Indian Journal of Economics and Development, January 2019, Vol 7 (1)
ISSN (online): 2320-9836
ISSN (Print): 2320-9828

Effect of periphyton (aquamat installation) in the profitability of semi-intensive shrimp culture systems

Santhana Kumar V. [1*], P. K. Pandey[2], Saurav Kumar[3], T. Anand[4], Boriah Suryakumar[5], Rathi Bhuvaneswari[6]

[1]Student, Aquatic Environment and Health Management Division, ICAR- Central Institute of Fisheries Education, Panch Marg, Off Yari Road, Versova, Mumbai, Maharastra-400061, India
[2]College of Fisheries, Central Agricultural University, Lembucherra, Agartala, Tripura- 799210, India
[3,6]Aquatic Environment and Health Management Division, ICAR- Central Institute of Fisheries Education, Panch Marg, Off Yari Road, Versova, Mumbai, Maharastra-400061, India
[4] Department of Fisheries Science, College of Fisheries Engineering, Tamilnadu Fisheries University, Nagapattinam-611001, Tamilnadu, India
[5] CEO, HitideSeafarms, Mahendrapalli, Nagapattinam- 611001, Tamilnadu, India
[1*]santhana.v@icar.gov.in, [2]pkpandey_in@yahoo.co.uk, [3]sauravsinha535@gmail.com, [4]marine1anand@gmail.com, [5]hitide.seafarms@gmail.com, [6]rathi@cife.edu.in

Abstract

Objectives: In the present study, economic analysis of with and without periphyton substrate (aquamat installation) as treatment and control, respectively, was evaluated with semi-intensive culture (stocking density 20 numbers m^{-2}) of *Penaeus vannamei*. Total duration of the culture was 120 days.
Methods/Statistical analysis: Economic parameters of both ponds were estimated via fixed cost, variable cost and gross revenues, and performance indicators such as benefit cost-ratio (BCR), net profit, break-even price, rate of return on investment, rate of return on operating cost, production per man day and contribution margin were calculated based on the profitability and the capital investment. The primary data was used for the calculation and the experiment was carried out in duplicates.
Findings: The capital investment for periphyton (US$ 23192, INR 62.5= US$) was higher than the control pond (US$ 17544). Higher production in periphyton pond resulted in the increased net income generation by 35.4 % than the control. Periphyton improves the economic return (US$ 18021; BCR – 2.3) of the semi-intensive shrimp farming and reduced the breakeven point (496) and feed cost (US$ 7426) of the culture pond. This indicates that the aquamat installation in semi-intensive shrimp culture system is a profitable venture and paves the way to attain sustainable intensification in the shrimp farming sector. The study was conducted on the field; it depicts the exact scenario of the profitability of aquamat installation when compared to the laboratory trial.
Application/Improvements: This technology also reduces and recycles the wastes, so it can also be applied as economically viable effluent treatment system for shrimp farming.
Keywords: Economics, Benefit-cost ratio, *Penaeus vannamei,* Periphyton, Shrimp farming, Semi-intensive culture

1. Introduction

Shrimp farming is one of the lucrative food producing sector generates employment and income for millions of people thrive in the developing countries [1]. *Penaeus vannamei* is the leading species cultured in many parts of the world including India. It contributes significantly to the national economy of India, as it is the highest exporting seafood commodity in India [2]. The cultual practice of the same is ranging from traditional to the scientific super intensive biofloc ponds. However, semi-intensive type of shrimp farming is highly suitable for the developing countries in Asia [1]. Still, it is associated with huge environmental risks such as degradation of land and water quality and also imposes a huge financial risk to the farmers and households found near the farm premises [3]. Semi-intensive farming needs more water exchange in order to maintain the optimum water quality parameters in the culture water and also for refilling the evaporation or leaching loss [4]. The effluents mostly consist of uneaten feed, faecal materials and other unused chemicals which impose a major threat to the adjacent water bodies, and also the accumulation of uneaten food residues and metabolites within ponds causes degradation of sediments and water quality, impose disease risk and reduces the profit generation [5].

