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Crop Rotation as a Better Sanitary Practice in Culture of *Penaeus monodon* (Fabricius, 1798)

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A B S T R A C T

Crop rotation for disease control in shrimp culture is not yet widely recognized although it is already an established practice in Agriculture, Many researchers used this practice in various species like potato cyst-nematodes. The same practice was followed by researchers. Information about crop rotation in aquaculture is very less and it is yet to be explored. Crop rotation with shrimp and tilopia indicate that the practice reduces diseases incidence in shrimp culture. In addition, crop rotation may be effective in preventing not only bacterial diseases but viral diseases as well to a certain extent as proven in agriculture. Crop rotation is a type of " Sanitation" practice and is an integral part of plant health management.

Introduction

The farming of tiger shrimp (*Penaeus monodon*) contributes significantly to the economy of many countries in the Asia Pacific region. However, in recent years the shrimp farming ponds in many of these countries have declined due to persistent disease problem. Rather than white spot syndrome virus (WSSV), the luminous bacterium *Vibrio harveyi* has been associated with many of the disease out breaks.

Although *V. harveyi* has been considered a part of the normal microflora of shrimp and its environment, certain strains may be more pathogenic than others. When these pathogenic strains are plentiful, they can over whelm the immune system of shrimp, allowing diseases to occur. In naturally diseased *P. monodon*, *V. harveyi* invades the hepatopancreas tubules and causes extensive lesions even in the absence of other pathogen such as baculovirus and parasites (Jiravanichpaisal *et al.*, 1994). *V. harveyi* produces proteases, phospholipases or hemolysins which may play important roles in the pathogenicity of *P. monodon* (Liu *et al.*, 1996).

Continuous culture of shrimp over the past few years might have caused the increase of shrimp-pathogenic *V. harveyi* in the culture systems and related environments. Although many of the farms might have employed thorough pond preparation techniques, these

bacteria would have passed over into succeeding cultures as they are protected by the biofilms. Bacterial biofilms are notably resistant to drying and disinfection (Paclibare *et al.,* 1998). Karunasagar *et al.,* (1996) found that *V. harveyi* can survive in sediments that are treated with high doses of disinfectants.

Because of the difficulty in reducing the concentration of pathogenic bacteria in shrimp ponds by conventional chemical disinfection, other effective means such as biological control should be explored. The additions into the environment of bacterial microorganisms that serve as antagonists of the target pathogens and the manipulation of the environment in such a way that beneficial microorganism are favored to proliferate. Examples of these approaches are the use of probiotics and crop rotation respectively.

Assuming probiotics can reduce pathogenic bacteria in shrimp ponds, the method may still not be cost-effective to small farms because high amounts of the costly probiotic products must be added to the ponds frequently. The second approach, *i.e.,* crop rotation for disease control in shrimp cultures is not yet widely recognized although it is already an established practice in agriculture (Sieczka, 1989; Reeves *et al.,* 1984; Kommendahl and Todd, 1991) and suggested for adoption in shrimp farming.

Crop rotation is a type of "sanitation" practice and is an integral part of plant health management. A sanitation practice should reduce the initial inoculum to a sufficiently low level so that the normal development of disease will not reach a high level to cause appreciable yield loss, provided unusual influx was avoided (Berger, 1977). Crop rotation in shrimp aquaculture is worth exploring and may prove feasible in view of the recent findings on the host specificity/preference of certain strains of *V. harveyi*. Liu *et al.,* (1996) found differences in the pathogenicity of *V. harveyi* isolated from penaeid and non-penaeid sources.

In this present study, finfishes (*Mugil cephalus* and *Chanos chanos*) were cultured between crops of shrimps for crop rotation and the reduction in the incidence of shrimp diseases was observed.

Materials and Methods

The study was carried out in a shrimp farm situated on the Southern banks of Marakkanam (Lat. 12^0 12' 30" N; Long. 79^0 56' 27"E). This shrimp farm has two ponds each with water spread area (WSA) of 1.3 ha. The first crop was a fish culture experiment for 6 months followed by a shrimp culture experiment for 4½ months in one pond and the other pond was used as control and two shrimp culture experiments were carried out.

Pond preparation

Soil culture

Initially the pH of the pond soil was checked and was found to be between 6.0 and 6.5. Required quantity of lime [Ca $(OH)_2$] was applied to increase the pH to 7.2 and the bottom was tilted for oxygenating. The total amount of lime applied was 600 kg per pond. After a week of soil preparation, water from Marakkanam uppanar estuary was pumped in with the help of a 10 HP (Kirloskar) pump.

Water culture

The water was pumped in directly from the source and filtered in an 80 µ mesh filter bag. Initial fertilization was done using cow dung at the rate of 100 kg per hectare and inorganic fertilizers in the ratio of 10:2 (N:P) for fish culture. For shrimp culture, fertilizers were not applied but dosages of dolomite were

added regularly throughout the culture period. Within a period of one week, plankton development could be observed, mainly represented by diatoms.

Stocking

The fish seeds of 5 to 7 g individual weight were collected from the wild and required numbers were sorted out and stocked in the ponds at the rate of 7000 and 8000 numbers of *Mugil cephalus* and *Chanos chanos* respectively in 1.3 ha. For shrimp culture, the seeds were purchased from a reputed fish hatchery (MMR Hatcheries, Marakkanam) and were stocked at a density of 7.7 shrimps / m^2. In the control pond, the shrimps were stocked at the same density.

Feeding

Initial feeding was done using rice bran and groundnut oil cake and during the later stages, a commercial fish feed (Higashimaru feeds India Ltd) was used. The feed was given at 5 % of the body weight regularly. During the early stages, bottom algae and animal cules (*Lab lab*) were allowed to grow, as they serve as an important natural food to the milk fishes.

For shrimp culture, feeding was done using CP feed (Chennai). The feeding schedule was based on the feed chart provided by the manufacturing company. Blind feeding was done for the first 30 days. Later, the feeding was adjusted based on the check tray observation and sampling. Four check trays / pond were installed.

The daily feed ration was divided for 4 feeding, 25% for morning (6.00 AM), 20% for noon (12.00 Noon), 30% for evening (6.00 PM) and 25% for night (1.00 AM) feeding respectively. The feed was broadcast from the dyke during the initial phase and boat feeding followed during the later stages. The same practice was followed in the control pond also (Plates 2 and 3).

Sampling

Random sampling was done every fortnight for fish culture and once in 10 days for shrimp culture, during early hours of the day with a cast net. Five hauls were made in the pond.

The animals caught per haul and their individual weights were recorded. Healthiness, survival rate, average body weight (ABW) and average daily growth (ADG) of the animal was estimated through the samples. The diameter of the cast net used for sampling was 3.3 mts. The area of the net was calculated with 60% efficiency of coverage at the bottom.

Water exchange

Water exchanges were done at the rate of 10 – 15 cm/ day on a weekly once basis for both the cultures and the control experiments.

Water quality assessment

Water quality analysis was done following standard methods mentioned.

Microbial analysis

In this study, sediment and water samples from fish, shrimps and the control experiments separately, were analyzed. Water and sediment samples were taken from the pond with the help of presterilized bottles and polythene bags.

The collected samples were transferred to the laboratory immediately and analyzed within an hour of collection to avoid possible contaminations. Five tube three dilution MPN (Most Probable Number) methods were followed for all the samples. For water sample, 10 ml of unfiltered water was

transferred to double strength Alkaline Peptone Water (APW). Then, 1 ml and 0.1 ml aliquots were transferred to a single strength APW. For analysis of sediment samples, approximately 10 gm of sediment was added to 90 ml of water blank and from the water blank 10 ml, 1 ml and 0.1 ml aliquots were transferred to double strength and single strength APW respectively (Five dilution in five tube method) (U.S. Food and Drug Administration (FDA) bacteriological manual, 1984).

Results and Discussion

Water quality assessment

Temperature

Temperature was found to vary between 28.5 and 32.4^{o}C and 24.3 and 28.1^{o}C during fish and shrimp culture respectively. It ranged between 29.6 and 32.9^{o}C and 25.6 and 29.9^{o}C in control ponds (experiment 1 and 2) respectively (Figs. 1, 2, 3 and 4).

Salinity

During fish culture, salinity ranged from 26 to 42 ppt. the same ranged between 10 to 19 ppt during the shrimp culture experiment. In the control experiments 1 and 2, it ranged from 28.7 to 44 ppt and 12 to 21 ppt respectively (Figs. 5, 6, 7 and 8).

Transparency

Transparency reduced from 95 to 55 cm during fish culture experiment and 95 to 58 cm during shrimp culture experiment. In control experiment 1, it reduced from 90 to 49 cm and in control experiment 2, it reduced from 85 to 55 cm (Figs. 9, 10, 11 and 12).

