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The Effect of Pond Water Colour, Plankton Diversity, Culture Techniques and Feed Management on Production Characteristics of Vannamei Shrimp Farming in Kerala, India

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Abstract

Currently white-legged shrimp, *Penaeus vannamei* is the most cultured shrimp species worldwide. Vannamei farming has already received immense response from the farmers due to the availability of high-quality specific pathogen-free (SPF) seed, amenability of the species to high stocking density and possibility of high production from the unit area. The pond watercolor, plankton diversity, culture techniques and feed management on production potentialities of the species were evaluated at different stocking densities in the semi-intensive culture system in Kerala, India. Six different stocking rates 15, 25, 30, 40, 50 and 60 nos m^{-2} designated as T1, T2, T3, T4, T5 including control in triplicates were adopted and reared for a period of 120 days. During the culture period, farmers maintained stable pond watercolour and natural productivity by keen observation employing regular manuring and fertilization. Phytoplankton of the group *Bacillariophyta* dominated in the majority of the culture ponds followed by *Chlorophyta*. whereas Copepoda and Rotifera were the major dominated zooplankton groups. The majority of the growth parameters did not show any significant differences except Average Daily Growth (ADG) which showed highly significant differences in both the crops. The findings of this study revealed that natural production in vannamei culture ponds is appeared to be an important source of food and nutrition and also provides good environmental conditions for shrimp cultivation. Moreover, this also helps to reduce the cost of production effectively.

Keywords: *Penaeus vannamei*, growth performance, stocking density, culture management

Introduction

Aquaculture is the fastest-growing food production sector in the world, providing almost half of the global fish and shrimp which peaked at about 172.6 million tonnes in 2019 (FAO, 2020). Shrimp farming is the face of Indian brackish water aquaculture which plays a crucial role in the socio-economic and nutritional security of the coastal communities and forms a major share in the seafood export earnings of the country. Being a lucrative profession, shrimp culture attracts many progressive farmers to venture into the commercial-scale culture.

Penaeus vannamei was the most widely cultured shrimp in the western hemisphere where the species contributes to about 90% of the total shrimp culture (Wurmann et al., 2004) which slowly got popularized to other parts of the world. The species was introduced in India for the first time during 2008 (CAA, 2010) and then onwards the production of this species surpassed the production of *Penaeus monodon* owing to its faster growth, compatibility to higher stocking rate, less disease risk, euryhaline as well as eurythermic nature, lower dietary protein requirement and lower feed conversion ratio (FCR). In scientific shrimp culture systems, the Coastal Aquaculture Authority of India (CAA) recommended a stocking rate of up to 60 m^2 (CAA, 2010) and the majority of the farmers follow this stocking rate. But many of the marginal farmers in India are not able to afford such a high stocking rate due to the huge operational cost involved since previously

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they were following only modified extensive (SD less than 10) and semi-intensive (less than 20) farming practices for *P. monodon* (Laureatte et al., 2012). The qualitative and quantitative abundance of plankton in a shrimp pond is of great importance in managing the success-ful and sustainable aquaculture. Other than serving as the major source of oxygen in the water, the phytoplankton population also represents the biological wealth of a water body whereas the zooplankton forms the principal source of food for shrimp within the system (Prasad & Singh, 2003).

Heterotrophic Auto-recycling Aquaculture Technology (HAAT) is an environment-friendly shrimp culture technique consisting of selectively reared SPF zooplankton (*Brachionus* spp.) and probiotic bacteria that have a huge potential to enhance yields of *P. vannamei*. Maintaining the transparency level at 25 cm for the better growth of zooplankton is a specialty of the above system. The vannamei shrimp farmers of Kerala have recently developed and used the natural HAAT system by the application of fermented wheat bran juice by their acquired knowledge from miscellaneous sources blended with their indigenous technical knowledge. This improved HAAT system has been proved to be a very efficient and cost-effective system in shrimp farming. It is reported to have significantly improved the total production of shrimp in many trials. Within no time, this system emerged as a popular protocol among the farmers of Kerala with improved popularity. The additional cost of production due to the adoption of HAAT has been estimated at Rs. 21,000/- per hectare (ha.)

