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Composite fish culture-an ecologically viable and economically profitable fish culture technique- A Review

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ABSTRACT

Fish culture in which more than one type of compatible and non-competing fishes are cultured simultaneously through the utilization of different feeding zones in a pond so as to increase the total fish production per unit area of water body is known as composite fish culture. Suitable selection of fish in composite fish culture can boost nutrient flux and is very important in maximizing the productivity, both in terms of quantity and quality. In composite fish culture, on the basis of growth performance of different species, modifications are made in stocking density, species ratio, fertilization and supplementary feeding programmes to improve the growth rates of the fishes and thus to achieve better production. The three IMCs, namely catla (*C. catla*), rohu (*L. rohita*) and mrigal (*C. mrigala*) contribute the bulk of production to the extent of 70 to 75% of the total freshwater fish production, followed by exotic carps comprising silver carp (*Hypophthalmicthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp(*Cyprinus carpio*) forming the second important group contributing to the balance 25 to 30%. The Composite culture practice of fish production is ecologically viable and profitable compared to the traditional practices. Since, composite fish culture is a promising enterprise, study on the economics and technical bottlenecks on regional as well as national basis are necessary. Economic benefits of composite fish culture need to be vividly highlighted to convince fish farmers to adopt this culture practice. Composite fish culture brings forth the socio-economic changes in the rural society which helps in alleviating rural poverty and generating livelihood security.

Key words: Composite fish culture, species combination, methodology, water quality, economics

INTRODUCTION

Fish is the cheapest and most easily digestible animal protein and obtained from natural sources from time immemorial for consumption by human beings. However, due to over exploitation and pollution, the availability of fish in natural waters has declined considerably forcing scientists to adopt various methods to increase fish production (Das and

Sinha, 1985). The technology developed for fish culture in which more than one type of compatible and non-competing fishes are cultured simultaneously through the utilization of different feeding zones (all the natural niches) in a pond so as to increase the total fish production per unit area of water body is known as composite fish culture and it is the most popular culture technique in the country (Baghel and Sexena, 2002).

Composite fish farming in pond culture system consists of Indian major carps (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) and exotic carps (*Hypophthalmicthys molitrix*, *Ctenopharyngodon idella* and *Cyprinus carpio*). Specific interactions among compatible fish species are also important in the sustenance of any composite culture system (Sahu *et al*., 2007). Suitable selection of fish in composite fish culture can boost nutrient flux and is very important in maximizing the productivity, both in terms of quantity and quality (Rahman, 2006).Exotic species are introduced along with the existing indigenous fishes to increase species diversity, improve fish yield and fill an apparent vacant niche (Sinha *et al*., 1973). Therefore, polyculture concept is largely based on the principle that each stocked species has its own feeding niche without entirely overlapping with the feeding niches of other species and can be considered the most favoured fish culture practice because this facilitates efficient utilization of all ecological zones within pond environment enhancing the maximum fish productivity (Lutz, 2003). The three IMCs, namely catla (*C. catla*), rohu (*L. rohita*) and mrigal (*C. mrigala*) contribute the bulk of production to the extent of 70 to 75% of the total freshwater fish production, followed by exotic carps comprising silver carp, grass carp and common carp forming the second important group contributing to the balance 25 to 30% (FAO, 2017). In composite fish culture, on the basis of growth performance of different species, modifications are made in stocking density, species ratio, fertilization and supplementary feeding programmes to improve the growth rates of the fishes and thus to achieve better production (Mathew *et al*., 1979; Haque and Ray, 1983; Lutz ,2003; Tripathi *et al*., 2003; Hussain *et al*., 2011; Rajeshkumar and Balusamy, 2017). Rahman *et al.,* (2006) opined that in composite fish culture set up, three Indian major carps *Catla catla, Labeo rohita*, *Cirrhinus mrigala* and two exotic carps, *Hypophthalmicthys molitrix* and *Ctenopharyngodon idella* are considered the best combination. Planktophagous, herbivorous, fast growing, non-predatory species of fish are generally preferred for composite fish culture in freshwater ponds because they efficiently convert organic matter into fish flesh and consequently give high yields (Michael, 1988). Utilization of homestead organic waste, in polyculture carp proves to be the harmless for physico-chemical properties of water (Parvez *et al*. 2006). Milstein (1992) worked on the ecological aspects of composite fish culture pond and reported that farmers prefer to stock *C. carpio* as a bottom feeder instead of *C. mrigala* because *C. carpio* grows faster than *C. mrigala* and the overall production is higher when combined with *L. rohita* and *C. catla* in polyculture ponds. Azad *et al*.(2004) made an experiment on composite fish culture at Mymensing, Bangladesh and reported that water quality, growth and production of fishes in different species combinations in composite fish culture using tilapia(*Oreochromis niloticus*), pangas(*Pangasius hypophthalmus*), mrigal (*Cirrhinus mrigala*) and silver carp(*Hypophthalmicthys molitrix*). Chandra *et al.* (2005) observed in their studies that variations in fish growth depended on electrical conductivity, pH, and total alkalinity and phosphorus contents of rearing water. Time and dosage of organic manuring significantly affect the ecological processes of pond ecosystem in composite fish farming (Dhawan and Kaur, 2002; Bhakta *et al.,* 2006). According to Hussain *et al.* (2011) decrease in water temperature also reduces fish growth and phosphorus is a key metabolic nutrient in composite fish culture ponds which promotes planktonic production. Hussain *et al*. (2013) stated that there are many fish culture technologies available of which composite fish culture system is the most sustainable fish culture practice in India. Li and Mathias (1990) reported that grass carp consume low value vegetative waste and increase natural food production in the polyculture pond by nutrient recycling and faecal production. Vasanthakumar and Selvaraj (1985) in their study have explained the problems involved in the marketing of fish of composite fish culture. Dewan *et al.* (1991) in a study with Indian and Chinese carp in polyculture found a surface temperature of 30.2 - 34.0°C and a pH range of 6.6 - 8.8. Haque and Ray (1983) reported that pond and lakes with a range of total alkalinity of 40.0 - 90.0 mg/l are of medium to highly productive for composite fish culture. Aquaculture production models are highly dynamic, unless we assess the economics and understand the scale of economy of any given activity, system not sustains (Sivakumar *et al*., 2014). Several researchers (Suresh,1996; Roy *et al*., 2003; Biswas *et al*., 2017) emphasized on economic feasibility of composite fish culture. Considering its ecological viability and economic profitability, the present paper makes a review report on composite fish culture.

