilibrium and create sub–lethal stress
0.1–0.2 mg/l	Prawn die instantly

Measures to rectify increase in hydrogen sulphide levels include:

- Frequent water exchange to prevent building up of hydrogen sulphide in the water body;
- When pH of water is increased by liming, the toxicity of hydrogen sulphide decreases.

Some other treatments for sustainable pond productivity

Nutrient removal

It is possible to precipitate phosphorus from pond water by applying sources of iron, aluminum or calcium ions. These ions precipitate phosphate as insoluble iron, aluminum or calcium phosphates. Alum (aluminum sulfate) and ferric chloride are commercially available sources of aluminum and iron respectively. Alum is cheaper and more widely available than ferric chloride. Gypsum (calcium sulfate) is a good source of calcium, because it is more soluble than liming materials. Treatment rates of 20-30 mg/l of alum and 100-200 mg/l of gypsum have lower phosphorus concentration in pond waters. Alum is acidic and more suitable for use in waters of 500-mg/l total alkalinity and above. Gypsum is better for use in low alkalinity waters.

Phytoplankton removal

Algicides are used to reduce the abundance of phytoplankton in intensive fish culture ponds. Copper sulfate is recommended for reducing phytoplankton abundance and the abundance of blue green algae in particular. The usual recommendation is to apply a dose to copper sulfate equal to 1/100 of the total alkalinity. The best approach to phytoplankton control is to regulate nutrient inputs by moderate stocking and feeding rates, but it may feasible to use alum or gypsum to precipitate excessive concentrations of phosphorus.

Chlorination

Hypochlorus acid and hypochlorite (free chlorine residuals) are responsible for the disinfecting power of chlorine products in pond water. But, chlorination of waters containing fish or prawn is both dangerous and unbeneficial. It is possible to disinfect bottoms of empty ponds and water in newly filled ponds but not stocked by applying chlorine products. When this is done, enough chlorine should be applied to overcome the chlorine demand and provide 1 mg/l or more of free chlorine residual. The residuals will detoxify naturally in a few days so that ponds can be stocked safely.

Water exchange

There are reasons to exchange water in specific instances, such as to reduce salinity, to flush out excessive nutrients and plankton or to reduce ammonia concentrations. However, daily water exchange usually does not improve water quality in ponds, and pumping costs are a liability. Ponds are highly efficient in assimilating carbon, nitrogen and phosphorous inputs not converted to fish or prawn flesh, but if water exchange is great, these substances are discharged from ponds before they can be assimilated. Thus, the pollution potential of aquaculture ponds increases as a function of increasing water exchange. From both economic and environmental perspectives, water exchange should only be done when necessary.

Conclusion

The best method for preventing water quality problems in aquaculture ponds is to select a site with good soils and an adequate supply of high quality water to maintain moderate levels for prawn and fish production. If this is done, liming, fertilization and aeration can prevent most water quality imbalances. However, in some instances, sedimentation basin may be needed to prevent ponds from filling in and water exchange may be required periodically. Some treatments are either ineffective or potentially hazardous to the stock. Therefore, proper pond management is the key to sustainability in aquaculture, and enhancing sustainability of pond aquaculture can improve water quality in ponds and reduce the volume and pollution potential of pond effluents. Proper procedures for pond management will improve environmental conditions, sustainability and profits.

Abstract

APPLICATION OF METAL OXIDES FOR THE REMOVAL OF ARSENIC AND CHROMIUM FROM CONTAMINATED WATER

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World Health Organization (WHO) and Environment Protection Agency (EPA) has established a level of 10 mg/L arsenic and 50mg/L of chromium in drinking water from January 2006. But in several countries like Bangladesh, India, arsenic and chromium concentration in the drinking water can be as high as 500 mg/L or more. The reduction of arsenic and chromium from such high concentrations and made it potable as per WHO prescribe limit is a very challenging task. Arsenic occurs in rocks, soil, water and air in -3, 0, +3 and +5 valence state. It is widely distributed having average concentration of 2 mg/kg. The burning of fossil fuels, refining of petroleum mining, smelting of metals like Zn, Cu, Ni, and Pb, are major anthropogenic sources for arsenic contamination in air, water and soil. Hexavalent chromium is known for its negative health and environmental impact. It causes allergic and asthmatic reactions and it is 1000 times more toxic than trivalent chromium. Exposure to hexavalent chromium causes diarrhoea, stomach and intestinal bleeding, cramps, paralysis and liver and kidney damage.

Keeping these facts we have synthesized some metal oxides to investigate the role of metal oxide nanoparticles for the removal of arsenic and chromium contaminated water. Metal oxide nanoparticles of varying sizes from 5±1.5 to 50±5 nm size were synthesized using a wet chemical route and it has been concluded that by the use of proposed metal oxides nanoparticles, arsenic and chromium concentration in the contaminated water can be reduced from 10 ppm to less than 5 ppb, which is much less than the limit set by the environmental protection agency (EPA) for drinking water.