Dissolved oxygen

The D.O content ranged from 4.1 – 6.2 mg/l during fish culture and 4.2 – 6.1 mg/l during shrimp culture. In the control experiments, the values were from 4.2 to 5.9 and from 4.6 to 6.1 in 1 and 2 respectively (Figs. 13, 14, 15 and 16).

pH

The pH values ranged between 7.2 and 8.1 during fish culture and 7.1 and 8.6 during shrimp culture. In the control experiment 1, the values varied between 7.6 and 8.4 and in the control experiment 2, it ranged between 7.5 and 8.3 (Figs. 17, 18, 19 and 20).

Ammonia

The values of ammonia during fish culture increased from 0.30 to 1.18 ppm. During shrimp culture, the values increased from 0.52 to 1.03 ppm. The values ranged from 0.61 to 1.13 ppm and from 0.70 to 0.99 ppm in the control experiments 1 and 2 respectively (Figs. 21, 22, 23 and 24).

Nitrite

During fish culture, the values of nitrite ranged from 0.0022 to 0.0170 ppm and the values were from 0.0024 to 0.0119 ppm during shrimp culture. In the control experiments 1 and 2, the values were between 0.0026 and 0.0123 ppm and from 0.0034 to 0.0131 ppm respectively (Figs.25, 26, 27 and 28).

Nitrate

Nitrate values ranged between 0.0035 and 0.0157 ppm during fish culture and 0.0035 and 0.0125 ppm during shrimp culture. The values were from 0.0039 to 0.0130 ppm and from 0.0029 to 0.0136 ppm in control experiments 1 and 2 respectively (Figs. 29, 20, 21 and 32).

Phosphate

The values of phosphate ranged from 0.0017 to 0.0116 ppm during fish culture and the same fluctuated between 0.0030 and 0.0098 ppm during shrimp culture. In the control experiment 1, the values ranged from 0.0028 to 0.0097 ppm and in the control experiment 2, the values were between 0.0031 and 0.0102 ppm (Figs. 33, 34, 35 and 36).

Silicate

Silicate ranged between 0.0042 and 0.0128 ppm during fish culture and 0.0065 and 0.0130 ppm during shrimp culture. The values were from 0.0061 to 0.0134 ppm and 0.0059 to 0.0129 ppm in the control experiments 1 and 2 (Figs. 37, 38, 39 and 40).

Microbial analysis

The results from the microbial analysis showed that the population of sucrose positive bacteria both in the water and sediment samples increased during the fish culture experiment ($3.3x10^2$ – $1.1x10^3$ MPN/100ml and $3.8x10^2$ – $1.4x10^3$ MPN/100mg in water and sediment respectively). The sucrose negative bacterial population was more or less stable throughout the culture period ($2.6x10^2$ – $4.6x10^2$ MPN/100ml and $5.6x10^2$ – $8.4x10^2$ MPN/100mg in water and sediment respectively) (Table 1). During the shrimp culture experiment, there was a gradual reduction in the population of sucrose positive bacteria ($4.5x10^2$ – $3x10^2$ MPN/100ml and $6.2x10^2$ – $3x10^2$ MPN/100mg in water and sediment samples respectively) and an increase in the population of sucrose negative bacteria ($3.3x10^2$ – $1.1x10^3$ MPN/100ml and $4.6x10^2$ – $1.3x10^3$ in water and sediment samples respectively) (Table 2). In the control experiment 1, the population of sucrose positive bacteria in the water sample was found to be reducing from $3.2x10^2$ to $2.3x10^2$ MPN/100ml, whereas the population of sucrose negative strain increased from $4.3x10^2$ to $1.4x10^3$ MPN/100ml. In sediment samples, the sucrose positive bacterial populations ranged between $2.4x10^2$ and $3.4x10^2$ MPN/100gm. The sucrose negative populations increased from $4.8x10^2$ to $1.5x10^3$ MPN/100gm (Table 3). In the control experiment 2, the population of sucrose positive bacteria in the water sample was found to be reducing from $3.4x10^2$ to $2.4x10^2$ MPN/100ml, whereas the population of sucrose negative strain increased from $4.8x10^2$ to $8.6x10^2$ MPN/100ml. In sediment samples, the sucrose positive bacterial populations ranged between $2.6x10^2$ and $3.6x10^2$ MPN/100gm. The sucrose negative populations increased from $6.1x10^2$ to $1.6x10^3$ MPN/100gm. The control experiment 2 was terminated on 96^{th} DOC due to high mortalities due to *Vibrio*sis (Table 4).

Performance of the cultured organisms

In the crop rotation experiment, the total production of fishes (*Mugil cephalus* and *Chanos chanos*) was 1308.6 kg in 180 days. The ABW of *Mugil cephalus* and *Chanos chanos* was 108 g and 153 g respectively. In shrimp culture in the same pond after fish culture, the production of shrimp was 2557.5 kg with a survival of 75% in 130 days with an ABW and ADG of 34.1g and 0.26g respectively.

In the control pond (continuous shrimp culture), shrimp production during the first and second crops was 1696.5 and 1043.1 kg respectively with a corresponding survival rate of 56 and 57 %. However, in the control pond, during the second crop, culture could not be extended beyond 90 days, due to bacterial problems (Table 5, 6, 7, 8 and 9).

Table.1 *Vibrio* population in fish culture pond

Days Of Culture	Water sample		Sediment sample	
	Sucrose positive MPN/100 ml	Sucrose negative MPN/100 ml	Sucrose positive MPN/100g	Sucrose negative MPN/100g
10	$3.3X10^2$	$2.6X10^2$	$3.8X10^2$	$5.8X10^2$
20	$3.3X\ 10^2$	$3.2X10^2$	$3.9X10^2$	$7.6X10^2$
30	$3.9X\ 10^2$	$3.2X10^2$	$4.5X10^2$	$6.4X10^2$
40	$4.0X10^2$	$4.4X10^2$	$3.8X10^2$	$8.4X10^2$
50	$4.7X10^2$	$3.1X10^2$	$4.4X10^2$	$7.0X10^2$
60	$5.4X10^2$	$2.6X10^2$	$4.7X10^2$	$4.9X10^2$
70	$5.4X10^2$	$3.0X10^2$	$5.9X10^2$	$6.2X10^2$
80	$6.2X10^2$	$4.6X10^2$	$6.2X10^2$	$6.9X10^2$
90	$6.4X10^2$	$4.2X10^2$	$6.9X10^2$	$5.6X10^2$
100	$5.4X10^2$	$3.2X10^2$	$7.6X10^2$	$6.4X10^2$
110	$7.6X10^2$	$4.4X10^2$	$8.4X10^2$	$7.2X10^2$
120	$7.6X10^2$	$3.8X10^2$	$8.4X10^2$	$6.9X10^2$
130	$8.4X10^2$	$3.3X10^2$	$9.5X10^2$	$5.9X10^2$
140	$8.4X10^2$	$3.9X10^2$	$1.1X10^3$	$6.4X10^2$
150	$9.5X10^2$	$3.9X10^2$	$1.3X10^3$	$7.0X10^2$
160	$1.1X10^3$	$4.4X10^2$	$1.4X10^3$	$6.4X10^2$
170	$1.1X10^3$	$3.6X10^2$	$1.4X10^3$	$7.6X10^2$

Table.2 *Vibrio* population in Shrimp culture pond

Days Of Culture	Water sample		Sediment sample	
	Sucrose positive MPN/100 ml	Sucrose negative MPN/100 ml	Sucrose positive MPN/100g	Sucrose negative MPN/100g
10	$4.5X10^2$	$3.3X10^2$	$4.5X10^2$	$4.5X10^2$
20	$6.2X\ 10^2$	$4.6X10^2$	$6.2X10^2$	$4.8X10^2$
30	$5.8X\ 10^2$	$4.3X10^2$	$5.8X10^2$	$5.8X10^2$
40	$5.4X10^2$	$5.8X10^2$	$5.4X10^2$	$4.6X10^2$
50	$5.2X10^2$	$6.4X10^2$	$5.2X10^2$	$7.0X10^2$
60	$4.8X10^2$	$7.2X10^2$	$4.8X10^2$	$8.1X10^2$
70	$4.7X10^2$	$7.6X10^2$	$4.7X10^2$	$8.1X10^2$
80	$4.5X10^2$	$7.6X10^2$	$4.5X10^2$	$8.4X10^2$
90	$3.9X10^2$	$7.6X10^2$	$3.9X10^2$	$9.5X10^2$
100	$4.2X10^2$	$8.1X10^2$	$4.2X10^2$	$1.1X10^3$
110	$3.6X10^2$	$8.4X10^2$	$3.6X10^2$	$1.1X10^3$
120	$3.6X10^2$	$9.5X10^2$	$3.6X10^2$	$1.2X10^3$
130	$3.0X10^2$	$1.1X10^3$	$3.0X10^2$	$1.3X10^3$