Fish species involved in composite fish culture

For yielding best production of fish through composite fish farming experiments have been performed with combination of different species of fish. Two broad combinations are –

A. Culture of Indian major carps alone

In India, Indian major carps namely Catla(*Catla catla*), Rohu(*Labeo rohita*) and Mrigal(*Cirrhinus mrigala*) are stocked and grown together in the same pond.

B. Culture of Indian major carps and Exotic carps together

In such culture practices, Indian major carps namely Catla(*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*) and exotic carps namely Common carps (*Cyprinus carpio*), Silver carps (*Hypophthalmicthys molitrix*) and Grass carps (*Ctenopharyngodon idella*) are stocked and grown together in the same pond. Rahman *et al*. (2006) opined that in India, suitable and most common combinations of fish for composite fish culture system used to be are catla, rohu, and mrigal along with grass carp, silver carp and common carp. Mahapatra *et al*.(2006) also emphasized the introduction of exotic species in the species composition spectrum under composite fish culture system. Santhanam *et al*., (1990) emphasized on species combination and reported the percentages of different carp species in composite fish culture (Table1).

Methodology adopted in composite fish farming

1. Reclamation of pond

This is done by removing aquatic insects, useless weeds and muddy earth of the bottom. Aquatic insects cause considerable damage to the carp fry in the nursery ponds. Pakrasi(1953) developed an emulsion of mustard or coconut oil and cheap washing soap in the ratio of 56:18 kg/ ha at CIFRI's Cuttack centre for the removal of aquatic insects. Of all the floating weeds, water hyacinth (*Eichhornia crassipes*) is the most noxious and for its successful control the chemical 2,4-D is used at the rate of4.5 to 6.7kg/ha (Phillipose,1957). Ramachandran *et al*.(1975) opined that floating weed, *Pistia stratietes* can be cleared by foliar spray of aqueous ammonia(1-2%) with 0.25% wetting agent. It is better to make the pond rectangular in shape. Depth of the pond is considered as one of the prime factors in productivity. Generally speaking, a depth of about 2m is considered congenial from the point of view of biological productivity of a pond. Tripathi *et al*. (2003) opined that fish productivity decreases with an increase in pond depth above 5m.

2. Removal of predatory and weed fishes

Predatory fishes are *Channa* sp.(Lata, Chang, Sal, Sol), *Anabas* sp.(Koi), *Clarias* sp.(Magur), *Wallogonia* sp. (Boal) and Weed fishes such as *Puntius* sp. (Puntis), *Oxygaster* sp.(Chala), *Gudusia* sp.(Khoira)etc. will be removed from the cultured pond by using fish poisons like Mahua oil cake(*Brassia latifolia*). Sinha *et al*. (1985) emphasized the adverse impact of weed fishes (e.g.*Puntius* sp., *Oxygaster* sp.,*Amblypharyngodon mola*, *Colisa* sp., *Rasbora* sp., etc.) in composite fish culture and reported that these weed fishes compete with the culturable species of fishes for food, space and oxygen and causing serious problem to fish culture.

