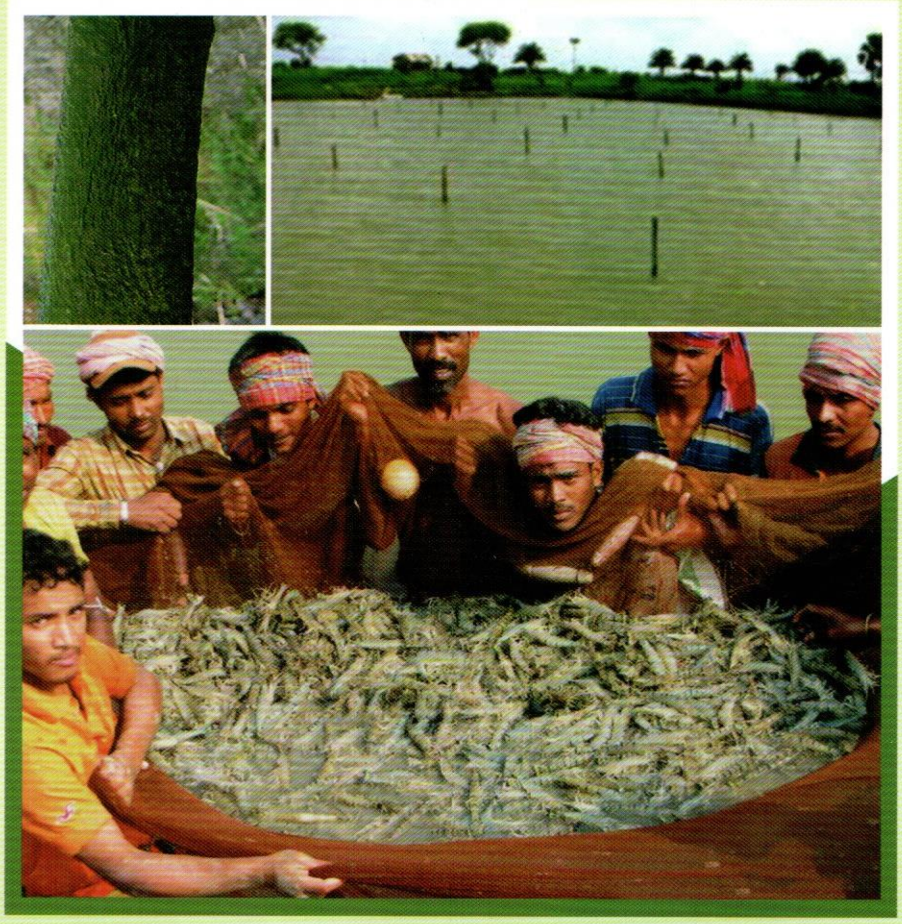
CIBA Technology Series No.11

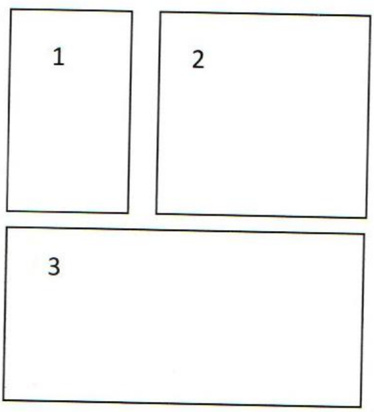
PERIPHYTON BASED SHRIMP CULTURE - A SUSTAINABLE TECHNOLOGY



केन्द्रीय खारा जलजीव पालन अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद्)

KAKDWIP RESEARCH CENTRE
CENTRAL INSTITUTE OF BRACKISHWATER AQUACULTURE
(Indian Council of Agricultural Research)
Kakdwip, South 24 Parganas, West Bengal – 743 347

April 2014



1. Periphyton developed over bamboo substrate
2. Substrate based shrimp pond
3. A haul of harvest from periphyton based black tiger shrimp farm