Table.3 *Vibrio* population in control experiment 1

Days Of Culture	Water sample		Sediment sample	
	Sucrose positive MPN/100 ml	Sucrose negative MPN/100 ml	Sucrose positive MPN/100g	Sucrose negative MPN/100g
10	$3.2X10^2$	$4.3X10^2$	$3X10^2$	$4.8X10^2$
20	$3X\ 10^2$	$5.6X10^2$	$3X10^2$	$5.1X10^2$
30	$3X\ 10^2$	$5.3X10^2$	$3X10^2$	$6.2X10^2$
40	$2.9X10^2$	$5.8X10^2$	$3.4X10^2$	$5.9X10^2$
50	$2.8X10^2$	$6.7X10^2$	$3.4X10^2$	$6.8X10^2$
60	$2.5X10^2$	$7.6X10^2$	$2.8X10^2$	$7.9X10^2$
70	$2.5X10^2$	$7.8X10^2$	$2.6X10^2$	$8.4X10^2$
80	$2.7X10^2$	$8.4X10^2$	$3X10^2$	$9.6X10^2$
90	$2.4X10^2$	$8.4X10^2$	$2.9X10^2$	$1.1X10^3$
100	$2.4X10^2$	$8.8X10^2$	$2.5X10^2$	$1.3X10^3$
110	$2.3X10^2$	$9.6X10^2$	$2.5X10^2$	$1.4X10^3$
120	$2.5X10^2$	$1.2X10^3$	$2.4X10^2$	$1.3X10^3$
130	$2.3X10^2$	$1.4X10^3$	$2.6X10^2$	$1.5X10^3$

Table.4 *Vibrio* population in control experiment 2

Days of Culture	Water sample		Sediment sample	
	Sucrose positive MPN/100 ml	Sucrose negative MPN/100 ml	Sucrose positive MPN/100g	Sucrose negative MPN/100g
10	$3.4X10^2$	$4.8X10^2$	$3.6X10^2$	$6.1X10^2$
20	$3.8X10^2$	$5.4X10^2$	$3.6X10^2$	$6.8X10^2$
30	$3.6X10^2$	$5.8X10^2$	$3.8X10^2$	$7.3X10^2$
40	$2.8X10^2$	$6.4X10^2$	$3.6X10^2$	$8.6X10^2$
50	$2.9X10^2$	$6.9X10^2$	$3.4X10^2$	$9.7X10^2$
60	$2.7X10^2$	$7.6X10^2$	$2.9X10^2$	$1.4X10^3$
70	$2.7X10^2$	$8.2X10^2$	$2.6X10^2$	$1.4X10^3$
80	$2.7X10^2$	$8.6X10^2$	$2.8X10^2$	$1.6X10^3$
90	$2.4X10^2$	$8.6X10^2$	$2.7X10^2$	$1.6X10^3$

Table.5 Growth and Survival of Mullets (*Mugil cephalus*)

Days of Culture	Survival %	ABW (gm)	ADG (gm)	Biomass (kg)
15	85	15	1.0	89.25
30	83	22	0.73	127.82
45	81	26	0.57	147.42
60	80	31	0.51	173.60
75	79	40	0.53	221.20
90	77	48	0.53	258.72
105	75	54	0.51	283.50
120	73	68	0.56	347.48
135	70	76	0.56	372.40
150	68	86	0.57	409.36
165	65	95	0.57	432.25
180	63	108	0.6	476.28

Table.6 Growth and Survival of Milk Fish (*Chanos chanos*)

Days of Culture	Survival %	ABW (gm)	ADG (gm)	Biomass (kg)
15	90	20	1.3	144
30	87	28	0.93	194.88
45	85	33	0.73	224.40
60	82	37	0.61	242.72
75	82	51	0.68	334.56
90	80	67	0.74	428.80
105	77	76	0.72	468.16
120	76	88	0.73	535.04
135	74	100	0.74	592.00
150	72	120	0.8	691.20
165	70	136	0.82	761.60
180	68	153	0.85	832.32

Table.7 Growth and Survival of the Shrimp (*P. monodon*)

Days of Culture (DOC)	Survival %	ABW (gm)	ADG (gm)	Biomass (kg)
40	95	6.2	0.15	589.0
50	90	8.5	0.23	765.0
60	90	11.7	0.32	1053.0
70	85	14.0	0.23	1190.0
80	84	17.5	0.35	1470.0
90	82	21.2	0.35	1738.4
100	80	24.0	0.28	1920.0
110	79	27.2	0.32	2148.8
120	75	30.2	0.30	2265.0
130	75	34.1	0.26	2557.5

Table.8 Growth and Survival of the Shrimp (*P. monodon*) in control experiment 1

Days of Culture (DOC)	Survival %	ABW (gm)	ADG (gm)	Biomass (kg)
40	85	5.9	0.14	501.5
50	83	7.8	0.15	647.4
60	80	10.9	0.18	872.0
70	75	13.8	0.19	0.35.0
80	72	16.1	0.2	1159.2
90	69	20.2	0.22	1393.8
100	65	23.6	0.23	1534.0
110	63	26.1	0.26	1644.3
120	60	28.2	0.23	1692.0
130	56	30.3	0.23	1696.5

Table.9 Growth and Survival of the Shrimp (*P. monodon*) in control experiment 2

Days of Culture (DOC)	Survival %	ABW (gm)	ADG (gm)	Biomass (kg)
40	80	5.6	0.14	448.0
50	72	6.9	0.13	496.8
60	68	9.2	0.15	625.6
70	65	12.6	0.18	819.0
80	60	15.8	0.19	948.0
90	57	18.3	0.19	1043.1