Table1. Percentages of different carp species in composite fish culture

Type of fish	4 species combination	5 species combination	6 species combination	8 species combination
Catla	30	30	10	10
Rohu	15	15	15	10
Mrigal	30	25	20	20
Common carp	25	20	20	15
Silver carp	-	-	25	25
Grass carp	-	-	10	10
Fringe-lipped carp	-	10	-	5
Milkfish	-		-	5

(Source: Santhanam et al., 1990)

Table 2. Lime doses at different pH values of soils

pH	Soil condition	Dose of lime(kg/ha)
4-4.5	Highly acidic	1000 kg/ha
4.5-5.5	Medium acidic	700 kg/ha
5.5-6.5	Slight acidic	500 kg/ha
6.5-7.5	Near neutral	200 kg/ha

(Source: Chatterjee, 1979)

*3. **Application of quicklime***

Addition of quicklime which increases the fertility of the pond and keep the fishes healthy. 200-500 kg of quick lime per hectare is recommended dose. Hussain *et al*. (2011) reported that the application of lime is done not only for fertilizing the pond in composite fish culture but also as a remedial measure necessary in acidic pond. According to Chatterjee(1979) lime doses recommended for fish culture at different pH values for soils are shown in Table-2.

*4. **Application of fertilizers and manures***

Fertilisation of the pond is an important means of intensifying fish culture by increasing the natural productivity of the pond. The fertiliser programme has to be suitably modified depending on the growth of the fish, available food reserve in the pond, physico-chemical conditions of the pond. Fertilizers are of two types, inorganic and organic and they are applied in phases. Common fertilizers are cow dung, single superphosphate, Triple superphosphate, Ammonium sulphate, Urea etc. Organic manure to be applied after a gap of 7-10 days from the date of liming. Cow dung @ 5000 kg/ha is recommended dose. Inorganic fertilisation to be undertaken after 15 days of organic manuring. Single superphosphate @ 40kg/ha/month, Triple superphosphate @ 15kg/ha/month, Ammonium sulphate @70 kg/ha/month and Urea@30 kg/ha/month is recommended dose. Parvez *et al*. (2006) reported that *C. mrigala* and *C. carpio* respond best in manured ponds with homestead organic wastes while *C. idella* do not show any marked response. Rajeshkumar and Balusamy(2017) in their composite fish culture experiment studied three earthen fish ponds manured with desi poultry droppings, duck droppings and turkey droppings respectively and reported a total fish yield of 696.9kg,671kg and 637.1kg was obtained from the fish manured with duck droppings, desi poultry droppings and turkey droppings respectively.

5. Water quality management in composite fish culture pond

Fish growth depends on water quality in order to boost its production and physico-chemical parameters are known to affect the biotic components of an aquatic environment in various ways (Ayodele and Ajani, 1999). In the presence of environmental stress such as low dissolved oxygen, high temperature and high ammonia, the ability of organisms to maintain its internal environment (i.e. metabolism, catabolism and reproduction) is reduced (Boyd, 1981; Meade, 1985). In view of this, monitoring of water quality, which centres on determination of optimal, sub-lethal and lethal values of physico-chemical parameters standardized for composite fish culture pond should be embraced (Boyd and Lichtkoppler, 1985). The relationship between fish yield and water parameters showed that no single parameter can be singled out in relation to fish growth and health(Lakshmanan *et al*., 1971). However, water quality parameters such as temperature, transparency, pH, dissolved oxygen, free carbon dioxide, alkalinity, phosphate-phosphorus and nitrate-nitrogen) must be kept at optimal level to guarantee high fish yield (Alabaster and Lloyd, 1982; Haque and Ray, 1983; Dewan *et al.*, 1991; Baghel and Saxena, 2002; Jhajhria, 2003; Chandra *et al.*, 2005). (Table-3)

Table 3. Physico-chemical parameters in composite fish culture pond

Physico-chemical parameters	Range
Temperature	18.3-37.8^{0}C
Transparency	40-60 cm
pH	6.5-8.5
Dissolved oxygen	6.0-9.0 ppm
Free carbon dioxide	1.0-3.0 ppm
Total alkalinity	50-200 ppm
Phosphate-phosphorus	0.05-0.10 ppm
Nitrate-nitrogen	0.2-0.5 ppm

6**. Stocking of fish fry in the pond**

Fish fry about 1.0-1.5 cm in length are to be let loose in the ponds three weeks after the application of (first phase) fertilizers. Number of fish fry per ha of pond should be between 5000-7500. Sinha *et al*. (1985) emphasized on the stocking density in composite fish culture pond and reported that a pond having average water depth of 2.0-3.0 m may be stocked at the rate of 5,000 fingerlings/ha.