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PERIPHYTON BASED SHRIMP CULTURE - A SUSTAINABLE TECHNOLOGY

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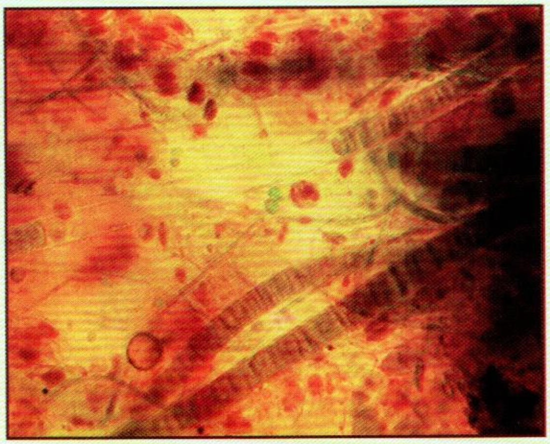
BACK GROUND

Expansion of large-scale semi-intensive and intensive shrimp culture has been facing issues like increasing price of commercial feed, disease outbreaks, environmental degradation and future challenges from climate vulnerability. This necessitates exploring eco-friendly culture methods which enhance sustainable shrimp production. In periphyton based aquaculture, submerged substrates in culture ponds provide sites for the development of periphyton, a complex mixture of autotrophic and heterotrophic micro-organisms like microalgae, bacteria, zooplankton, benthic organisms and detritus.

Natural biota associated with submerged substrates form an excellent quality of natural food for cultured fishes and shrimps. Thus, periphyton-based shrimp culture enhances the nutrient-transfer efficiency of the system due to shift from less stable phytoplankton to more stable periphyton community. Apart from providing natural food, periphytic algae grown on the substrate act as biofilter, enhance nitrification process and help to reduce total ammonia nitrogen (TAN), nitrite-N (NO_2-N) and nitrate-N (NO_3-N) in the water column.



Microscopic view of periphyton (40×)

In recent years, Central Institute of Brackishwater Aquaculture (CIBA) has prioritized the research and development thrust in utilization of natural productivity to augment shrimp production and to develop environmentally sustainable and economically viable culture technology. Periphyton-based farming is widely practiced in finfish culture and its benefit in aquaculture ponds varies with type of cultured species, their feeding habits, growth stages and stocking density. For instance, penaeid shrimps are physically more efficient to graze two-dimensional layer of periphyton than to filter plankton from a three-dimensional aquatic environment.

To develop a sustainable periphyton based shrimp culture technology, a series of experimental trials were performed with the target species of shrimp (*Penaeus* *monodon*) based on the use of submerged substrates, natural nutrients, indigenous probiotic based preparations and bioremedial measures. The technology package on periphyton-based shrimp culture is a valid outcome of the extensive laboratory and field experiments with regard to use of different substrates, stocking density etc. The technology has successfully been tested in on-station field and farmer's pond demonstration trials with improved productivity and better feed conversion ratio as desired.

SUBSTRATES USED IN SHRIMP CULTURE

Submerged substrate acts as a shelter and reduces any negative effect of space by increasing the living area for the cultured organism. It has been noticed that substrate serves as refuge in the early growth stages for penaeid shrimp preventing cannibalism during moulting period and improves the survival even at high stocking density. Natural substrates like bamboo, sugarcane bagasse and artificial substrates like discarded plastic irrigation pipes, nylon webbing, ceramic tile and fibrous scrubber are used for periphyton development. Natural bio-degradable substrates are more efficient than synthetic substrates because of the nutrient leaching that occurs at the substrate-water interface which promotes faster growth of micro flora and fauna.

Periphyton over split bamboo substrate

Periphyton over whole bamboo substrate

TECHNOLOGY PACKAGE

The following steps are the basic units involved in periphyton-based shrimp farming.

POND PREPARATION AND PRE-STOCKING MANAGEMENT MEASURES

- Pond preparation to be initiated with pond drying followed by desilting and application of soil amendment for optimal pH development. Agricultural lime ($CaCo_3$) commonly known as lime stone powder (LSP) can be applied @100-200 kg ha1 to maintain optimum pH.