 ISSN (online): 2320-9836
ISSN (Print): 2320-9828

Farmers were also aware of the need for developing the shrimp farming industry with more concern about biosafety and sustainability [6, 7]. This demands an innovative technology to make the semi-intensive shrimp farming more eco-friendly and a farmer-friendly option. Periphyton-based aquaculture system serves the purpose by effectively utilized the nitrogenous waste present in the effluents and reduced the FCR of the culture system [8, 9]. Periphyton technology works on the principle that the non-degradable substrate will be installed inside the culture water for supporting the growth of attached microbial/algal biomass. Installation of substrates inside the culture water has shown to improve the growth performance and water quality of both finfish and shrimp aquaculture [10-17, 9]. Installation of low-cost substrates in the culture system performs better than the traditional non-fed or fed systems, in both ecological and economic points of view [18, 19, 9]. However, periphyton grown in shrimp culture proves the ecological sustainability of shrimp aquaculture, but sustainability comprises both ecological and economic sustainability. Economic sustainability represents the capacity of the production system to produce a positive income in the long run [3]. The increased profitability is one of the important drivers for the fish farmers who are likely to be invested in the innovative technologies that might contribute to the increased productivity of the cultured animals [20]. Most of the research work on the periphyton has been done on a laboratory scale or in a research pond for a short duration, which might not represent the results of the on-farm trial. The culture of shrimp or fish up to market size is necessary to determine an accurate profitability of any aquaculture practice as the demands and prices of shrimp and fish are overwhelmingly reliant on size/weight of the fish/prawn. Profitability also varies based on the culture system in which the animals are growing [21]. Therefore measuring the economics of periphyton based semi-intensive shrimp farming will found to be helpful for the identification of lacunas in further improvement and determine the earning potential of the system. This will facilitate the extension workers to transfer this technology to the needy farmers. Hence, a simple economic analysis detailing costs and returns is used to estimate the profitability of periphyton based production system is required [21]. The present study investigated the profitability of periphyton (aquamat installation) in semi-intensive shrimp culture system in comparison to the feed based (control) shrimp culture system.

2. Materials and Methods

The experiment was carried out in Hitide Sea Farms ($11^0$21’34.1’’N, $79^0$48’45.4”E), Mahendrapalli, Nagapattinam, Tamil Nadu, India for a period of 120 days in two different groups of the semi-intensive earthen pond (0.66 ha). The experimental pond where substrate installed was treated as periphyton and the other group without substrate installation (i.e. control pond) and in both groups shrimp larvae were fed with commercial sinking pelleted shrimp feed (Chareon Pokphand India Pvt. Ltd., Chennai; India) at the rate of 5-3% of shrimp biomass ad libitum four times a day. The periphyton pond was prepared by installing substrates (aquamats) which were made up of black shade netting, having an area of 20 x 0.5 m and 1 mm mesh size. Aquamats were suspended vertically with the help of empty plastic bottles as floats and sand-filled bottles as sinkers above 50 cm from the pond bottom. There are about 30 aquamats were placed in a parallel line in front of aerators to facilitate the oxygen, nutrient and the water flow inside the substrates. Healthy and uniform sized juveniles (PL 15) of *P. vannamei* (0.015 g) were selected and stocked at the rate of 20 m^{-2}.

Information regarding the variables of economics i.e. capital investment, operating cost and returns of both periphyton and control pond was collected from the farm and utilized for further analysis. The data required for analyzing the profitability includes the fixed cost, variable cost and gross revenue. The variable cost includes the labour wages, feed, seed, fertilizer, carbon source and electricity cost. The fixed cost included salary, depreciation of machinery and equipment used during culture period and interest for the capital cost. The interest rate is of 6% on capital investment and variable cost, and depreciation of permanent assets. Depreciation was calculated by following the straight line method [22]. Gross revenue includes the part of total output consumed [23]. The performance indicators include gross revenues, net profit, break-even price, the rate of return on investment, the rate of return on operating cost, production per man-day, the value of production per man-day and contribution margin. They were evaluated by means of estimated costs and income from the primary data. To estimate the various cost and income [24] and the performance indicators [25], the following formulae were used.