7. **Application of supplementary food**

Supplementary food in the form of mustard oil cake, rice bran etc. aids in the rapid growth of the fishes. Fishes in the pond can be fed with a mixture of rice bran and oil cakes in the ratio of 4:1. Fish feed can be placed in a feeding bag and should be lowered down to the bottom of the pond or feed can be dispersed at the corners of the pond. The mean survival rate for various fish in different treatments in the study varied between 82 and 91% reported by Wahab *et al*(1991) for Indian major carps in polyculture where supplemental feed (mustard oilcake + rice bran, 2:1) was given. Hussain *et al*.(2011) preferred maize gluten over rice bran as supplemented feed(maize gluten : rice bran 3:1 and 1:3) and reported that growth performance of *Labeo rohita, Cirrhinus mrigala and Ctenopharyngodon idella* was comparatively higher when supplemented with maize gluten than those of rice bran. Tekchandani *et al*.(1999) opined that the nutritive value of rice bran has been observed to be relatively low as compared to maize gluten. Lakshmanan *et al.* (1971) reported a production ranging from 2230 to 4209 Kg/ha/yr in a 7 species composite culture of Indian and Chinese carps with the application of fertilizer and supplemental feeding. Murty *et al*. (1978) reported a net fish yield of 2275.37 Kg/ha/yr with fertilization alone as against a yield of 3558.58 Kg/ha/yr with fertilization and feeding.

Szumiec (1969) reported that the contribution of natural food organisms in the composite fish culture pond cannot be under emphasized and estimated that the natural food contributes about 30% of the overall food for carp fishes in a supplementary feeding schedule.

For a pond of one ha with 5000-7500 fish fry, the requirements of supplementary food (Table 4**)** are.

Table 4: Requirements of supplementary food

Period	Amount of supplementary food(kg/day)
During 1st month to 2nd month	4 kg/day
During 3rd month to 4th month	6 kg/day
During 5th month to 6th month	10kg/day
During 7th month to 8th month	14kg/day
During 9th month to 10 month	18kg/day
During 11th month to 12th month	24kg/day

(Source: Banerjee, 2007)

8**. Harvesting**

For table use, fishes may be netted after culturing for a year or when the fishes become 750-1,000 gm in weight. Harvesting can be done by partial de-watering and repeated netting. In some cases, complete de-watering of ponds is resorted to.

Table 5. Economic profitability of one acre composite fish culture pond

Sl. No.	Items	Rate(Rs./unit)	Amount
	Capital cost		
1.	Excavation of land(4000 m^3)	25 /m^3	1,00,000/=
2.	Construction of sluice gate(inlet/outlet)	__	25,000/=
3.	Fish seed(4000 fingerlings)	3	12,000/=
4.	Liming(200 kg)	15	3,000/=
5.	Fertilizers & Manures		20,000/=
6.	Supplementary feeding(6000 kg)		1,80,000/=
7.	Regular investments(including labour)		60,000/=
8.	Total investment		4,00,000/=
9.	Total investment(excluding capital investment)	4,00,000- - 1,00,000	3,00,000/=
10.	Total fish production(Approx. 4500 kg)	Rs. 100/kg	4,50,000/=
11.	Net Income per year	4,50,000 - 300000	1,50,000/=
12.	Benefit cost ratio(B:C)		1:1.37
13	Net Income per month		12,500 /=

(Source: Prakash et al., 2018

9. Yield in composite fish culture

With proper scientific management, fish production of 4 to 6 tons/ha can be achieved in a year.

Economics of composite fish culture

The economic feasibility of the composite fish culture practices was analyzed (Table 5) on the basis of the expenditure incurred and total return from sale price of fish in the local market(Shang,1981; Gittinger,1982; Suresh,1996; Roy *et al*., 2003; Prakash *et al*., 2018).

The operating costs of fish production are reduced by use of fertilizer (manure) and feed inputs (Shang and Costa-piere, 1983). Biswas *et al*. (1991) and Ghosh et. al. (1993) emphasized that the economic motivation of farmers was positively and significantly related to extent of adoption of composite fish culture practices and reported that those farmers, who have a tendency to maximize their earnings, have higher adoption of composite fish farming system.

CONCLUSION

It can be concluded that composite fish farming is the most ecologically viable as well as economically profitable fish culture technique which facilitates efficient utilization of all ecological niches within the pond ecosystem thereby enhancing fish productivity manifold on one hand and on the other, it brings forth the socio-economic changes in the rural society which help in alleviating rural poverty and generating livelihood security.

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Conflict of interest

The author declares that there is no conflict of interest.

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