ROLE OF KVKS IN TECHNOLOGY DISSEMINATION IN INDIA

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Introduction

The government of India is giving utmost emphasis for second green revolution to augment the food security of India. The agricultural development policy pursued in the country, particularly since the mid-sixties, is recognised and appreciated world over. The integration of agricultural research with quality education and a properly planned extension education system has been one of the fundamental foundations of this developmental strategy, which also led to revolutions in many other sectors of agriculture and allied enterprises like white revolution for milk, yellow revolution for oil seeds, blue revolution for aquaculture etc. As a part of this strategy, several programmes for transfer of technology from research station to farmers' field were launched in the country. These include National Demonstration Project (1965), Lab to Land Programme (1979), Operational Research Project (1974) and Krishi Vigyan Kendras (1974). Presently the Krishi Vigyan Kendras (Farm Science Centres) have been recognised as an effective link between agricultural research and extension system in the country.

Use of Extension Methodology for the Sustainable Development

In the most recent couple of decades, the growth of Indian agriculture is meagre. However, for sustainable development of Indian agriculture a number of extension methodologies could be adopted. The improvement of the farming systems, the enhancement of the farming technologies and the input of the research findings are the key factors in increasing the agricultural production, but they further demand effective extension methodologies that bridge the research and the farmers, thus, converting the research outputs to the production power at the farmers' level and sustaining the development of agriculture.

Institutions Engaged in Agriculture Extension

In the country about 589 KVKs, 97 ICAR research institutions, 47 agricultural universities, other central and state government agencies, NGOs and business houses are promoting agricultural development in the country.

Identification of Technology

Depending upon the available resources, topography of the area, local need of the farmers' market and other social factors are considered before operation of any extension programme on a targeted individual or group balancing the relations between the economical returns and environmental impacts. To mobilise and lead the farmers to a new technology for better production is one of the important steps in extension.

Transfer of Technologies

In India, the extension efforts, particularly transfer of technology, have largely been taken up by the state department of agriculture and other line department as a state subject. The Indian Council of Agricultural Research (ICAR) as the apex body to provide new technologies in agriculture and allied aspects has its own transfer of technology activities too.

Agriculture and rural development encompasses the all round development of people in its effective dimensions of economic, social and agricultural scenario. KVK is a grass-root level organisation that can help to fight poverty, to foster education of rural people, and to promote behaviour and technology that link high productivity with natural resource sustainability.

Sustainable agriculture is termed as the system of raising crops for human utility through utilization of resources with greater efficiency without disturbing and polluting the environment. KVK personnel should note that adoption of exploitative agriculture without proper understanding of its consequences may lead to an era of agriculture and environmental disaster in the long run rather than an era of agricultural revolution and prosperity.

Agriculture, however, must be more than economically competitive. It must also be suitable, which entails conserving natural resources, such as soil, water and biological diversity, and taking into account agriculture's social and cultural context. This complex challenge can also be overcome if traditional and new knowledge are effectively combined in new production system that are compatible with the cultural and social values of rural societies. Contributing to the development of such systems will be one of the most important tasks of KVKs.

Today, KVKs are the focal point for assessment, refinement and demonstration of front line technologies for all developmental activities related to agriculture, community and industries in rural India.

Transfer of Portable Carp Hatchery Technology - KVK Perspective

Seed is a critical input in any aquaculture activity. With the fast growth of aquaculture in the country, demand for seed is increasing day by day. In many disadvantageous, remote hilly and tribal areas, where means of transport are not sufficient, unavailability of carp seed is still a limiting factor and aquaculture is not coming in a big way. To develop freshwater aquaculture in these areas, a sustained timely supply of fish seed is the prerequisite. To meet this demand, establishment of portable FRP carp hatchery in the identified areas suitable for fish culture can play an important role in this endeavour. Vast network of KVKs spread throughout the country could be utilised for dissemination of this technology particularly in disadvantageous areas.

Cluster approach concept is an effective mean for higher rate of adoption of any technology. In this direction, KVK can select remote and disadvantageous villages where quality seed is the primary constraint to carry out carp culture. By identifying and motivating selected group of farmers on seed production, FRP hatchery complex could be initiated at their doorstep which will help in producing seed to fill the gap between demand and supply of the area. Simultaneously, a number of entrepreneurs can be developed by imparting rural youth training to them, which is one of the mandatory activity of KVKs. Demonstration plays a vital role for adoption and expansion of a proven technology. So, the KVK scientists can demonstrate the various steps viz. FRP hatchery installation, operation, seed production and different management practices through hands-on training. This will boost the expansion of rural aquaculture both horizontally and vertically. Last but not the least; interested farmers can be encouraged to avail the financial benefit from various government sponsored schemes exclusively made for the upliftment of the farmers.

Participatory Approach

Under this approach local knowledge available with fish farmers and the scientific knowledge of researchers are combined together to find suitable solution for a particular location specific problem. In

this approach, extension personal facilitate the interaction between farmers and researchers to build the capacity of farmers to improve their livelihood. Researchers present various farming systems to the farmers for evaluation locally. This Participatory Technology Development (PTD) approach has been found very effective in agriculture.