 ISSN (online): 2320-9836
ISSN (Print): 2320-9828

2.1. Benefit-Cost Ratio

It is the ratio between gross income and total cost.
BCR = Gross income / Total cost
Where,
Gross income is the total output in monetary term at a market price
Total cost is the addition of total variable cost and total fixed cost,
Depreciation is also taken into consideration.

2.2. Net income

Net Income was calculated by the following formula
Net income = Gross income - Total cost

2.3. Rate of return on investment

Rate of return on investment = (Gross income / Total investment cost) X 100

2.4. Rate of return on operating cost

Rate of return on operating cost was calculated by the following formula
Rate of return on operating cost = (Gross income / Total variable cost) X 100

2.5. Production per man-day

Production per man-day was calculated by the following formula
Production per man-day = Total yield / Total man days

2.6. Contribution margin

Contribution margin was calculated by the following formula
Contribution margin = Total sales – Total variable cost

2.7. Breakeven price

Breakeven price was calculated by the following formula
Breakeven price = Fixed cost / Contribution margin

3. Results

To estimate profitability of each production system a simple economic analysis describing costs and returns is used [21]. The profitability of shrimp farming mainly depends on the cost structure and the returns [3]. The cost of shrimp culture was classified into variable and fixed costs. The total cost for culturing shrimp in the periphyton pond was estimated at about 13,979 US $/ha/crop out of which about 86% was accounted by variable cost and 14% by fixed cost. In case of the conventional pond (control), it was estimated about 15021.3US $ out of which about 91% was accounted by variable cost and 9% by fixed cost (Table 1). The total cost to produce 1 kg of shrimp is 2.8 US $ and 3.83 US $ for periphyton and control pond, respectively. Shrimp feed used in both periphyton pond (53.12%) and control pond (53.26%) contributes a higher proportion to the total cost followed by electricity cost (about 13.25%), seed cost (about 9.16%) and harvesting cost (about 5.15%). Carbon cost, mat installation and labour requirement in periphyton pond contribute around 4% higher in total costs in comparison to the control pond.

 ISSN (online): 2320-9836
ISSN (Print): 2320-9828

Table 1. Estimated production cost of shrimp grown in periphyton and conventional feed based shrimp culture system (Control) per crop

Item			Periphyton				Control			
Cost	Unit price (US $)	Quantity	Value (US $)	Value (US $/ kg production)	% of Total cost	Unit price (US $)	Quantity	Value (US $)	Value (US $/ kg production)	% of Total cost
Operating cost										
Labor	2.4	240 man-days	576	0.115	4.12	2.4	120 man-days	288	0.073	1.92
Feed	1.17	6358 kg	7426	1.49	53.12	1.17	6850	8000.8	2.04	53.26
Seed	0.006	3200	1280	0.26	9.16	0.4	3200	1280	0.33	8.52
Fertilizer	1.34	60 kg	80	0.02	0.57	1.34	60	80	0.02	0.53
Carbon source	0.48	100 kg	48	0.1	0.34					
Electricity	0.128	14468 kw-hr	1852	0.37	13.25	0.128	25511kw-hr	3265.5	0.83	21.74
Harvesting cost			720	0.14	5.15			720	0.18	4.79
Stocking labour wage	3.2	4 persons	13	0.003	0.09	3.2	4 persons	13	0.003	0.09
Total variable cost			11995	2.4	86			13647.3	3.48	90.85
Fixed cost										
Salaries (Administration and management)	160	1	160	0.032	1.14	160	1	160	0.04	1.07
Depreciation			432	0.086	3.09			200	0.05	1.33
Interest @ 6.00%			1392	0.27	9.96			1053	0.27	7.01
Total fixed cost			1984	0.4	14			1374	0.35	9.15
Total cost			13979	2.8	100.00			15021.3	3.83	100

The net returns, the rate of return on investment, the rate of return on operating cost, production per man-day, the value of production per man-day, contribution margin, breakeven price and benefit-cost ratio (BCR) of the periphyton and control pond are presented in Table 2.