Materials and Methods

The present investigation was carried out in brackish water shrimp farms at Ernakulum, Thrissur, Kollam, and Kannur Districts of Kerala State (Fig. 1). Two crop cycles of varied stocking densities and areas with specific crop durations of 120 days of culture (DOC) had been undertaken during the period from October 2018 to August 2019. The crops were taken in ponds of varied sizes ranging from 0.40-1.011 ha with a water depth of 1.2- 1.5 m. The investigation was based on the field study including farm visits, collection and analysis of water and plankton samples. The primary data were collected from the selected vannamei shrimp farmers who have been involved in shrimp farming for more than five years. The mode of data collection included interviewing respondents and accessing records maintained by the respondents. All information and data gathered from the field were combined and analyzed. Identification of plankton was done under a compound light microscope using keys and illustrations by Prescott (1962), Patrick & Reimer (1966), Round et al. (1990), Tomas (1997).

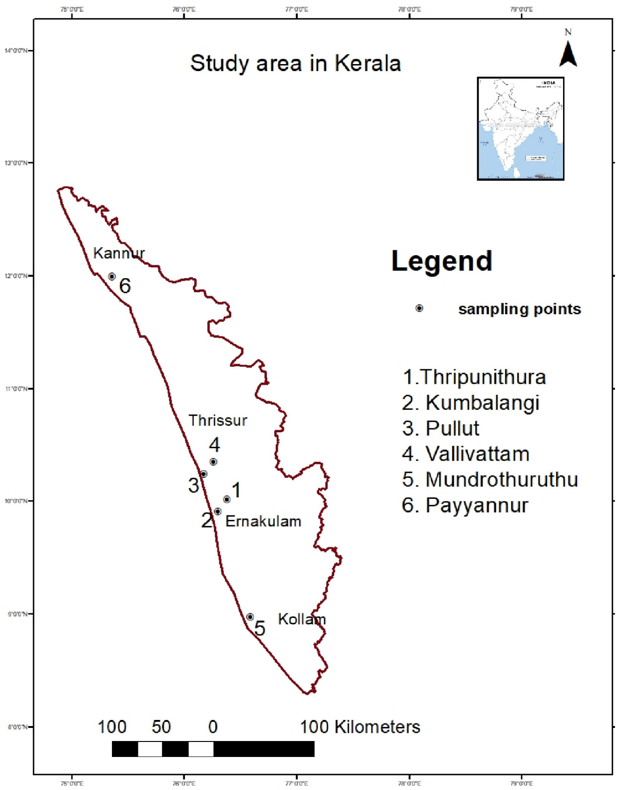

Fig. 1. Location map of research area

There were five treatments and one control with three replications each having stocking densities of 15, 25, 30, 40, 50 and 60 m^{-2} (control). The first two treatments had stocking densities of 15 and 25 m^{-2} respectively which intermittently went through Autotrophic and Heterotrophic culture techniques in the both crops (T1) while in T2, the system was 'Natural HAAT' in both crops. In Treatment 3, shrimp post larvae were stocked at a density of 30 m^{-2}, with the Autotrophic system in both crops using 'Naulgi'- a patented product for diatom enhancement. In T4, the HAAT system is supported by probiotic bacteria with a stocking density of 40 m^{-2} applying the inocula developed by RGCA and MPEDA. The T5 adopted a stocking density of 50 m^{-2} wherein the Autotrophic and Heterotrophic systems appeared intermittently similar to T1. In control, the same system was followed with a stocking density of 60 m^{-2}.

To evaluate growth performance, 50 shrimps were sampled weekly from each pond starting from the 30th day of culture (DOC) using a cast net. The weight of the shrimps was taken using a top-loading balance with an accuracy of 0.1 g. The growth parameters were calculated according to Robertson et al. (2000), Felix & Sudharsan (2004) and Venkat et al. (2004). The following formulae were used to evaluate the growth of *P. vannamei*.

a. Average daily gain (g) (ADG) =

$$\frac{\text{Final weight (g)}}{\text{Duration of culture (days)}}$$

b. Survival rate % =

$$\frac{\text{No of shrimp harvested}}{\text{No of shrimp stocked}} \times 100$$

c. Feed Conversion Ratio (FCR) =

$$\frac{\text{Total feed fed (dry wt.) (Kg)}}{\text{Total yield (kg)}}$$

Data were presented as the mean± standard error (SE) of triplicates. Statistical analysis was performed using SPSS statistical software (version 20.0). The significant difference between means was determined using Duncan's multiple range test (DMRT). The level of significance was set up at $p \leq 0.05$.