Extension Science Studies

Well-tested quality research outputs and practical farmers experience act as powerful extension methodologies before reaching the farmers. A team of the extension personnel will be able to establish the extension programmes and able to help the farmers, select appropriate technology aside from important considerations on the needs of the individual farmers, local communities, impact of the environment, etc. Up gradation of the subject matter knowledge along with extension skill of the extension personnel should be at regular basis so that they can better understand the changing trend. This will help in motivation and mobilisation of farmers.

Strengthening Extension Service

Technology transfer to rural people demands a good quality extension team, which is always available for the farmers. Extension workers with poor knowledge, lack of extension means, less access to the fresh knowledge leads to failure of the programmes. In the extension process an extension staff should be able to apply what they have learned in the fields and show to the farmers in a better way. In culture practice an extension personal should be able to make proper decisions. A good extension worker always generates congenial and a strong ground among the farmers.

Good communication is an effective means in establishing contact with the farmers. The extension people should be active in speaking their minds, fluent wording, easy to probe the problems, etc. of course it demands good communication skills. On the other hand, the extension people can not only help the farmers to find out their own problems, but also, be able to help the farmers to propose new projects in development.

INVITED TALK

ROLE OF CONDUCTING POLYMERS AS SOFT ACTUATOR AND IT'S APPLCATION IN THE FIELD OF BIOMEDICAL SCIENCE AND WATER PURIFICATION

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Abstract

The remarkable switching capability of conducting polymer materials between the conducting oxidized (doped) and the insulating reduced (undoped) state is the basis of many applications. These can have large strain (2% - 30% out of plain) that can be exploited in linear, volumetric or bending actuator and can be electrically controlled and micro fabricated. Apart from this, these required low voltage for actuation, typically < 1V, are light weight and have high strength (stress are 1000 times as great as skeletal muscle) and can operate in liquid electrolytes, including body fluids. The electrochemical techniques for the fabrication of porous conducting polymers film with various sized inorganic/organic dopant molecules will be discussed in detail along with it applications in the field of biomedical and water purification system.

WATER QUALITY IN FRESHWATER AQUACULTURE PONDS

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Introduction

The aquatic environment governs fish life; hence water quality should be suitable for fish culture. When environmental condition does not conform to optimal range for normal fish growth, then fish culture could be affected. The major concerns of the fish culturist should be to deal with the aspects of water quality that may cause poor growth or death of fish (Boyd, 1978). Water quality management aims to regulate environmental conditions so that they are within a desirable range for growth and survival of fish. To a great extent water determines the success or failure of an aquaculture operation. The aquatic environment is composed of many aquatic variables. Fish culturists must know the variables that are potential sources of stress for the fish. The variables may also explain the causes of fish culture problems.

Water quality includes all physical, chemical and biological factors that influence the beneficial use of water. There are many water quality variables in pond fish culture. All other things being equal, a pond with good water quality will produce more and healthier fish than a pond with poor quality.

Fish and crayfish perform all bodily functions in water which include eating, breathing, excreting wastes, reproducing and taking in or removing salts. Water quality within aquaculture ponds can affect these functions and therefore will determine the health of the fish and consequently the success or failure of a fish farming operation.

Water quality within an aquaculture pond is continuously changing depending on certain conditions. These behavioural changes are referred to as "Pond Dynamics" and must be understood if a pond system is to be managed effectively.

Water quality is divided up into physical, biological and chemical characteristics. Each one will be discussed separately.

Physical Characteristics

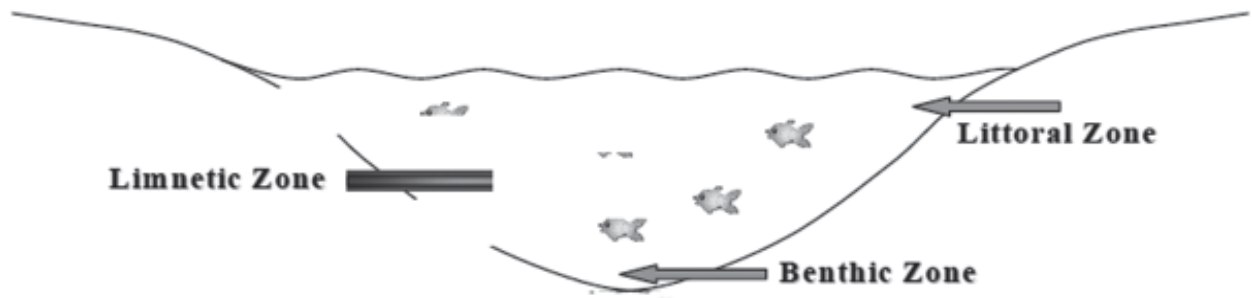

Fig 1: Physical zones within an aquaculture pond.

Physical characteristics of an aquaculture pond refers to its structure or "zones" (Fig 1). A pond is divided up into different zones, each with their own biological and chemical characteristics

The pond wall is known as the "littoral zone". Within this region aquatic plants thrive as they are able to access sunlight. Aquatic plants can be important in aquaculture ponds as they provide oxygen to the pond water, and food and shelter for some aquaculture species. However it is important not to allow aquatic plants to overrun your pond.