Table 2. Production and Revenue output of periphyton and conventional feed based shrimp culture system (Control) per crop

Item	Periphyton pond		Control pond			
Cost	Unit price (US $)	Quantity	Value	Unit price (US $)	Quantity	Value
		Kg				
Production and revenue output						
Shrimp (Gross income) (US $)	6.4	5000	32000	6.4	3920	25088
Profitability						
BCR (unit-free)			2.3			1.7
Net income (US $)			18021			10066.7
Rate of return on investment (%)			137.979			143
Rate of return on operating cost (%)			266.778			183.831
Production per man day (kg)			20.8333			32.6667
Contribution margin = Sales-TVC (US $)			20005			11440.7
Breakeven point=Fixed cost/ contribution margin per unit			496			474

It has been observed that higher capital investment was required by the periphyton pond (US $ 23192) when compared to the control pond (US$ 17544) (Table 3). On the other hand, the net income was 56% higher in periphyton pond in comparison to control pond. Conventional (Control) shrimp culture system (BCR = 1.7) was less profitable than periphyton based culture system (BCR = 2.3).

ISSN (online): 2320-9836
ISSN (Print): 2320-9828

A higher breakeven point has noticed in periphyton pond in comparison to control pond. Contribution margin and the rate of return on operating cost in periphyton pond were higher than the control pond. This specifies the reduced risk of running this venture.

Table 3. Total capital investment required to produce shrimps in periphyton and control pond for a period of 120 days (1 crop) in 1 ha pond

Capital Investment Costs	Unit	US $/unit	Periphyton pond		Control pond	
			Quantity required	Cost	Quantity required	Cost
				(US $)		(US $)
Land	ha	8000	1 ha	8000	1 ha	8000
Catwalk structure	ha	96	4	384	4	384
Pond construction includes outlet structure	ha	1600	1	1600	1	1600
Support Equipment						
Aerators	nos.	640/3HP	13	8320	6	3840
Emergency Generator	nos.	1	1	2000	1	2000
Feed trays	nos.	24	4	96	4	96
Feeding Equipment (feed boat)	nos.	24	1	24	1	24
Water Quality Equipment	nos.	160	1	160	1	160
Feed Storage room	nos.	800	1	800	1	800
Aqua mat	nos.	6.7	150	1008	Nil	Nil
Miscellaneous equipment (nets, scale, testing equipment, purge tanks, buckets etc)	nos.	480	Lump sum	480	Lump sum	480
Miscellaneous labor (installation of system, utilities, plumbing, etc)	nos.	160	2	320	1	160
Total Capital Investment / crop				23192		17544

4. Discussion

P. vannamei farming has been gaining popularity in Asian countries and lures more people into the venture because of high export demand and profitability**.** However, it is associated with the most critical risks such as disease occurrence, high capital investment because of the higher feed requirement. In the present study, the labour cost required for periphyton is 52% higher than the control pond, which is due to the additional requirement of labour for installation and brushing off the aquamat to remove the settled solids over it (maintenance) for facilitating the free flow of nutrients inside the aquamat. In order to manage the periphyton pond of 1 ha, minimum 2 labours are required for the day to day activities. This is in line with the findings of the study [26]. Feed cost is one of the significant cost items for the semi-intensive culture system. In the present study, it contributes 53.12% and 53.26% of the total costs in periphyton and control pond, respectively. The equal feed cost in both periphyton and control pond is due to the survival of the shrimp, as reduced survival decreases feed consumption. Many researchers found out that the feed contributed more amounts in total expenditure for intensive/semi-intensive shrimp farming in Asia [26-28]. Around 10% reduction in total feed cost was noticed in periphyton pond when compared with the control pond. This could be due to the improved FCR, which is linked with the reduction of feed wastage and improved feed formula [27]. The presence of periphyton in the present study acts as a supplementary feed for the cultured organisms [29] and also improvise the settlement of feed over the vertical substrates, which increases the feed availability time and reduce the feed wastage [19]. Periphyton grown in the aquamat helps to reduce dependence on protein from feed and stabilizes water quality and enhances the shrimp growth with reduced FCR [9]. On the other hand, frequent feeding of 4 times a day during the daytime, and optimizing the feeding regime through regular monitoring of check tray, animal behaviour and climate manages the feed and improved the FCR of the present study [26]. Disease prevention was a major challenge in the semi-intensive aquaculture industry, the higher cost of production incurs a huge economic loss to the farmers from the developing countries like India [27].