Results and Discussion

Watercolour in ponds usually remain very good and stable during the first 50 days of culture and subsequently changes with an increase in levels of organic matter in the ponds due to the increase in feed inputs for the growing shrimp. Maintaining stable watercolour throughout the culture period requires keen observation and a better understanding of our culture system and so managing the watercolour in ponds is the key to maximizing the profit. It is reported that water with light yellowish green, light green, or light yellowish-brown colour is considered to be the most ideal if maintained throughout the culture period (Manoj M. Sharma, 2019). In Treatment 1, 5 and control, light or bright green colour was quite stable and reported a very good growth rate (autotroph-based culture system) whereas light yellowish-brown colour was reported in Treatment 2, 3 and 4 due to the blooming of diatoms, copepods and rotifer. This type of pond colour is quite difficult to achieve and is also reported to be more nutritious to the shrimp. It is mainly seen in heterotroph-based systems.

The diversity of phytoplankton observed in all experimental ponds were almost similar. It is represents five groups of algae (Bacillariophyta (or Diatom), Chlorophyta, Euglenophyta Dinophyta, and Cyanophyta), which were identified from the treatments throughout the study period. Overall, the most commonly observed genera were shown in Table 1. The Bacillariophyta appeared to be the predominant group followed by Chlorophyta. The other three algal groups had very limited representation.

According to Chinark and Boyd (2010), the increasing primary productivity (chlorophyll content) during culture periods demonstrates the sufficient nutrient for phytoplankton growth in the pond. Chlorophyta predominantly present in the T 1, T 5

Table 1. Phytoplankton with their groups observed in vannamei shrimp farms in Kerala

PHYTOPLANKTON	
	1. Coscinodiscus
	2. *Chaetoceros*
Diatoms	3. *Cyclotella*
Bacillariophyta	4. *Navicula,*
	5. *Nitzschia,*
	6. *Skeletonima,*
	7. *Thalassiosira,*
	8. *Synedia,*
	9. *Tabellaria*
	10. *Pleurosigma*
	1. *Chlorella,*
Green algae	2. *Dunaliella,*
Chlorophyta	3. *Senedesmus,*
	4. *Oocystis,*
	5. *Nanochloropsis*
	6. *Eudorina*
Euglenophyta	1. *Euglena*
	1. *Peridinium,*
Dinoflagellates	2. *Gyrodinium,*
Dynophyta	3. *Ceratium*
	4. *Gymnodium*
	1. *Oscillatoria*
Blue-green algae	2. *Anabaena*
	3. *Microcystis*
Cyanophyta	4. *Spirulina*

and control were previously obtained in the study by Cremen et al. (2007) with similar green watercolour. Meanwhile, the third pond (T 3) dominated by the diatom group (brown colour) was earlier recorded in a similar study conducted by Hadi et al. (2016). Predominant phytoplankton in a shrimp pond may be affected by various water quality parameters including nitrogen and phosphorus ratio. According to Keawtawee et al. (2012) the pond productivity probably not only depends on stocking density, feed administration and water quality but also on the community and biomass of phytoplankton.

In the present culture trial, the diversity of zooplankton did not differ markedly between treatments. The identified zooplankton populations were falling in four orders namely, Copepoda, Rotifera, Cladocera, Ostracoda and miscellaneous crustacean larvae. A total of 14 zooplankton genera were recorded from the culture ponds. Among the collected zooplankton, the order Rotifera with five genera (*Brachionus, Keratella, Lecane, Polyarthra* and *Filinia,* among these *Brachionus* was the dominant genus) was dominant in Treatment 2 and 4, followed by Copepoda (4 genera: *Cyclops*, *Diaptomus*, *Helidiaptomus* and *Mesocyclops,* the first one being the most abundant) predominant in Treatment 1, 3. 5 and control. These ponds had the proliferation of 'Copefloc' (mass abundance of copepods) resulting from the use of fermented rice bran (FRB). Other groups like Cladocera (2 genera: *Diphansoma* and *Daphnia*, the second is being the most abundant), Ostracoda (2 genera: *Cypris* and *Cyclocypris,* both genera were found in small numbers) and mysids (1 genus: *Mesopodopsis* which were found monthly intervals in small numbers). Islam et al. (2007) found that Copepods was a dominant group in two shrimp fields (popularly known as gher) at Khulna, Bangladesh. Maruthanayagam et al. (2003) studied the zooplankton diversity along with the physico-chemical parameters in Thiukkulam pond, Tamilnadu and found a higher density of zooplankton during the rainy season, with copepods forming the dominant group followed by cladocerans, rotifers and ostracods.