The "limnetic zone" is commonly referred to as the water column of the pond. Aquatic organisms such as phytoplankton, zooplankton and fish will inhabit this area. It is within this zone that the majority of water quality measurements are taken.

The "benthic zone" or pond bottom is perhaps the most forgotten area within aquaculture ponds. However this area is extremely important particularly for freshwater crayfish culture. Pond soil must be kept in good condition otherwise a build up of decaying organic matter can lead to oxygen problems within a pond. This will be discussed in more detail further on.

Biological Characteristics

Biological characteristics of an aquaculture pond refer to the aquatic organisms that live within the pond. This includes both plants and animals.

The relationship between aquatic plants and animals is known as a trophic level or a food chain(ie who consumes who). This relationship is a continuous cycle as shown in Fig 2. Bacteria form the base of the food chain within an aquaculture pond. Bacteria break down organic matter to produce nutrients such as phosphorus and nitrogen, and carbon dioxide (CO2). These products are then utilised by phytoplankton, microscopic algae, to produce oxygen via photosynthesis. Oxygen and phytoplankton are then consumed by zooplankton which are tiny aquatic organisms. Fish and crayfish feed on zooplankton as well as larger aquatic plants and supplementary feed that may be added to the aquaculture ponds. Uneaten supplementary feed, dead aquatic organisms (including planktonic organisms and aquaculture species) and animal wastes will settle on the pond floor. Bacteria will feed on this decaying organic matter and the cycle will commence again.

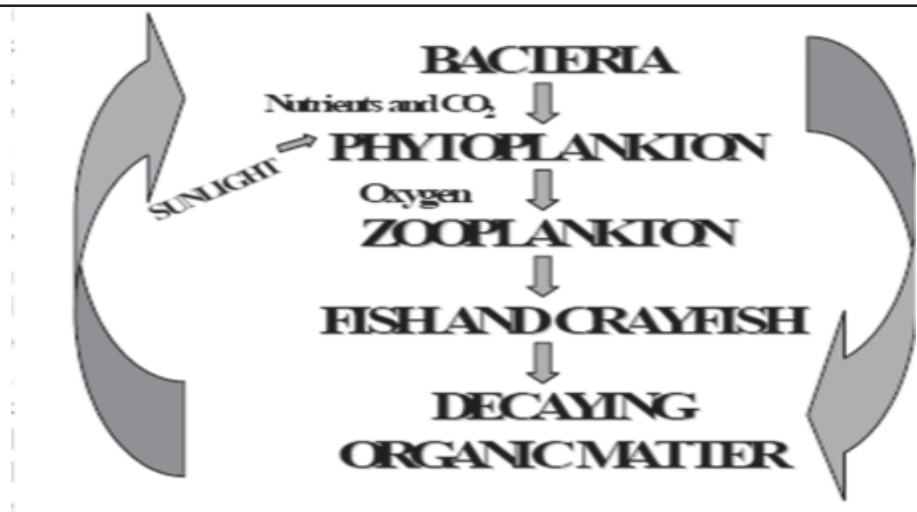

Fig 2: Trophic levels within an aquaculture pond.

Inorganic or organic fertilisers consisting of nitrogen and phosphorus can be added to aquaculture ponds to stimulate the growth of phytoplankton. This in turn will promote zooplankton growth. Before fish fry can be stocked within a pond, there must be a sufficient amount of zooplankton for them to feed on if the fry are to survive and grow.

The individual biomass of aquatic organisms within an aquaculture pond will vary over time (Fig3). It is therefore important to have a good understanding of the population dynamics within your pond to stabilise population numbers of aquatic organisms and to ensure that the system will not crash.

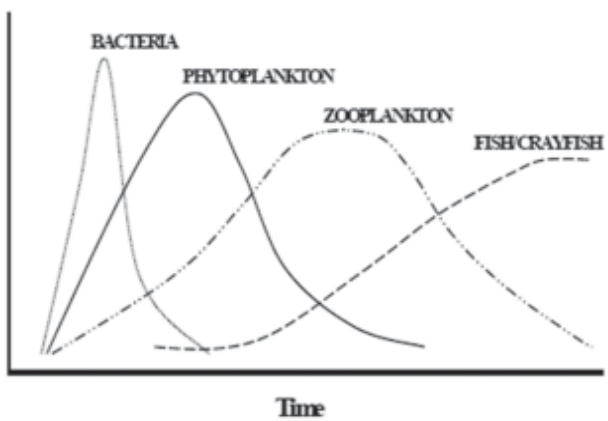

Fig 3: Phases in the succession of different organisms during the development of an aquaculture pond community (Ingram et al 1997).

Chemical Characteristics

Chemical characteristics refer to the water quality parameters that are measured within an aquaculture pond. Water quality in ponds changes continuously and is affected by each other along with the physical and biological characteristics that have been mentioned previously.

With this in mind water quality should be monitored regularly. This can be achieved by recording simple visible water characteristics such as water colour, clarity, plant and animal life. Alternatively relatively inexpensive testing kits and recording probes (more expensive) can be purchased from analytical supply stores.

The following water quality parameters are considered to be the most important in aquaculture.