ISSN (online): 2320-9836
ISSN (Print): 2320-9828

It has been noted that both periphyton along with the carbon addition has the capacity to improve the health and enhance the growth of shrimp [30, 31, 16]. This excludes the usage of probiotics and medicine in the present study which costs around 2.5-4.66% of total costs [27] (US $ 640 /ha/crop) and also lay a stepping stone towards sustainable shrimp farming. It requires a study to compare the economics of cultural practices involving the use of drugs and vaccines for the disease control with the sustainable cultural practices.

Seed cost remains same for both the culture system as there is uniform stocking density. The low electricity cost in periphyton pond was due to the reduced operation of aerators. The addition of carbon source usually increases the operating cost of the aquaculture farm [32]. The contradiction in results of the present study could be due to the dominance of autotrophic nitrifying bacteria and algae in the periphyton pond than the heterotrophic bacteria [30]. The increased DO concentration due to the algal activity reduced the running time of the aerator during morning hours ultimately made the electricity costs less than that of control pond which is purely plankton based. It was found that 2hp/ha aeration could be sufficient to stratify the oxygen layer in the water column of periphyton pond [19]. The total variable costs of periphyton pond were lower than the control pond. It is mainly due to the reduced aeration rates, and feeding rates by the periphyton biomass. The total fixed cost (TFC) required for the periphyton pond is 30% higher than the control pond. The increased requirement of capital investment could be attributed to the present result. It can be compensated by increased shrimp yield in periphyton pond (5000 kg/ha/crop) of the present study. In brief, addition of substrate provides additional shelter, natural food in the form of periphyton and also improves the environmental conditions, ecological and biological process [33-36], which could improves the production of shrimp from periphyton pond about 1.2 times higher than that of control pond. This leads to the generation of more net income by periphyton pond (1.5 times higher) than the control pond. This is in agreement with the findings of [19] shows higher income in vertical substrate installed biofloc pond.

BCR of the periphyton pond (2.3) is higher than the control pond (1.7). Further, it is higher than the BCR of a semi-intensive shrimp farm in India (1.95) [37]. The difference in BCR might be due to the difference in species composition, species density, and sex, individual stocking weight, feed management, culture area and duration [21]. On the other hand, the BCR calculated from the society point of view will be lower than the normal BCR for the shrimp culture practices involving in the damage of natural environment via pollution [38]. In case of periphyton system, the societal BCR might be the same as that of economic-based BCR, due to its capacity to reduce the waste nutrients in the effluents [9]. The breakeven point for the periphyton (496) is higher than that of control pond (474), which specifies that the shrimp can be sold at a lower price to cover the costs of manufacturing it. This is mainly because of following the better management practices during the farm trial. The BMPs of the present study mainly focus on the reduction of input quantity in order to prevent the pollution via run-off and emissions. The periphyton grown on the aquamats effectively increases the feed settlement time and organic matter was effectively degraded by the periphytic biofilms, which in turn recycles the waste nutrients into useful biomass [9]. These cost-saving strategies seem to be profitable or profit neutral to businesses [39, 4].

Periphyton based aquaculture is a both economically and ecologically sustainable venture. According to Coastal Aquaculture Authority (CAA), India, it is mandatory that the effluent from the aquaculture pond should be treated before releasing into the adjacent environment. For this purpose, an effluent treatment system (ETS) covering 10% of the farm area is proposed for shrimp farms larger than 5ha. Farmers cannot afford to setup an ETS on limited land resource and also the small farms below 5ha don't even have guidelines to establish one. Moreover, difficulty in maintenance, huge labour requirement and operating cost hampers the operation of ETS by farmers. It has been noted that the operating cost of ETS was 0.151- 0.37 US $ m^{-3} in which labour and electricity costs contributed significantly [40]. The environmental benefit obtained from operating ETS was 0.4306 US $ m^{-3} as a shadow price [41] and the total investment cost for ETS was 2,730.91US $ for treating 750 KLD [42]. By means of periphyton technology, the effluent nitrogen concentration was greatly reduced by 19% when compared to conventional shrimp culture, the retention of nitrogen in shrimp biomass was also higher and effluent nitrogen concentration was reduced and comparable to CAA standards [9]. This indicates the exclusion of separate ETS in the shrimp farm installed with aquamat. Therefore, the cost of operating the ETS will be excluded from the periphyton-based aquaculture system and it facilitates the farmers to earn more profit in a sustainable manner.