Fig.1 Range of temperature during fish culture experiment

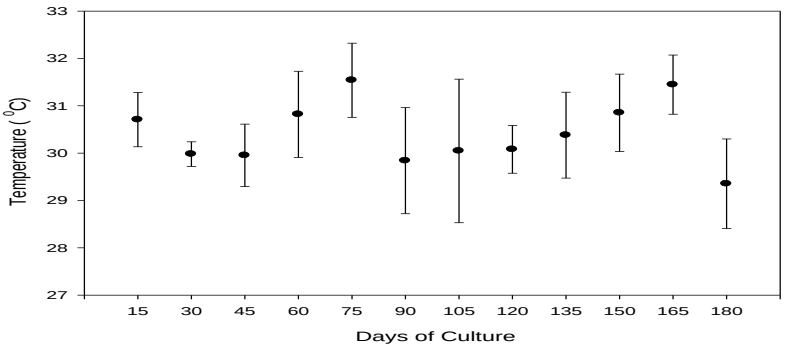

Fig.2 Range of temperature during shrimp culture experiment

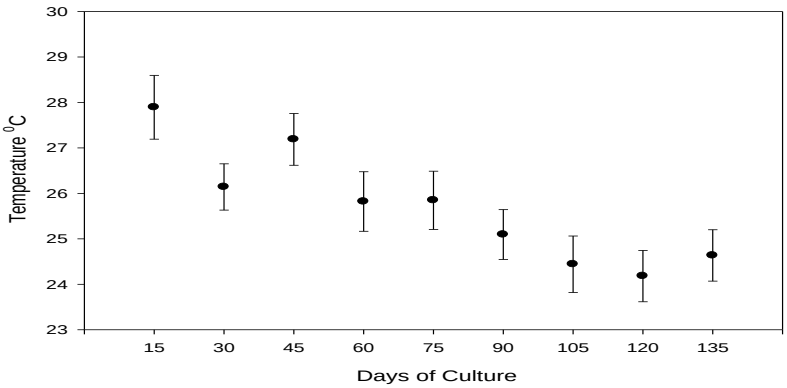

Fig.3 Range of temperature during shrimp culture control experiment 1

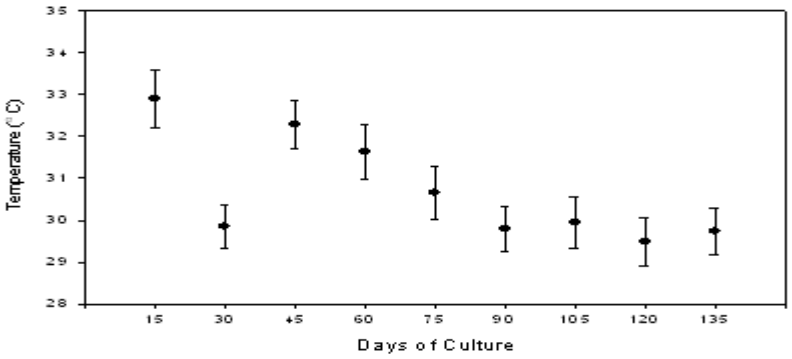

Fig.4 Range of temperature during shrimp culture control experiment 2

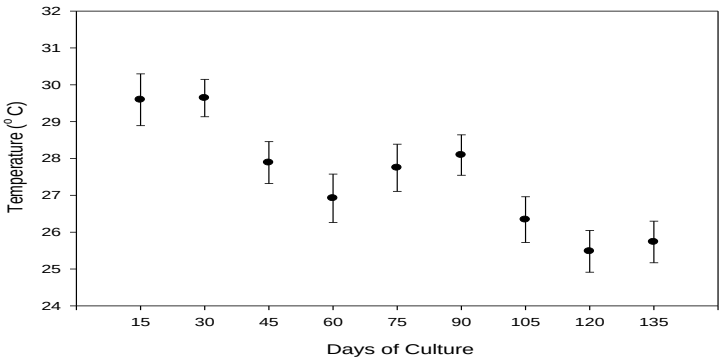

Fig.5 Range of salinity during fish culture experiment

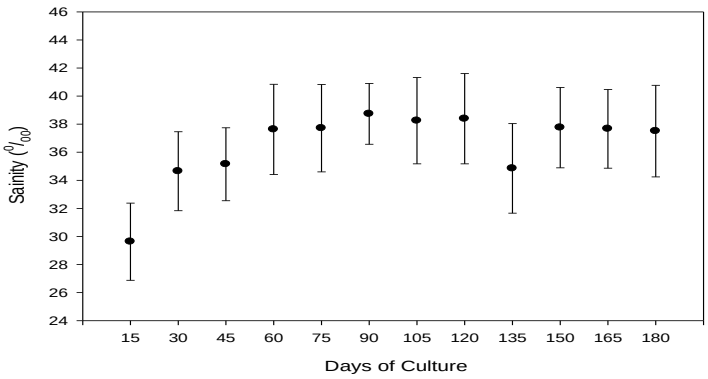

Fig.6 Range of salinity during shrimp culture experiment

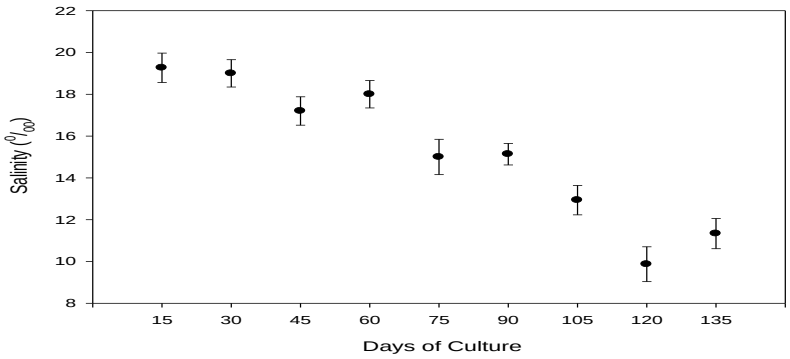

Fig.7 Range of salinity during shrimp culture control experiment 1

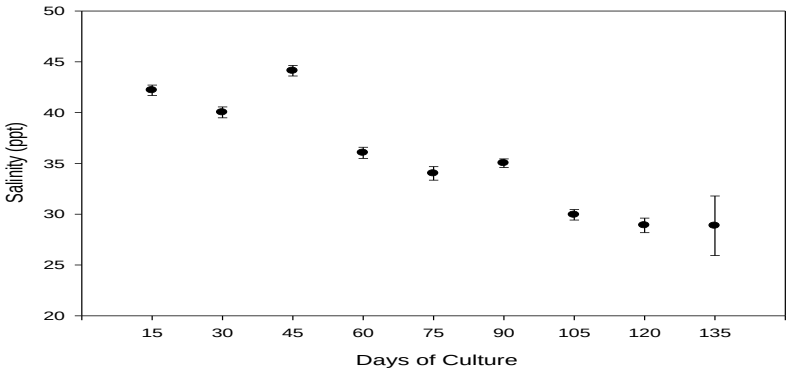

Fig.8 Range of salinity during shrimp culture control experiment 2

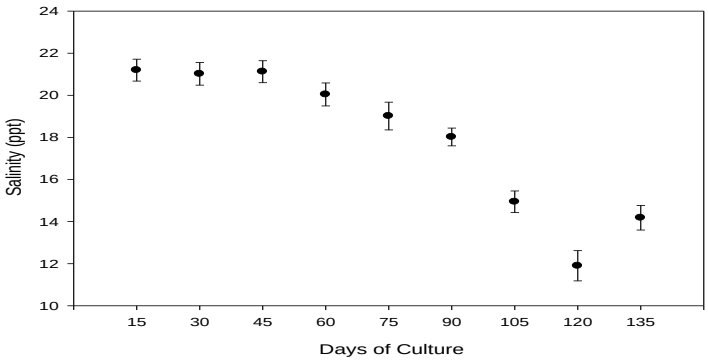

Fig.9 Range of transparency during fish culture experiment

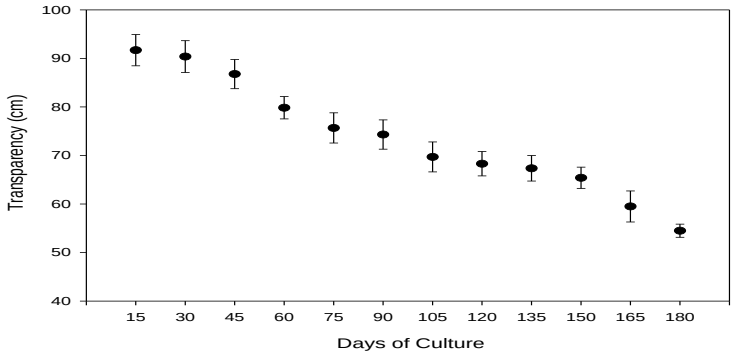

Fig.10 Range of transparency during shrimp culture experiment

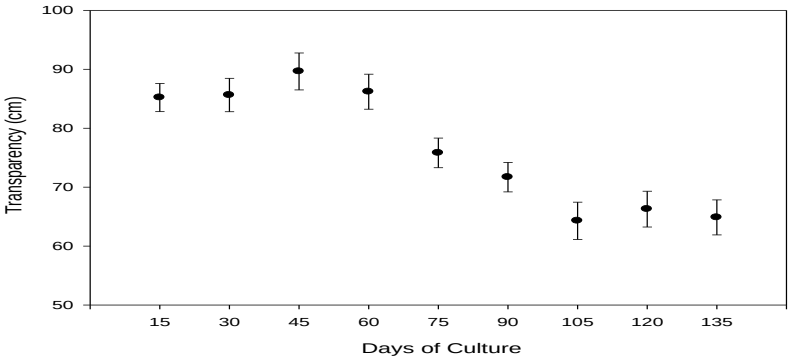

Fig.11 Range of transparency during shrimp culture control experiment 1

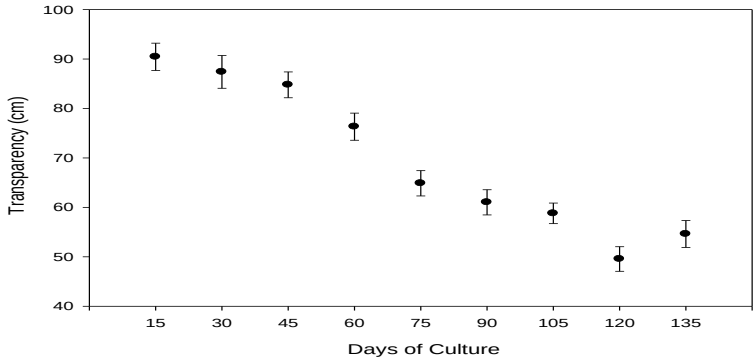

Fig.12 Range of transparency during shrimp culture control experiment 2

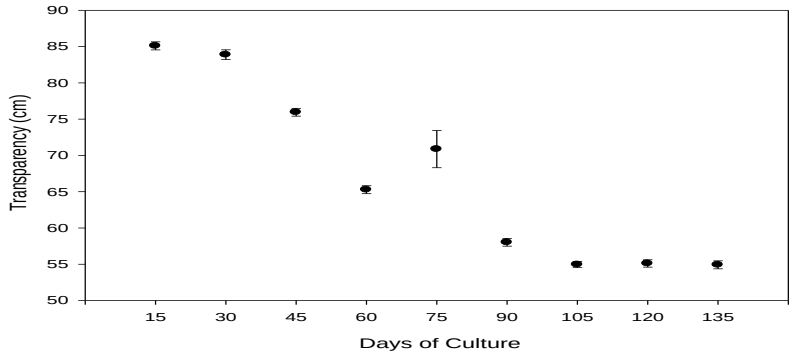

Fig.13 Range of DO during fish culture experiment

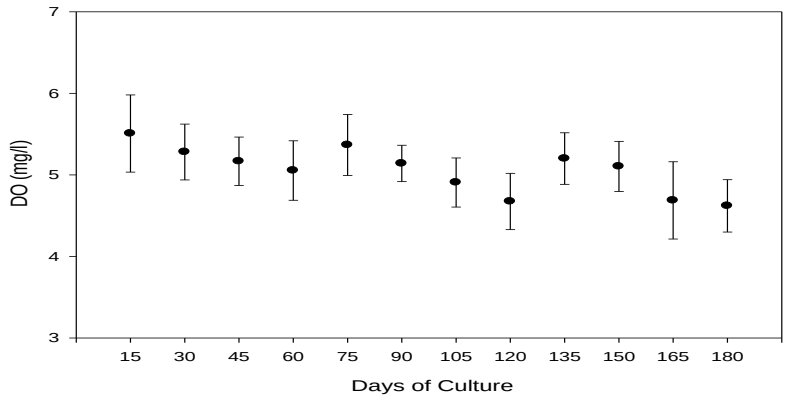

Fig.14 Range of DO during shrimp culture experiment

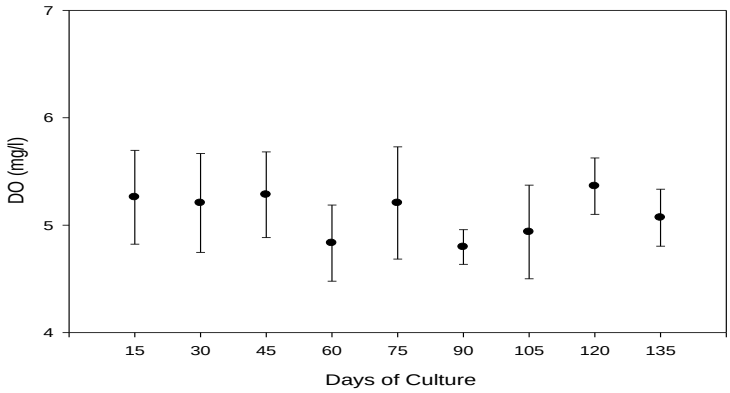

Fig.15 Range of DO during shrimp culture control experiment 1

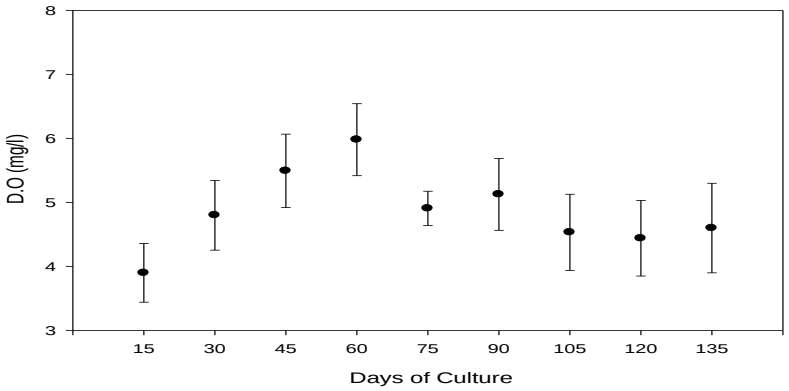

Fig.16 Range of DO during shrimp culture control experiment 2

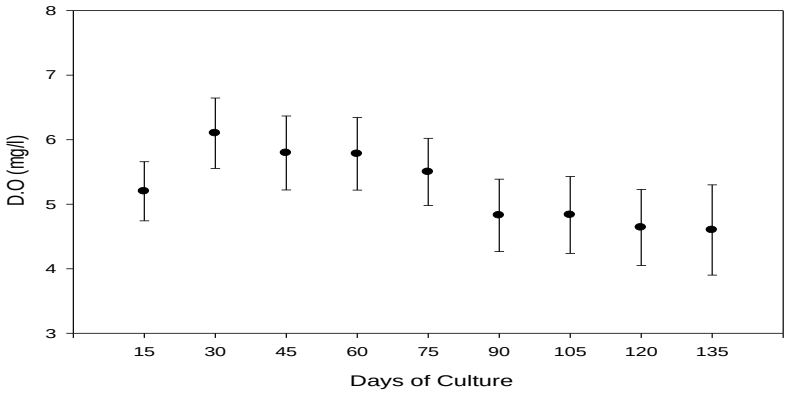