Harvest details of first and second crops of *P. vannamei* are given in Table 2 and 3 respectively. Though the culture parameters differ slightly in different ponds due to the difference in culture strategies, the production figures help to have a sensible comparison of various treatments.

The effect of culture techniques and feed management on the Feed Conversion Ratio (FCR) of *P. vannamei* in crops 1 and 2 are shown in Fig. 2. In the present investigation, FCR values do not show any significant difference between the treatments in both the crops. The FCR values were significantly higher in Treatment 4 followed by Treatment 1 and 2 while the lowest FCR was reported in control ponds in both crops. Adoption of innovative culture techniques like the 'HAAT' system must have helped to reduce the FCR by 75% in T4. Valderrama and Engle (2002) found that the FCR values ranged

Table 2. Culture performance of vannamei shrimp in crop 1. Data are presented as mean± standard error (Mean ±SE). Values in the same row having the same superscripts are not significantly different (p>0.05).

Parameters	Treatment1	Treatment2	Treatment3	Treatment4	Treatment5	Control
Area (ha)	1.01	.40	1.05	1.01	.49	.81
SD (nos./m^2)	15	25	30	40	50	60
Total production (Kg)	3850.33^b±10.74	2342.67^a±9.06	7734.33^d±7.45	9499.00^e±18.19	5815.67^c±10.27	9937.33^f±16.83
Average final harvest size(g)	30.05^e±.11	29.40^d±.16	29.04^c±.09	28.37^b±.05	28.27^b±.04	25.90^a±.08
Count (Nos./kg)	33.28^a±.12	33.92^b±.21	34.44^c±.11	35.24^d±.07	35.38^d±.04	38.61^e±.12
Survival (%)	85.42^e±.33	79.68^b±.58	83.24^{cd}±.19	83.70^d±.19	82.29^c±.21	76.73^a±.20
ADG (g)	$.25^c$±.00	$.25^c$±.00	$.24^b$±.00	$.24^b$±.00	$.24^b$±.00	$.22^a$±.00
FCR	1.13^b±.01	1.22^c±.01	1.31^d±.00	$.79^a$±.00	1.41^e±.01	1.59^f±.00
Feed Management Cost (Rs.)	90.42^b±.51	97.49^c±.69	98.00^c±.23	63.54^a±13	112.88^d±.37	119.34^e±.20

Table. 3. Culture performance of vannamei shrimp in crop 2. Data are presented as mean± standard error (Mean ±SE). Values in the same row having the same superscripts are not significantly different (p>0.05).

Parameters	Treatment1	Treatment2	Treatment3	Treatment4	Treatment5	Control
Area (ha)	1.01	.49	.40	1.01	.61	.81
SD (nos./m^2)	15	25	30	40	50	60
Total production (Kg)	4066.00^{c}±14.18	3337.00^{b}±11.93	2913.67^{a}±7.54	9501.67^{e}±10.14	7137.00^{d}±21.66	10835.67^{f}±23.00
Average final harvest size (g)	32.80^{e}±.08	31.74^{d}±.17	29.67^{c}±.09	28.32^{b}±.05	28.25^{b}±.05	26.66^{a}±.10
Count (Nos./kg)	32.86^{a}±.42	30.49^{b}±.16	35.96^{c}±.16	35.32^{c}±.07	35.40^{c}±.07	37.51^{d}±.14
Survival (%)	82.64^{b}±.09	84.12^{c}±.38	81.84^{a}±.29	83.89^{c}±.20	84.28^{c}±.10	81.28^{a}±.14
ADG (g)	.27^{e}±.00	.26^{d}±.00	.25^{c}±.00	.24^{b}±.00	.24^{b}±.00	.22^{a}±.00
FCR	1.17^{b}±.00	1.23^{c}±.01	1.34^{d}±.01	.79^{a}±.00	1.44^{e}±.00	1.59^{f}±.01
Feed Management Cost (Rs.)	93.45^{b}±.23	98.33^{c}±.35	100.50^{d}±.37	65.56^{a}±.31	115.33^{e}±.25	119.22^{f}±.19

from 1.42 to 4.07 in the semi-intensive rearing of *P. vannamei*. Garza de et al. (2004) registered FCR values ranging from 1.97 to 2.12 for *P. vannamei* cultured at stocking densities of 10, 20 and 30 shrimp m^{-2}.