 ISSN (online): 2320-9836
ISSN (Print): 2320-9828

5. Conclusion

Standardizing the production process and sufficient information about the culture/operational system supports the investor to invest in a new or less established technology. Periphyton proves the production potential in practice as mentioned in the literature. However, increased intensification increases the production and simultaneously increases the energy requirement and other operating expenses. Installation of an artificial substrate (periphyton) in semi-intensive culture system increases the economic return. It facilitates the farming community to switch over from the traditional cultural practice into scientific semi-intensive farming without compromising the profit and production cost. The shrimp produced in this eco-friendly system will have both economic and environmental benefits. This may act as an efficient technology to march towards responsible aquaculture in future.

6. Acknowledgement

Authors are thankful to the Director and Vice-Chancellor, ICAR – Central Institute of Fisheries Education, Mumbai; Vice-Chancellor, Tamil Nadu Fisheries University, Nagapattinam and CEO (Mr. BoraiahSuryakumar), farm manager and labors, Hitide Sea Farms, Tamil Nadu for providing all the facilities, required for the present work. The funds provided by the Indian Council of Agricultural Research, New Delhi for the research work is also acknowledged.

7. Reference

1. M.M. Dey, R. Kamaruddin, F.J. Paraguas, R. Bhatta. The economics of shrimp farming in selected Asian counties. In: *Shrimp Culture: Economics, Market, and Trade*. Blackwell publishing. 2006; 241-261.
2. MPEDA (Marine Products Export Development Authority) press release report, (2016-17). http://pib.nic.in/newsite/PrintRelease.aspx?relid=164454. Date accessed: 07/07/2017.
3. P. Bhattacharya. Economics of shrimp farming: A comparative study of traditional vs. scientific shrimp farming in West Bengal. The institute for social and economic change, Working Paper. 2009; 218, 1-21.
4. Stanley, D. L. The economics of the adoption of BMPs: the case of mariculture water management. *Ecological Economics*. 2000; 35(2), 145-155.
5. Y. Avnimelech. Biofloc Technology - A practical guide book, 3rd edition. *The World Aquaculture Society: Baton Rouge*, Louisiana, United States. 2015.
6. M.C.S. Abreu, P. Mattos, P.E.S. Lima, A.D. Padula. Shrimp farming in coastal Brazil: reasons for market failure and sustainability challenges. *Ocean & Coastal Management*. 2011; 54(9), 658-667.
7. J.A. Hargreaves. Photosynthetic suspended-growth systems in aquaculture. *Aquacultural Engineering*. 2006; 34(3), 344-363.
8. Y. Avnimelech, M. Kochba. Evaluation of nitrogen uptake and excretion by tilapia in bio floc tanks, using 15 N tracing. *Aquaculture*. 2009; 287(1), 163-168.
9. V.S. Kumar, P.K. Pandey, T. Anand, R. Bhuvaneswari, S. Kumar. Effect of periphyton (aquamat) on water quality, nitrogen budget, microbial ecology, and growth parameters of *Litopenaeus vannamei* in a semi-intensive culture system. *Aquaculture.* 2017; 479, 240-249.
10. P. Keshavanath, B. Gangadhar, T.J. Ramesh, A.A. Van Dam, M.C.M. Beveridge, M.C.J. Verdegem. The effect of periphyton and supplemental feeding on the production of the indigenous carps *Tor khudree* and *Labeo fimbriatus*. *Aquaculture*. 2002; 213(1), 207-218.
11. A.A. Van Dam, M.C. Beveridge, M.E. Azim, M.C. Verdegem. The potential of fish production based on periphyton. *Reviews in Fish Biology and Fisheries*. 2002; 12(1), 1-31.
12. B. Hari, B.M. Kurup, J.T. Varghese, J.W. Schrama, M.C.J. Verdegem. The effect of carbohydrate addition on water quality and the nitrogen budget in extensive shrimp culture systems. *Aquaculture*. 2006; 252(2), 248-263.
13. M.E. Azim, D.C. Little. Intensifying aquaculture production through new approaches to manipulating natural food. In: *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*. 2006; 1(62), 1-23.