Fig.17 Range of pH during fish culture experiment

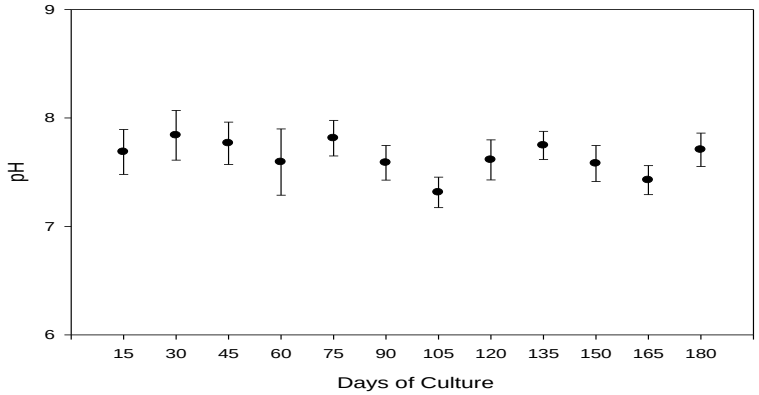

Fig.18 Range of pH during shrimp culture experiment

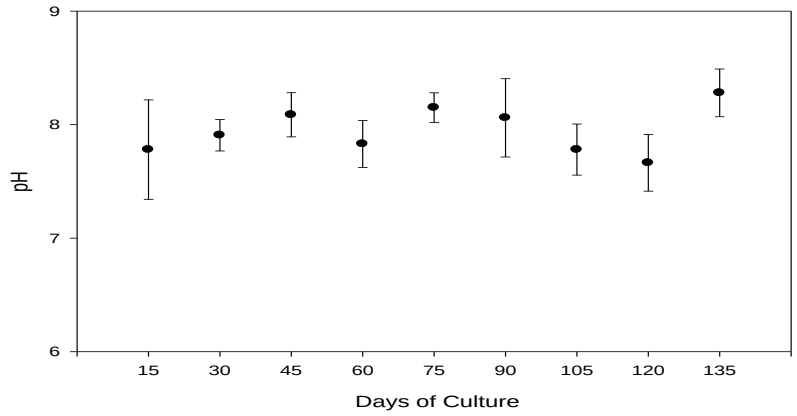

Fig.19 Range of pH during shrimp culture control experiment 1

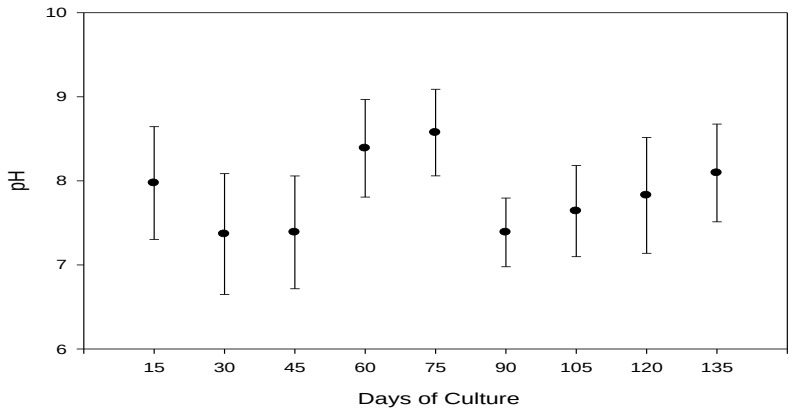

Fig.20 Range of pH during shrimp culture control experiment 2

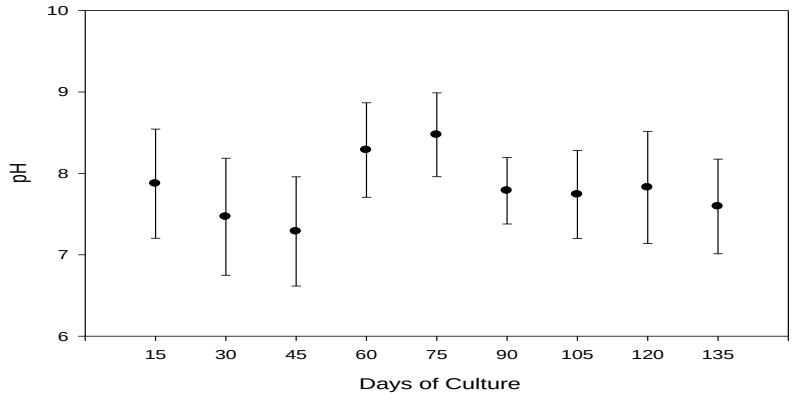

Fig.21 Range of ammonia during fish culture experiment

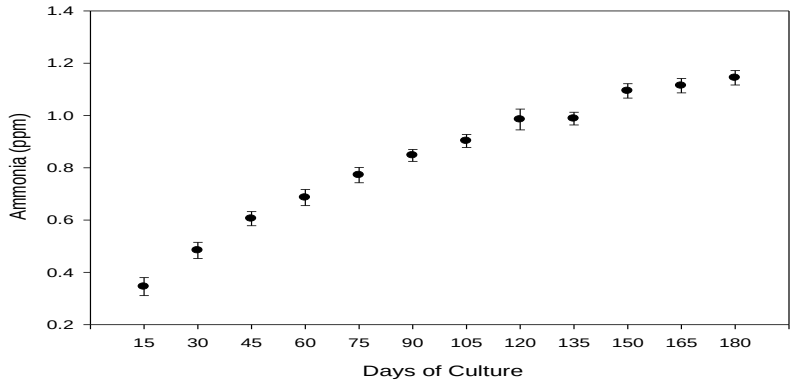

Fig.22 Range of ammonia during shrimp culture experiment

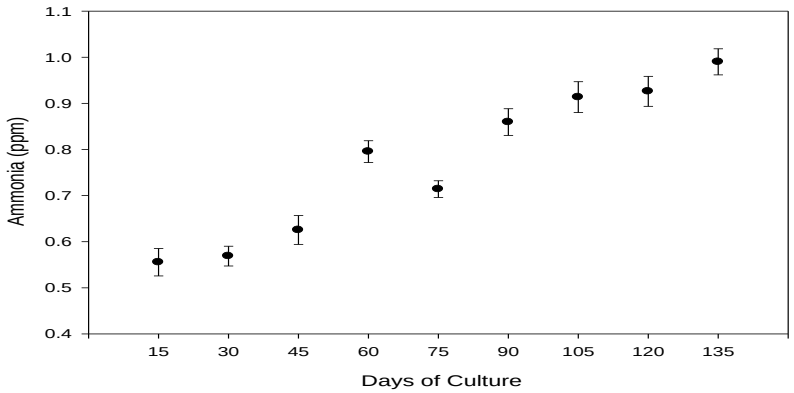

Fig.23 Range of ammonia during shrimp culture control experiment 1

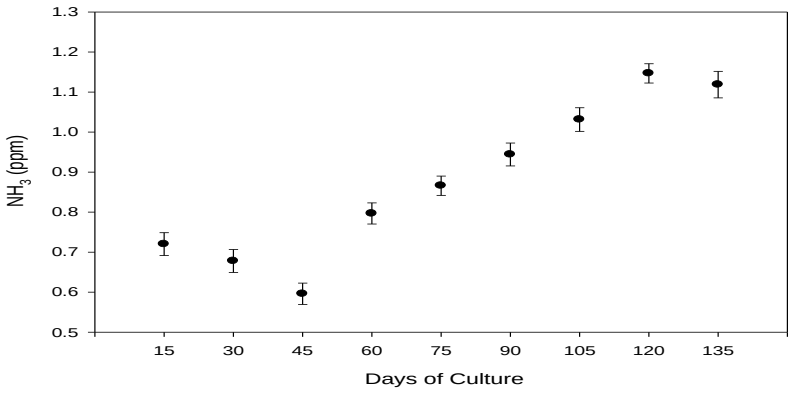

Fig.24 Range of ammonia during shrimp culture control experiment 2

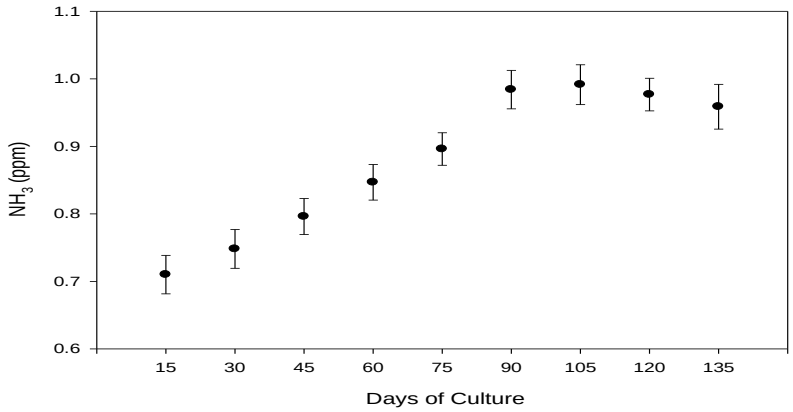

Fig.25 Range of nitrite during fish culture experiment

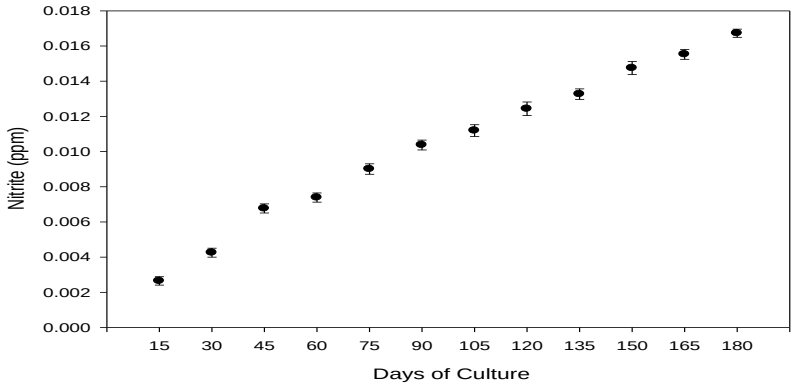

Fig.26 Range of nitrite during shrimp culture experiment

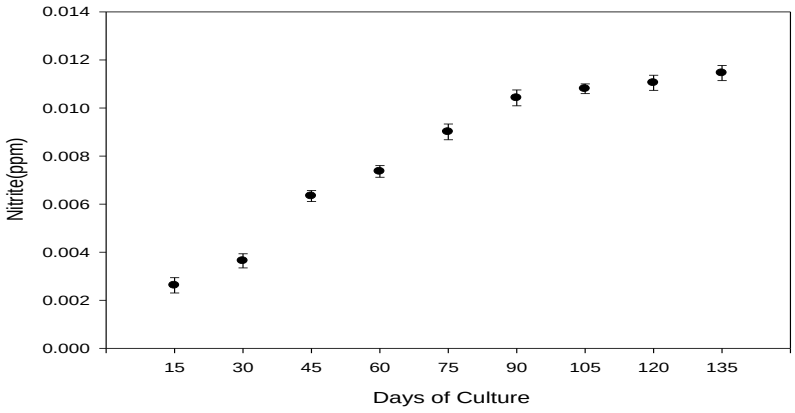

Fig.27 Range of nitrite during shrimp culture control experiment 1

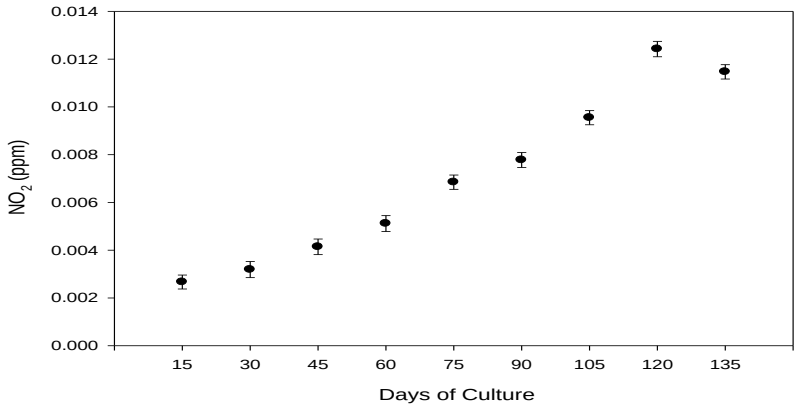

Fig.28 Range of nitrite during shrimp culture control experiment 2

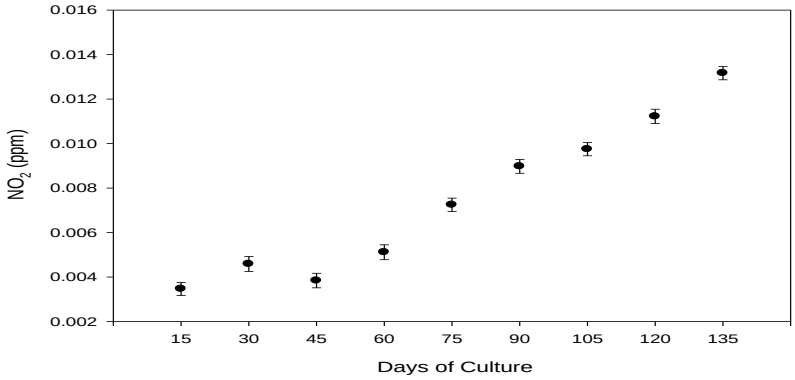

Fig.29 Range of nitrate during fish culture experiment

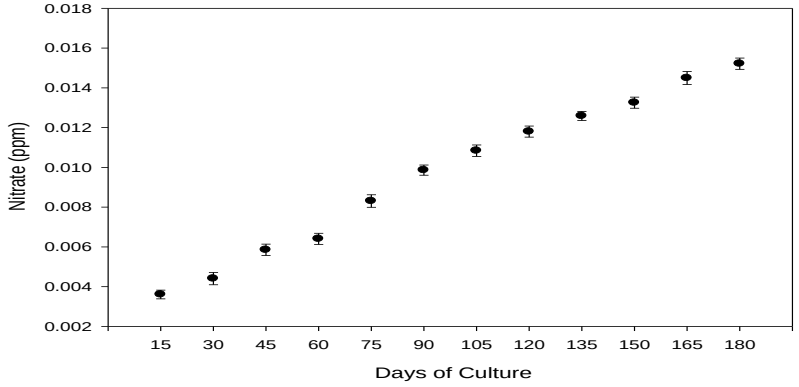

Fig.30 Range of nitrate during shrimp culture experiment

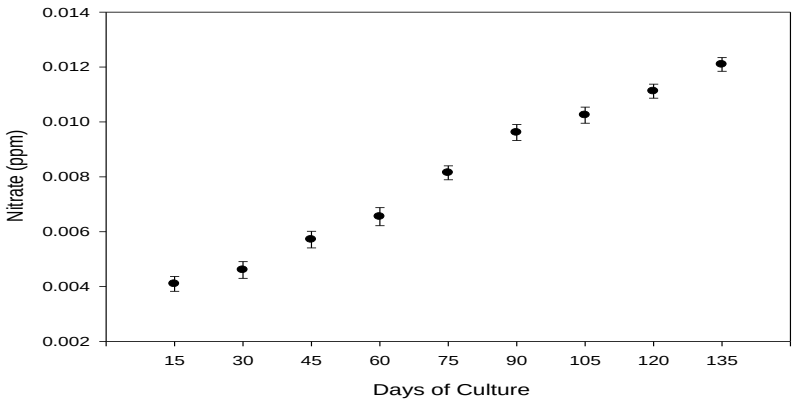

Fig.31 Range of nitrate during shrimp culture control experiment 1

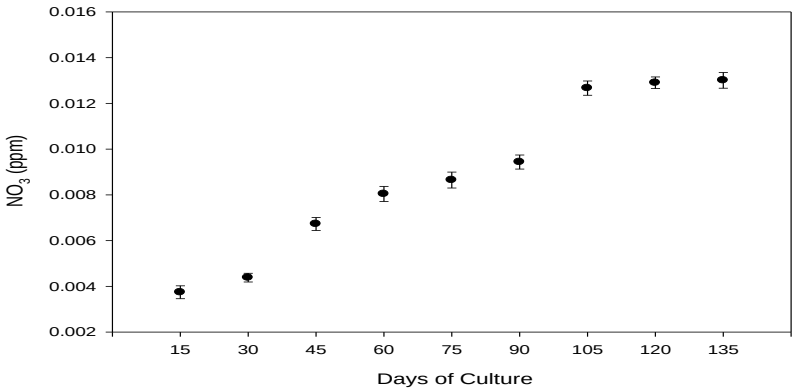

Fig.32 Range of nitrate during shrimp culture control experiment 2

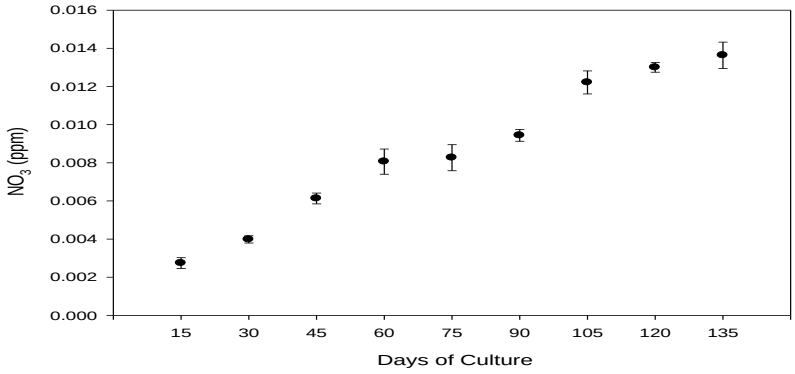