- After intake of filtered water through 60-80 µm filter bag, it should be disinfected with bleaching powder @ 600 kg $ha^{-1.}$

- Install substrates to generate an additional 5- 10% pond surface area. Natural substrates like bamboo (1.4 × 0.06 m) can be fixed in ponds @ 2000-5000 numbers ha^{-1}. Artificial substrates like velon nets can be fixed at 15 to 30 velon net bundles (30 × 1 m) ha^{-1} ponds.

Periphyton-based pond

- Development of periphytic algae and its distribution is dependent upon the nutrient level in the water column. Application of organic and inorganic fertilizers stimulates the growth of periphytic algae. Organic fertilizer like vermicompost or cow dung @ 500-1000 kg ha^{-1} and inorganic fertilizers like urea and single super phosphate @ 25-100 kg ha^{-1} can be applied for development of periphytic algae on the submerged substrate. Fertilized ponds develop a considerable amount of periphyton in a period of 2 - 4 weeks period. Periodic fertilization can be done to maintain an optimum primary productivity. About 10% of the original dose of inorganic fertilizers i.e. urea and SSP at 10-20 kg ha^{-1} can be applied periodically (monthly) if sufficient primary productivity of pond is not maintained.

STOCKING

Healthy, disease free and PCR tested seed (PL-20) is stocked at low stocking density (8-12 nos. sq. m), to address the animal health and sustainability of the system.

WATER AND SOIL QUALITY MANAGEMENTS

- Minimum or zero-water exchange is advisable to minimize nutrient loss and to address the biosecurity threat. Optimum level of nutrient parameters like nitrate-N (100 - 200 µg/L) and phosphate-P (50-70 µg/L) in water column helps to develop good primary productivity which in turn can be used in the form of stable periphytic algae.
- Aeration can be provided during the early morning hours (4-6 h) to reduce hypoxic conditions especially during the later period of culture, generally 60 to 90 DOC onwards depending upon on the stocking density (8-12 nos. sq. m) when average body weight of shrimp crosses 10-12 g.

FEED MANAGEMENT


Shrimps grazing on substrate

Periphyton forms an excellent natural supplemental food for shrimp and reduces the amount of feed requirement. Thus, the judicious use of feed management can reduces the cost of production. Additional feed requirements beyond the portions can be met by providing quality supplementary shrimp feed based on the check tray observation. Quality supplementary feed (38% protein and 7-8% lipid) needs to be provided to meet additional nutrient requirement. Slight under feeding (5-10% less of the required quantity of feed) allows shrimp to utilize the natural productivity available in the form of periphyton

HEALTH MANAGEMENT

- Regular monitoring of shrimp health and microbial loads of the system should be followed.

- Yeast-based fermented probiotic preparations using ingredients like 60 kg paddy flour, 30 kg molasses and 3 kg yeast *Saccharomyces cerevisiae* per ha can be applied at fortnightly intervals to improve the fertility status of water.
- Application of potassium permanganate (1 kg/ha) and LSP (100-200 kg/ha) in pond bottom along with sand during late evening hours helps to improve soil quality problems in culture ponds.
- Proper biosecurity measures like crab net fencing, bird scare lines, minimum workers movement, separate implements for each ponds etc. should be strictly followed to prevent cross contamination