14. S. Kumar, P.S. Anand, D. De, J.K. Sundaray, R.A. Raja, G. Biswas, M. Muralidhar. Effects of carbohydrate supplementation on water quality, microbial dynamics and growth performance of giant tiger prawn (*Penaeusmonodon*). *Aquaculture International*. 2014; 22(2), 901-912.
15. P.K. Pandey, V, Bharti, K. Kumar. Biofilm in aquaculture production. *African Journal of Microbiology Research*. 2014; 8 (13), 1434-1443.
16. S. Kumar, P.S. Anand, P. Ravichandran, A. Panigrahi, J.S. Dayal, R.A. Ananda, A.G. Ponniah. Effect of periphyton on microbial dynamics, immune responses and growth performance in black tiger shrimp *Penaeusmonodon* Fabricius, 1798. *Indian Journal of Fisheries*. 2015; 62(3), 67-74.
17. W. Xu, T.C. Morris, T.M. Samocha. Effects of C / N ratio on bio floc development, water quality, and performance of *Litopenaeus vannamei* juveniles in a bio floc-based high-density zero-exchange outdoor tank system. *Aquaculture*. 2016; 453, 169–175.
18. M.E. Azim, M.C.J. Verdegem, H. Khatoon, M.A. Wahab, A.A. Van Dam, M.C.M. Beveridge. A comparison of fertilization, feeding and three periphyton substrates for increasing fish production in freshwater pond aquaculture in Bangladesh. *Aquaculture*. 2002; 212(1), 227-243.
19. B. Suryakumar, Y. Avnimelech. Adapting biofloc technology for use in small-scale ponds with vertical substrate. *World Aquaculture*. 2017; 54-58.
20. C.R. Engle, I. Neira. Tilapia farm business management and economics: a training manual. Aquaculture Collaborative Research Support Program. Oregon State University, Corvallis, OR, USA.2005, 1-41.
21. M.R. Haque, M.A. Islam, M.A. Wahab, M.E. Hoq, M.M. Rahman, M.E. Azim. Evaluation of production performance and profitability of hybrid red tilapia and genetically improved farmed tilapia (GIFT) strains in the carbon/nitrogen controlled periphyton-based (C/N-CP) on-farm prawn culture system in Bangladesh. *Aquaculture* Reports. 2016; 4, 101-111.
22. E.M. Cruz, A.A. Al-Ameeri, A.K. Al-Ahmed, M.T. Ridha. Partial budget analysis of Nile Tilapia *Oreochromis niloticus* cultured within an existing agricultural farm in Kuwait. *Asian Fisheries Science*. 2000; 13(4), 297-306.
23. F.K.E. Nunoo, E.K. Asamoah, Y.B. Osei-Asare. Economics of aquaculture production: a case study of pond and pen culture in southern Ghana. *Aquaculture research*. 2014; 45(4), 675-688.
24. S.S. Salim, R.S. Biradar. Practical manual on fisheries project formulation and management. *CIFE Publication*. 2001; 26-28.
25. V.T. Raju, D.V.S. Rao. Power function, farm income and profit efficiency measures", economics of farm production and management. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, India. 1993; 178-189.
26. M. Kumaran, P.R. Anand, J.A. Kumar, T. Ravisankar, J. Paul, D.D. Vimala, K.A. Raja. Is pacific white shrimp (*P.vannamei*) farming in India is technically efficient? A comprehensive study. *Aquaculture*. 2017; 468, 262-270.
27. Y.C. Shang, P. Leung, B.H. Ling. Comparative economics of shrimp farming in Asia. *Aquaculture*. 1998; 164(1-4), 183–200.
28. M. Navghan, N.R. Kumar, S. Prakash, D. Gadkar, S. Yunus. Economics of shrimp aquaculture and factors associated with shrimp aquaculture in Navsari district of Gujarat, India. *Ecology, Environment and Conservation.* 2015; 21(4), 247-253.
29. P.S. Anand, M.P.S. Kohli, S.D. Roy, J.K. Sundaray, S. Kumar, A. Sinha, S.M. Kumar. Effect of dietary supplementation of periphyton on growth performance and digestive enzyme activities in *Penaeusmonodon*. *Aquaculture*. 2013; 392, 59-68.
30. M. Asaduzzaman, M.A. Wahab, M.C.J. Verdegem, S. Huque, M.A. Salam, M.E. Azim. C/N ratio control and substrate addition for periphyton development jointly enhance freshwater prawn *Macrobrachium rosenbergii* production in ponds. *Aquaculture*. 2008; 280(1-4), 117–123.
31. P.S.S. Anand, M.P.S. Kohli, S. Kumar, J.K. Sundaray, S.D. Roy, G. Venkateshwarlu, A. Sinha, G.H. Pailan. Effect of dietary supplementation of biofloc on growth performance and digestive enzyme activities in *Penaeusmonodon*. *Aquaculture*. 2014; 418–419, 108–115.
32. M.A.S. Rego, O.J. Sabbag, R. Soares, S. Peixoto. Financial viability of inserting the biofloc technology in a marine shrimp *Litopenaeus vannamei* farm: a case study in the state of Pernambuco, Brazil. *Aquaculture International*. 2016; 1-11.