Fig.33 Range of phosphate during fish culture experiment

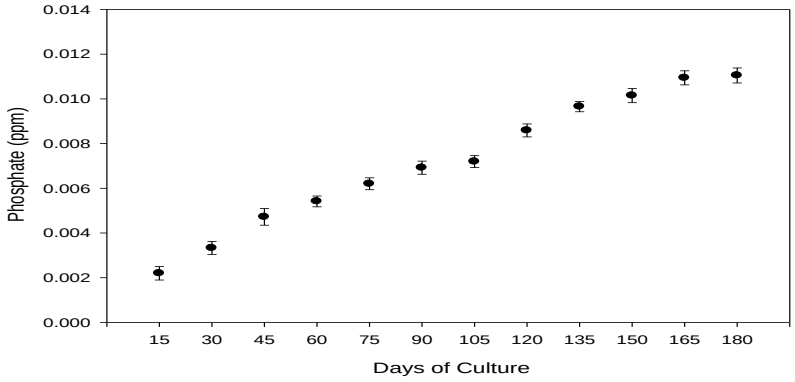

Fig.34 Range of phosphate during shrimp culture experiment

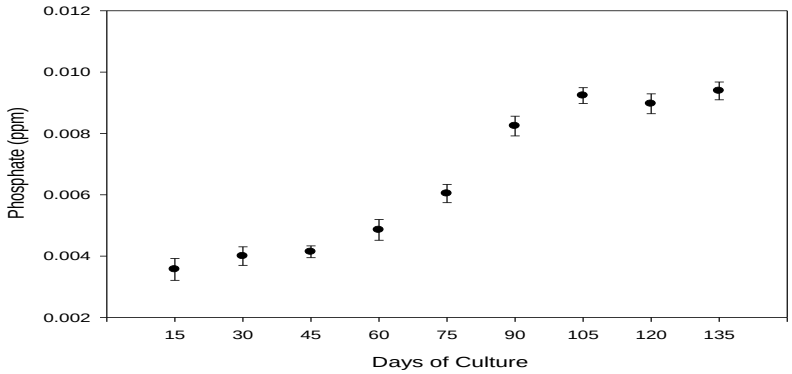

Fig.35 Range of phosphate during shrimp culture control experiment 1

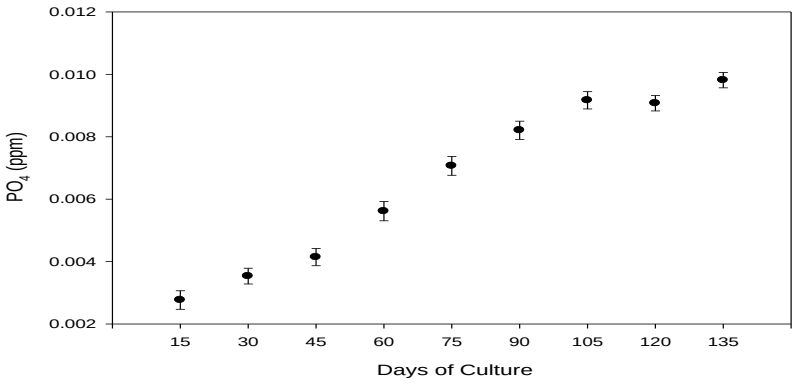

Fig.36 Range of phosphate during shrimp culture control experiment 2

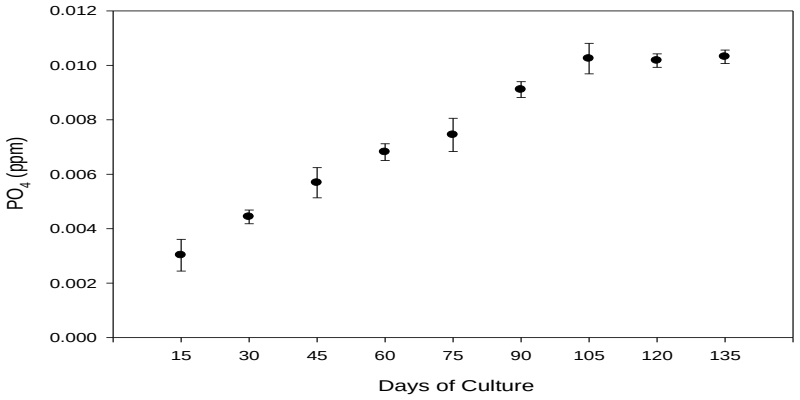

Fig.37 Range of silicate during fish culture experiment

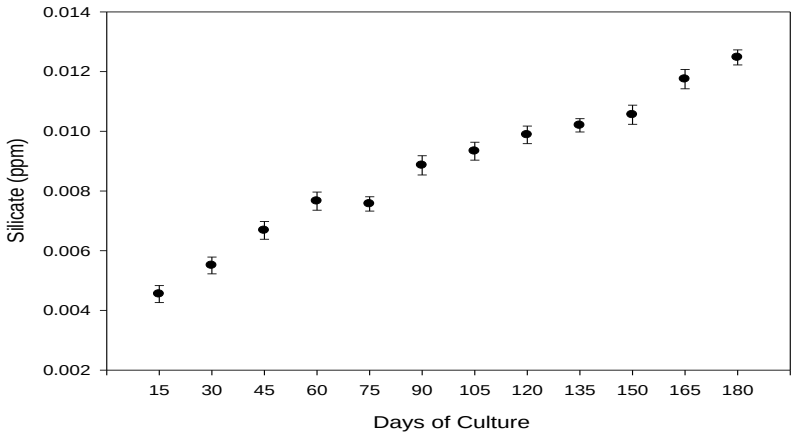

Fig.38 Range of silicate during shrimp culture experiment

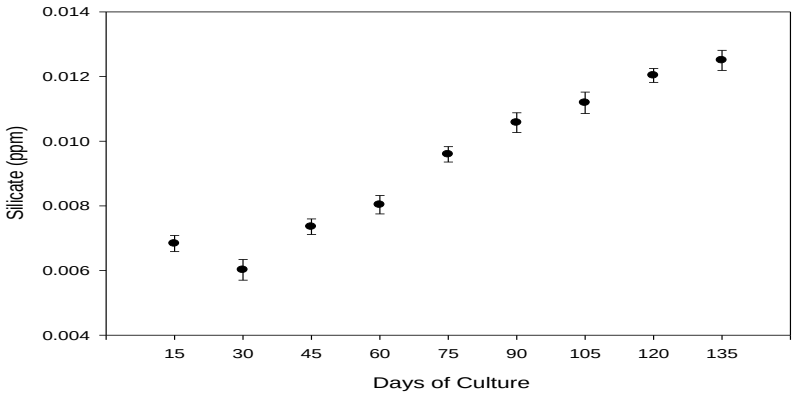

Fig.39 Range of silicate during shrimp culture control experiment 1

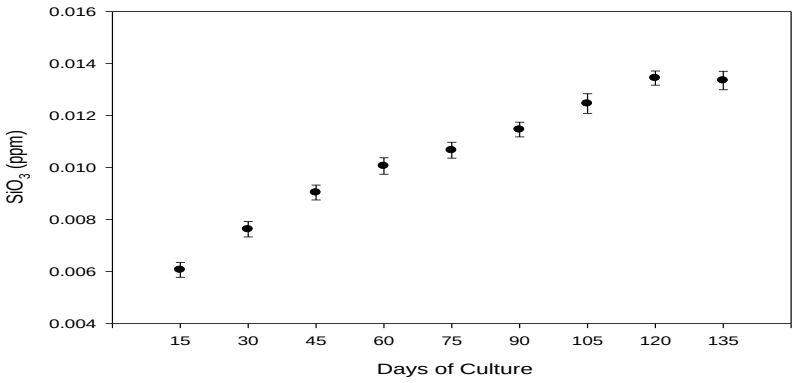

Fig.40 Range of silicate during shrimp culture control experiment 2

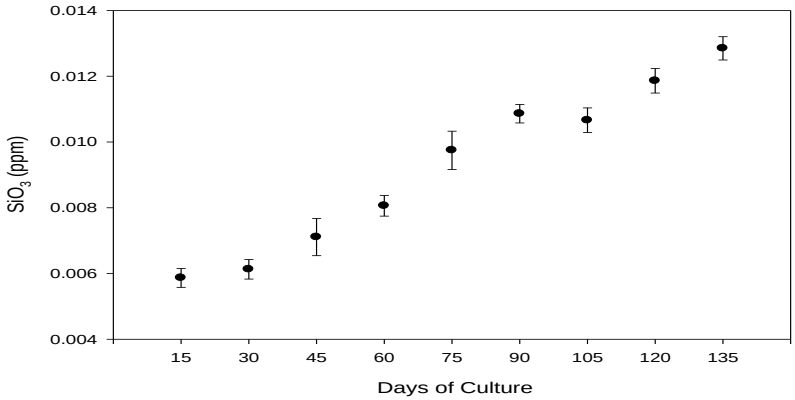

Plate II

View of the Experimental ponds

Shrimp feed used

Plate II

View of shrimps in the check tray

Harvesting of shrimps Harvested mullets

Harvested milk fishes Harvested shrimps

Water quality parameters

In shrimp culture, the water quality can be defined as the suitability of water for the survival, growth and production of shrimps. Hence to ensure a good water quality, the water quality parameters were monitored and accordingly, regular water exchange was done during the present experiment.

The water temperature is a major environmental factor that affects the growth and survival of any aquatic organism. In the present fish culture experiment, the water temperature of 28.5 to 32.4 ^{o}C had no harmful effect. In the case of warm water fishes the maximum metabolic activity was seen at 30 to 35^{o}C (Beamish and Dickie, 1967; Fry and Hart, 1984). In the light of this, temperature was favourable for the stocks in the pond with minor variations between unit times.