Dissolved Oxygen

Dissolved oxygen is probably the most critical water quality variable in freshwater aquaculture ponds.Oxygen levels in ponds systems depend on water temperatures, stocking rates of aquaculture species, salinity, and the amount of aquatic vegetation and number of aquatic animals in the ponds.

Dissolved oxygen concentrations will vary throughout the day. Dissolved oxygen in the water is obtained through diffusion from air into water, mechanical aeration by wind or aeration systems, and via photosynthesis by aquatic plants (Fig 4).

$$6CO_2 + 6H_20 + \text{Sunlight} \rightarrow C_6H_{12}O_6 + 6O_2$$

Carbon Dioxide *Water* *Sugar* *Oxygen*

Fig 4: Plants utilise carbon dioxide, water and sunlight to form simple sugars and oxygen – a process known as photosynthesis.

Oxygen is also lost from the system via respiration where oxygen is consumed by aquatic organisms (both plants and animals), and by decaying organic matter on the pond floor.

Declining oxygen levels can be caused by a number of factors. This includes large blooms of phytoplankton and zooplankton, high stocking rates, excessive turbidity that will limit the amount of photosynthesis occurring and high water temperatures. Levels of dissolved oxygen will also decrease after a series of warm, cloudy, windless days.

Low dissolved oxygen can be lethal to our aquaculture species. Some effects include stress, increased susceptibility to disease, poor feed conversion efficiency, poor growth and even death.

A number of measures can be put in place to help alleviate low oxygen problems. There are a number of different types of aeration systems that when installed in ponds will help circulate and oxygenate the water. The majority of existing growers use Airlift pumps however other systems include Paddle wheels, Aspirator pumps and Diffused air systems. Flushing ponds with fresh water and reducing feeding rates will also help increase oxygen levels within the pond. When taking measurements of dissolved oxygen within aquaculture ponds it is important to note that readings will alter depending on the time of day, the amount of plant growth within in the pond, and the position in the pond from where the measurement was taken. This is due to the following reasons.

Aquatic plant life, algae or phytoplankton are present in large numbers will produce high oxygen levels within a pond during the day due to photosynthesis occurring. However at night without the presence of sunlight, these organisms will be consuming oxygen rather than producing it via photosynthesis which may result in dangerously low oxygen levels (Fig 5). Therefore if the pond has extremely high oxygen levels during the day there may be a good chance they will drop considerably at night.

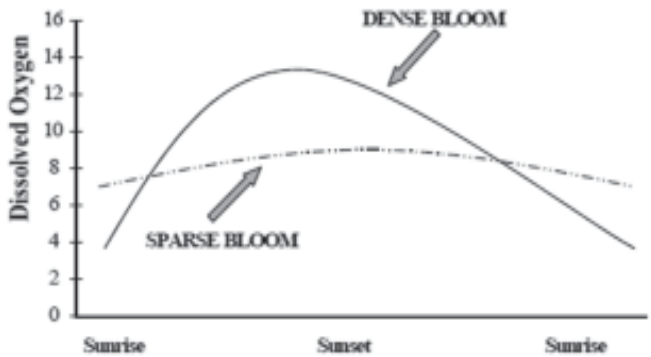

Fig 5: This graph shows the impact of algae blooms on dissolved oxygen readings of a pond. It is important to note that the time of day that dissolved oxygen readings are taken is extremely important and that the lowest readings are usually recorded at dawn.

Another factor which may affect the reliability of a dissolved oxygen reading is the location of the measurement taken within the pond. An aquaculture pond can undergo stratification where the pond's water column will split into two separate layers (Fig 6). The top layer will heat up however oxygen levels will still remain high due to oxygen diffusing from the air into the water. The bottom layer of the pond will remain colder and oxygen levels will deplete due to decaying organic matter on the bottom of the pond essentially sucking oxygen from the water. The top and bottom layers which are separated by a barrier known as a thermocline will not mix due to the lack of mechanical movement within the pond's water column.

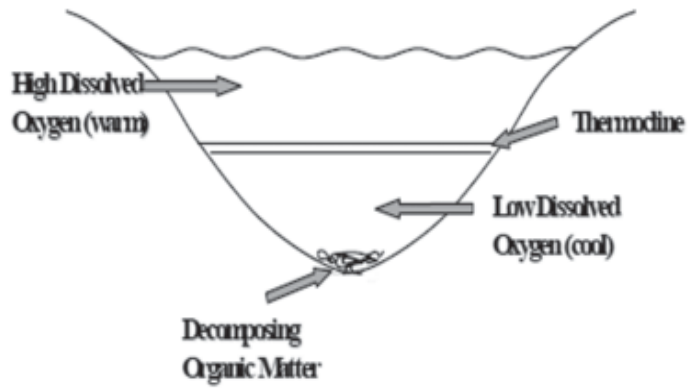

Fig 6: Stratification within an aquaculture pond. Oxygen levels within the bottom layer of the pond can drop to lethal levels especially for bottom dwelling culture animals such as freshwater crayfish.