As it is well known, the feed cost constitutes the major share of the production cost of shrimp. Normally, the feed cost ranges from Rs. 80 to 100 kg^{-1} shrimp in all types of farming systems practiced in Kerala. Feed management cost is the feed cost to produce 1 kg of shrimp. Balakrishnan et al. (2011) reported that feed cost was the major share in the production cost representing as high as 50.39% and the net profit was Rs. 78.56 kg^{-1} of shrimp. Kumar et al. (2016) also reported that the feed cost was the highest variable cost representing 38.20% in the total cost of production. The feed management cost of the current study corresponding to crop 1 and crop 2 are given in Fig. 3. The results show that the Feed management cost was the lowest in T4 in both crops with higher values in T1 and T2 and the highest was in control ponds. The highest feed management cost in control ponds might be due to the higher stocking density. Therefore, it can be interpreted that feed management cost has direct linkage with stocking density, pond watercolour, feed management and the adopted culture technique. Even though in Treatment 4, the farmers followed higher stocking density like 40 m^{-2}, it hasn't affected the culture performance due to the adoption of HAAT system

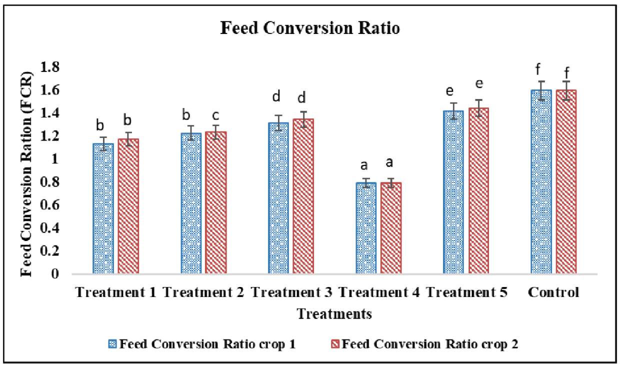

Fig. 2. The effect of cultural technique and feed management on the Feed Conversion Ratio (FCR) of *P. vannamei* in crop 1 and 2. Each bar represents the average value of three determinants with standard error (different letters indicate signicantly different values with p<0.05).

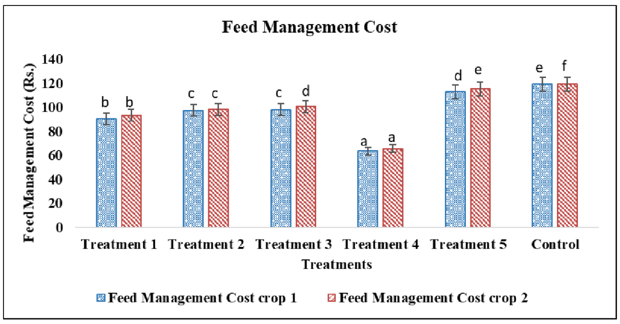

Fig. 3. The effect of different culture techniques on Feed management cost of *P. vannamei* farms in Kerala in crop 1 and crop 2. Each bar represents the average value of three determinants with standard error (different letters denote signicantly different values with p<0.05).

which promotes natural productivity through the effective utilization of zooplankton like selectively reared rotifer species.

It is fact that stable watercolour is the indication of stable water quality parameters in a culture system. If the shrimp is growing in a stress-free environment, it leads to stable growth and sustainable profits. Good and efficient farm management practices are essential to minimize the mortality. Regular use of water and soil probiotics is advised to maintain a good nitrogen cycle in shrimp ponds. Increased efficiency in farm management increases the profitability and makes shrimp farming more sustainable. Improved knowledge of feeding strategies also help to have improved feed utilization which reduces the FCR and waste, thereby reducing negative environmental impacts. The newly developed HAAT system may have the potential to address all of these concerns and should be investigated thoroughly. This will also facilitate culture trials to find out the efficacy of various diatom enhancing products like Naulgi.

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