In the present experiment, the pH varied from 7.2 to 8.1, which had positive effect on the activity of the fishes, as also reported by Huet (1975) who observed that the pH range of 7.0 to 8.0 (neutral or slightly alkaline) is best for fish culture. The present finding is in close agreement with those of Huet (1975).

The master environmental factor of salinity, during the experiment was ranging from 26 to 42 ppt. In spite of salinity values higher than 35 ppt in certain occasions, there was no adverse effect since the mullets and milkfishes can tolerate wide range of salinities as euryhaline species (Bardach *et al.,* 1972). The food intake, growth rate, food conversion and protein synthesis have been found to be affected by ambient oxygen level (Medale, 1985). In the present study, the dissolved oxygen values were fluctuated from 4.1 to 6.2 mg/l, the needs of the stocked stocks in the ponds without any stress for want of dissolved oxygen.

The microbial analysis during the present study indicates that there was an increase in the population of sucrose positive bacteria, mainly *Vibrio*, during the fish culture experiment, which may be attributed to the addition of carbon rich diets, such as rice bran and groundnut oil cake and in the case of the shrimp culture experiment, the populations of sucrose negative bacteria increased. In the experimental pond 2, the pathogenicity of sucrose negative strains went to the extent of termination of the experiment**.** Paclibare *et al.,* (1998) stated that *V. harveyi* have two major biotopes, namely the sucrose positive and sucrose negative forms. Most of the pathogenic strains of *V. harveyi* of shrimp are sucrose negative while the sucrose positive strains are benign and even used as probiotics (Owens *et al.,* 1996). Paclibare *et al.,* (1998) observed that the sucrose positive *Vibrio*sis usually dominate ponds of healthy tilapia and also noted that, crop rotation of shrimps and tilapia reduces disease incidence in shrimp culture. The greater phylogenetic differences between the cultured organisms used in crop rotation, the better sanitary effects have been experimented (Francis and Clegg, 1990). In this experiment, the shrimp crop rotated with mullets and milkfishes, which belong to different orders within the animal kingdom, resulted in rewarding crop, in the same culture system.

The performance of shrimp in experimental pond, after the crop of fish culture, was remarkably good. While comparing the performance of shrimps in the experiment pond and control pond, experimental shrimp pond yield was interesting with 695.3 kg of more production, similarly survival rate was 25% higher, ABW was 2.9 g higher and ADG was 0.16 gm higher for 90 days of culture. These results clearly establish the advantages of crop rotation with fish than continuous culture of shrimps in the same system. Further, it is to be stressed that in the

experimental pond, shrimp culture was possible upto 130 days due to previous fish culture, while, the shrimp crop could not continue beyond 90 days in the continuous shrimp culture pond due to severe bacterial disease and mortality.

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