Pond stratification may occur during periods of hot, still weather and is usually more prevalent in deeper, highly turbid ponds. Pond stratification is more likely to be avoided by installing aeration systems within the ponds to ensure that water is circulated during the critical periods of time, and making sure that pond depth is no greater than around two metres.

Water Temprature

Fish and crayfish are ectotherms as heat is obtained from their external environment. Therefore the body temperature of culture animals is usually the same as that of the water temperature.

Temperature will affect all chemical and biological processes.Temperature therefore has a direct effect on important factors such as growth, oxygen demand, food requirements and food conversion efficiency. The higher the temperature, the greater the requirement for oxygen and food and the faster the growth rate.

Optimum temperature conditions will depend on the species of fish that is cultured. These conditions will need to be met to ensure optimal growth and reproduction success. It is therefore important to select a culture species that is best suited to the climate in your area for pond culture, or in the case of tank culture, be prepared to heat or cool the water supply.

pH Levels

The pH is the measure of the hydrogen ion (H+) concentration in soil or water. The pH scale ranges from 0 to 14 with a pH of 7 being neutral. A pH below 7 is acidic and an pH of above 7 is basic. An optimal pH range is between 6.5 and 9 however this will alter slightly depending on the culture species.

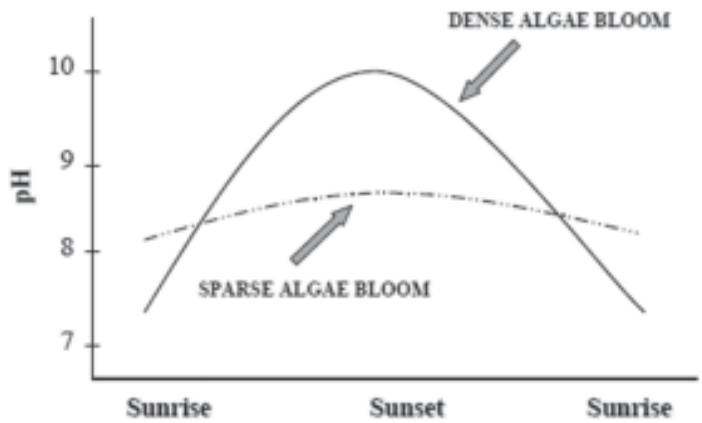

Fig 7: Diurnal fluctuations of pH will occur due to the amount of aquatic life within a pond. With higher algae concentrations, more CO_2 is removed from the system and hence pH levels will rise. The reverse will occur at night when more CO_2 is produced therefore leading to a drop in pH levels.

pH will vary depending on a number of factors. Firstly pH levels of the pond water will change depending on the aquatic life within the pond. Carbon dioxide produced by aquatic organisms when they respire has an acidic reaction in the water. The pH in ponds will rise during the day as phytoplankton and other aquatic plants remove CO2 from the water during photosynthesis. The pH decreases at night because of respiration and production of CO2 by all organisms. The fluctuation of pH levels will depend on algae levels within the pond (Fig 7).

Sub-optimal pH has a number of adverse affects on culture animals. It can cause stress, increase susceptibility to disease, low production levels and poor growth. Signs of sub-optimal pH include increase mucus on the gill surfaces of fish, damage to the eye lens, abnormal swimming behaviour, fin fray, poor phytoplankton and zooplankton growth and can even cause death.

In the case of freshwater crayfish low pH levels will cause the shell to become soft. This is due to the shell of the crayfish being composed of calcium carbonate which reacts with acid.

Sub-optimal pH levels are usually caused by acidic water and soils, poorly buffered water (will be discussed further on) and increased CO2 production.

Treatment methods will depend on whether there is a high pH problem or a low pH problem. To treat a pond with low pH, a pond can be limed with agricultural limestone or fertilised to promote plant growth. To decrease a high pH, the pond can be flushed with fresh water, feeding rates can be reduced to decrease nutrient input into the pond, gypsum (CaSO4) can be added to increase the calcium concentration, or alum (AlSO4) can be added in extreme cases.

Salinity

The term salinity refers to the total concentration of all dissolved ions in the water, it is not, as many people think, the concentration of sodium chloride in the water.

Measurements of salinity are referred to as mg/l or ppm. When salinity is high, it is common to report it as ppt. For a point of reference, seawater is approximately 35ppt.

Units of Measurement Conversions

"mg"	=	milligrams	1 g/l	=	1000mg/l
"l"	=	litres	1 ppt	=	1000ppm
"ppm"	=	parts per million	1 mg/l	=	1 ppm
"ppt"	=	parts per thousand	1 g/l	=	1 ppt
"gpg"	=	grains per gallon	1 gpg	=	14 mg/l (or 14 ppm)

Each species has an optimal salinity range. This range allows the fish to efficiently regulate their internal body fluid composition of ions and water. This process is known as osmoregulation (Fig 8).

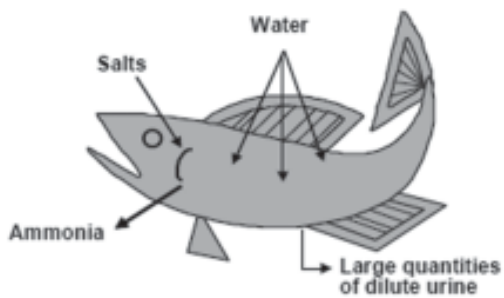

Fig 8: A freshwater fish will gain water via osmosis. Excess water is excreted in the urine and ion uptake is through the gills.