ISSN (online): 2320-9836
ISSN (Print): 2320-9828

33. J.H. Tidwell, S. Coyle, A. Arnum, C. Weibel. Production response of freshwater prawns *Macrobrachium rosenbergii* to increasing amounts of artificial substrate in ponds. *Journal of the World Aquaculture Society*. 2000; 31(3), 452-458.
34. J.H. Tidwell, S.D. Coyle, A. Arnum, C. Weibel. Effects of substrate amount and orientation on production and population structure of freshwater prawns *Macrobrachium rosenbergii* in ponds. *Journal of the World Aquaculture Society*. 2002; 33(1), 63-69.
35. A.A. Van Dam, M.C. Beveridge, M.E. Azim, M.C. Verdegem. The potential of fish production based on periphyton. *Reviews in Fish Biology and Fisheries*. 2002; 12(1), 1-31.
36. A. Milstein, M.E. Azim, M.A. Wahab, M.C.J. Verdegem. The effects of periphyton, fish and fertilizer dose on biological processes affecting water quality in earthen fish ponds. *Environmental Biology of Fishes*. 2003; 68(3), 247-260.
37. P. Leung, C.R. Engle. Shrimp culture: economics, market, and trade. John Wiley & Sons. 2008; 1-335.
38. M.Z. Haider, R. Akter. Shrimp paddy conflict in the South-West coastal region of Bangladesh. *International Journal of Agricultural Economics*. 2018; 3(1), 9-13.
39. P. Hawken. The ecology of commerce: A declaration of sustainability. *Society for Human Ecology*. 1994; 1(2), 351-353.
40. G. Rodriguez-Garcia, M. Molinos-Senante, A. Hospido, F. Hernández-Sancho, M.T. Moreira, G. Feijoo. Environmental and economic profile of six typologies of wastewater treatment plants. *Water Research*. 2011; 45(18), 5997-6010.
41. M. Molinos-Senante, F. Hernández-Sancho, R. Sala-Garrido. Economic feasibility study for wastewater treatment: A cost–benefit analysis. *Science of the Total Environment*. 2010; 408(20), 4396-4402.
42. S. Gautam, S. Ahmed, A. Dhingra, Z. Fatima. Cost- effective treatment technology for small size sewage treatment plants in India. *Journal of Scientific & Industrial Research*. 2017; 76, 249-254.

The Publication fee is defrayed by Indian Society for Education and Environment (www.iseeadyar.org)
Cite this article as:
Santhana Kumar V, P. K. Pandey, Saurav Kumar, T. Anand, Boriah Suryakumar, Rathi Bhuvaneswari. Effect of periphyton (aquamat installation) in the profitability of semi-intensive shrimp culture systems. Indian Journal of Economics and Development. January 2019, Vol 7 (1), 1-9.

Received on: 13/10/2018
Accepted on: 01/01/2019