CIBA'S EXPERIMENTAL AND FIELD TRIALS

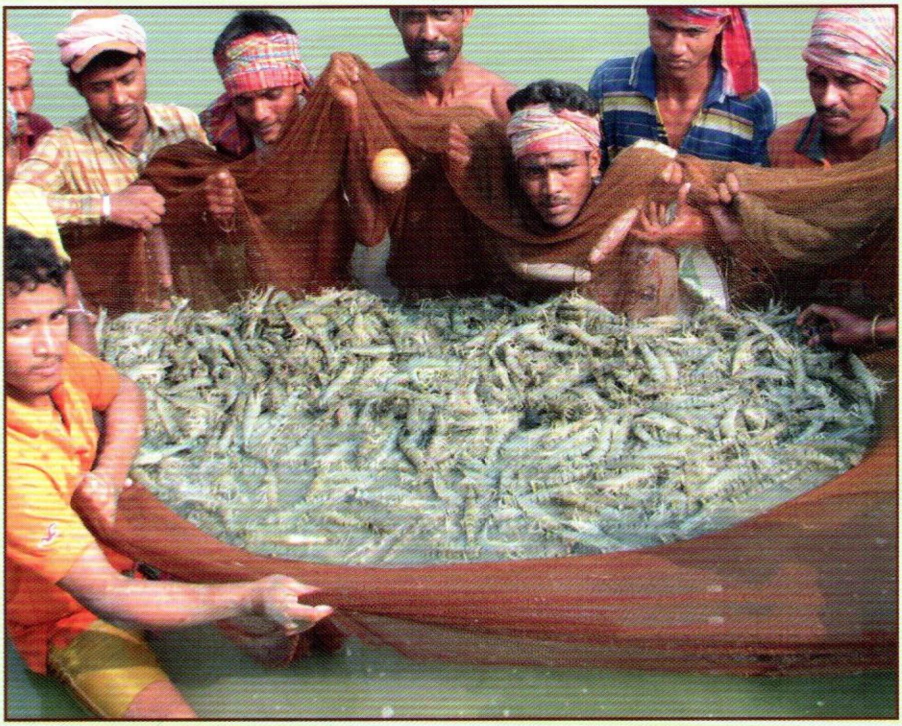
Field trials (Grow-out on station and demonstration trials in farmer's ponds) were conducted based on this technology for three years at Kakdwip Research Centre of CIBA, Kakdwip, West Bengal. The experiments were conducted with black tiger shrimp stocked at 8-12 nos. m-2 in grow-out ponds ranging from 0.1 to 0.35 ha size, for four months during the period from 2010 to 2013.

- Provision of substrates improved the water quality parameters by maintaining the water nutrient parameters like TAN (109.85 µg/L), NO_2-N (26.09 µg/L), NO_3-N (108.94 µg/L), PO_4-P (50.71 µg/L) and turbidity (30.5 ppm) within the permissible limit for shrimp culture.
- Periphyton developed over submerged substrate controlled the frequent occurrence of algal bloom with an average chlorophyll a level, 15.22 µg L^{-1} in water column.
- About 30 genera of phytoplankton belonging to Bacillariophyceae (13 genera), Chlorophyceae (9), Cyanophyceae (6) and Euglenophyceae (2) formed periphytic communities in the substrate.
- Development of periphyton over submerged substrate is estimated in terms of dry matter (DM), ash free dry matter (AFDM) and chlorophyll a concentration. Maximum periphyton developments coincide with the euphotic zone where a combination of light and nutrients is optimal. Average periphyton dry matter and ash free dry matter developed over the substrates during the study period was 5.9 and 3.0 mg cm^{-2} respectively.

* Application of external carbohydrate source like paddy flour, molasses for enhancing the C: N ratio (C: N 20), was also found to increase the quality and quantity of periphyton biomass. Provision of substrates enhances the shrimp immune parameters like total haemocyte count, prophenol oxidase activity and serum parameters. Similarly, periphyton-based system records comparatively lower level of total microbial and Vibrio load in the water column, 83.50×10^3 and 29.75×10^1 CFU/ml respectively compared with control ponds (288.00×10^3 and 46.00×10^1 CFU/ml) by competitive inhibition from periphytic algal community.

PRODUCTION PERFORMANCE

A stocking density of 8-12 nos. / sq. m yielded a better growth rate and quality shrimp with average body weight more than 26 g with a productivity range of 1640 to 2796 kg /ha/crop. There was a substantial gain in production (4.20 – 27.32%), size at harvest (2.10 – 17.5%) with better FCR (8.30- 22.30 %) in substrate-based shrimp



A haul of harvested shrimp from periphyton based ponds culture ponds compared to conventional ponds (Table 1). Enhanced growth performance and condition factor of tiger shrimp in periphyton based system indicate better utilisation of available natural food and natural productivity by cultured shrimp.