If salinity is too high, the fish will start to lose water to the environment. As freshwater fish are not physiologically adapted to osmoregulate within a saline water source, decreased growth and survival can occur under these conditions.

The salinity of the water source that is to be used for aquaculture should be tested before a project commences. Salinity tolerances will vary amongst species therefore it is important to chose an aquaculture species that is best suited to the salinity of the water source.

Turbidity

Water turbidity in freshwater ponds is caused by phytoplankton and zooplankton (microscopic plants and animals) and suspended solids such as clay and silt particles in the water column.

Water turbidity is important as it determines the amount of light penetration that occurs in the water column of a pond. This in turn will have an affect on the temperature of the water and the amount of vegetation and algae that will grow in the pond itself. For example a highly turbid pond will allow less light penetration therefore the temperature of the water will be lower. A combination of less sunlight and lower temperatures will result in a decreased amount of vegetation present with in the ponds which depend on sunlight and warmth to grow. A low turbid pond will of course have the opposite affect.

Turbidity is measured in centimetres using a sechii disk which consists of a round plate divided into alternate black and white "pie" sections. This disk is attached to a graduated rope or a metal handle divided into measuring units (usually at 2 cm intervals). The disk is lowered into the water until it can not be seen and then raised until it re-appears. Sechii depths between

20cm and 60cm are recommended for optimal management of freshwater ponds.

Water Alkalinity and Hardness

Alkalinity refers to amount of carbonates and bicarbonates in the water and water hardness refers to the concentration of calcium and magnesium. As calcium and magnesium bond with

carbonates and bicarbonates, alkalinity and water hardness are closely interrelated and produce similar measured levels.

Waters are often categorised according to degrees of hardness as follows:

0 – 75 mg/l	*soft*
75 – 150 mg/l	*moderately hard*
150 – 300 mg/l	*hard*
over 300 mg/l	*very hard*

It is recommended that alkalinity and hardness levels are maintained around 50 to 300 mg/l which provides a good buffering (stabilising) effect to pH swings that occur in ponds due to the respiration of aquatic flora and fauna (Fig9).

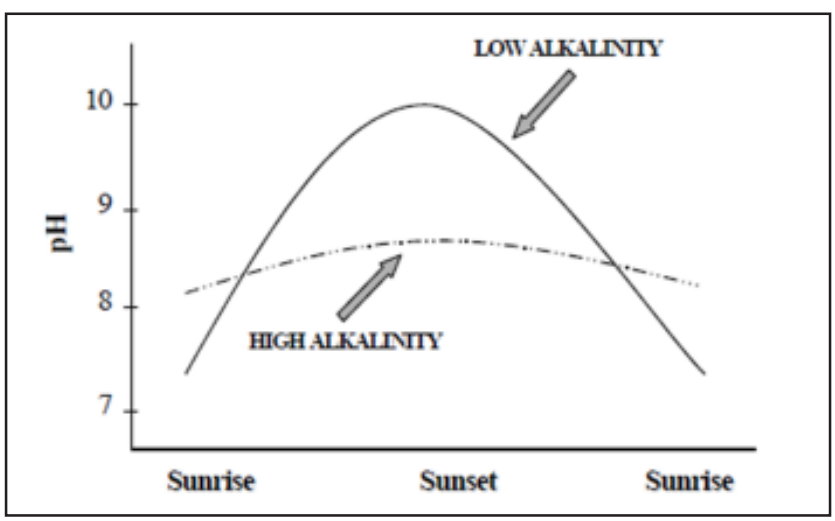

Fig 9: An optimum alkalinity level within the pond will prevent extreme diurnal pH fluctuations.

A lack of calcium in the water will also result in soft shelled marron as they rely on the intake of calcium from the water column to harden their shells after moulting.

Water alkalinity and hardness can be increased by liming ponds which involves adding a measured amount of lime to the pond. However there is no practical way of decreasing alkalinity and hardness when they are above desirable levels.

Ammonia

Ammonia in ponds is produced from the decomposition of organic wastes resulting in the breakdown of decaying organic matter such as algae, plants, animals and uneaten food. Ammonia is also produced by fish and crayfish as an excretory product.

Ammonia is present in two forms in water – as a gas NH3 or as the ammonium ion (NH4+). Ammonia is toxic to culture animals in the gaseous form and can cause gill irritation and respiratory problems.

Ammonia levels will depend on the temperature of the pond's water and its pH. For example at a higher temperature and pH, a greater number of ammonium ions are converted into ammonia gas thus causes an increase in toxic ammonia levels within the freshwater pond.

If high levels are ammonia are present within the pond's water, a number of measures can be taken. These include:

- reduce or stop feeding,
- flush the pond with fresh water,
- reduce the stocking density,
- aerate the pond,
- in emergencies – reduce the pH level.