Table 1. Performance of black tiger shrimp in substrate based system (Treatment) compared with conventional farming system (Control)

Parameters	Year 1		Year 2		Year 3	
	Treatment	Control	Treatment	Control	Treatment	Control
Average Water spread area (m^2)	2250	3160	1000	2750	1300	1300
Stocking density (nos. sq. m)	8	8	11	11	12	12
Days of culture	130	130	140	140	124	124
Survival (%)	80	80	74	73	82	68
ABW at harvest (g)	25.85	22.00	31.64	31.00	27.88	26.20
Productivity (kg/ha/crop)	1644	1399	2583	2479	2796	2196
Feed Conversion Ratio (FCR)	1.15	1.48	1.44	1.57	1.62	1.79
Protein efficiency Ratio (PER)	2.29	1.79	1.83	1.68	1.62	1.47
ABW	17.50 ⇧		2.10 ⇧		6.41 ⇧	
Production (%)	17.50 ⇧		4.20 ⇧		27.32 ⇧	
FCR (%)	22.30 ⇩		8.30 ⇩		9.50 ⇩	

ECONOMICS

Periphyton-based shrimp farming system developed by CIBA ensures a low cost of production (Rs. 193/-per kg) compared to relatively higher cost of production (Rs. 228/- per kg) when conventional farming system is followed (Table 2). The rate of return over operational cost was higher in periphyton-based system (92%) compared to the conventional farming (54%) The higher production with better ABW and lower input cost on feed are the two major factors behind this achievement.

Table 2. Economic evaluation of low density *Penaeus monodon* substrate based farming compared to that of conventional shrimp farming system (stocking density 8 nos./ sq. m) for 1 ha water spread area.

Items	Amount (ha)	Price rate (Rs)	Periphyton based farming (PSF)	Conventional farming (CF)
Shrimp seed (PL-20)	80000 PL	0.5 PL^{-1}	40,000	40,000
Bleaching powder	600 kg	25 kg^{-1}	15,000	15,000
Urea	50 kg	10 kg^{-1}	500	500
SSP	50 kg	8 kg^{-1}	400	400
Cow dung	500 kg	3 kg^{-1}	1,500	1,500
Lime Stone Powder	1400 kg	6.6 kg^{-1}	9,240	9,240
Dolomite	400 kg	6.8 kg^{-1}	2,720	2,720
Paddy flour	480 kg	27 kg^{-1}	12,960	12,960
Molasses	240 kg	30 kg^{-1}	7,200	7,200
Baker's Yeast	16 kg	80 kg^{-1}	1,280	1,280
Substrate (nylon net bundles)	15 net bundles (30 × 1 m)	650 net $bundles^{-1}$	9,750	nil
Bamboo poles for substrate installation	30 bamboo poles	80 bamboo $pole^{-1}$	2,400	nil
Labour management	231 mandays	250 $mandays^{-1}$	57,750	
	225 mandays	250 $mandays^{-1}$		56,250
Feed cost	1886 kg feed in PSF (FCR-1.15)	83 kg^{-1}	1,56,538	
	2057 kg feed (FCR:1.48) CF	83 kg^{-1}		1,70,748

4 number of 2 hp aerator engine operates 5 h for 60 days	300 hour	40 $hour^{-1}$	12,000	12,000
Total operational expenditure			3,15,738	3,16,298
Economic return	1,640 kg ; ABW:26 g-PCF	370 kg^{-1}	6,06,800	
	1,390 kg; ABW:22g-CF	350 kg^{-1}		4,86,500
Cost of production (per kg)			193	228
Rate of return over operational cost			92%	54%
Benefit/cost ratio			1.9	1.5

CONCLUSION

Periphyton-based shrimp culture helps to maintain water quality parameters by reducing metabolites like total ammonia nitrogen, nitrite-N, phosphate-P, turbidity and maintain optimum natural productivity. Autotrophic and heterotrophic microorganisms developed over submerged substrates form a quality natural food for cultured shrimp and improve microbial dynamics in cultured ponds. Thus, periphyton-based farming system forms a sustainable farming practice which enhances shrimp immune response, total productivity and lowers FCR through optimum utilization of natural productivity in an eco-friendly manner.

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