The amount of ammonia present in a pond can be calculated by recording the total ammonia- nitrogen (TAN), pH and temperature (Table 1).

For example to obtain the concentration of NH3: Water at pH 8.4, 280C and 2mg/l of TAN (sampled measurement) contains 15% NH3 (from table). Therefore 2mg/l x 15% / 100 = 0.3 mg/l of NH3.

Table 1: Percentage of TAN in the toxic unionised form NH_3 at different temperature and pH levels. Boyd (1982) "Water quality management for pond fish culture".

PH	Temperature °C						
	8	12	16	20	24	28	32
7.0	0.2	0.2	0.3	0.4	0.5	0.7	1.0
8.0	1.6	2.1	29.	3.8	5.0	6.6	8.8
8.2	2.5	3.3	4.5	5.9	7.7	10.0	13.2
8.4	3.9	5.2	6.9	9.1	11.6	15.0	19.5
8.6	6.0	7.9	10.6	13.7	17.3	21.8	27.7
8.8	9.2	12.0	15.8	20.1	24.9	30.7	37.8
9.0	13.8	17.8	22.9	28.5	34.4	41.2	49.0
9.2	20.4	25.8	32	38.7	45.4	52.6	60.4
9.4	30.0	35.5	42.7	50.0	56.9	63.8	70.7
9.6	39.2	46.5	54.1	61.3	67.6	73.6	79.3
9.8	50.5	58.1	65.2	71.5	76.8	81.6	85.8
10.0	61.7	68.5	74.8	79.9	84.0	87.5	90.6
10.2	71.9	77.5	82.4	86.3	89.3	91.8	93.8

Nutrient Levels

Nutrient levels refer to the amount of phosphorus and nitrogen that is present in the water column. Nutrients are important as they promote healthy plankton blooms which are necessary to maintain turbidity levels and provide feed for fish. Nutrient levels can be increased in the ponds by adding inorganic or organic fertilisers in measured doses.

Increased levels of nutrients however may be harmful. It can cause excessive plankton growth, potential blue-green algae blooms and oxygen depletion.

High levels of nutrients can be caused by high stocking densities, over feeding (very common especially during winter), high productivity, and dead plant and animal matter. To decrease high nutrient levels, feeding rates should be decreased (or stopped) and the pond may need to be flushed with clean water.

Table 2: Acceptable Concentration Ranges for Dissolve Inorganic Substances in Aquaculture Pond Waters Boyd (1998) "Water Quality for Pond Aquaculture".

Element	Form in water	Desired concentration
Oxygen	Molecular Oxygen (O_2)	5 – 15 mg/l
Hydrogen	H^+ [-log(H^+) = pH]	PH 7 – 9
Nitrogen	Molecular Nitrogen (N_2) Ammonium (NH_4^+) Ammonia (NH_3) Nitrate (NO_3^-) Nitrite (NO_2^-)	Saturation or less 0.2 – 2 mg/l < 0.1 mg/l 0.2 – 10 mg/l < 0.3 mg/l
Sulfur	Hydrogen Sulfide (H_2S) - rotten egg gas Sulfate (SO_4^-)	Not detectable 5 – 100mg/l
Carbon	Carbon Dioxide (CO_2)	1 – 10 mg/l
Calcium	Calcium Ion (Ca^{2+})	5 – 100 mg/l Can be higher in crustacean ponds
Magnesium	Magnesium ion (Mg^{2+})	5 – 100 mg/l
Sodium	Sodium ion (Na^+)	2 – 100 mg/l
Potassium	Potassium ion (K^+)	1 – 10 mg/l
Bicarbonate	Bicarbonate ion (HCO_3^-)	50 – 300 mg/l
Carbonate	Carbonate ion (CO_3^{2-})	0 – 20 mg/l
Chloride	Chloride ion (Cl^-)	1 – 100 mg/l
Phosphorus	Phosphate ion (HPO_4^{2-} , $H_2PO_4^-$)	0.005 – 0.2 mg/l
Silicon	Silicate ion (H_2SiO_3 , $HSiO_3^-$)	2 – 20 mg/l
Iron	Ferrous iron (Fe^{2+}) Ferric iron (Fe^{3+}) Total iron	0 mg/l Trace 0.05 – 0.5 mg/l
Manganese	Manganese ion (Mn^{2+}) Manganese dioxide (MnO_2) Total manganese	0 mg/l Trace 0.05 – 0.2 mg/l
Zinc	Zinc ion (Zn^{2+}) Total zinc	< 0.01 mg/l – 0.05 mg/l
Copper	Copper ion (Cu^{2+}) Total copper	< 0.005 mg/l 0.005 – 0.01 mg/l
Boron	Borate (H_3BO_3 , $H_2BO_3^-$)	0.05 – 1 mg/l

Conclusion

Water quality varies considerably at different geographical locations. Fish can use some water supplies considered impaired for human use, even some saline waters have aquaculture potential. Water quality affects growth and well being of fish. Therefore, water quality should be of great importance to the aquaculture. A high quality water testing kit is essential for measuring water quality on a regular basis. It is equally important to know how to interpret the water quality parameters that are measured to maintain the health and well being of their fish stock.

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