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Review Article

Mineral Fortified Inland Low Saline Water for Shrimp Culture

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Abstract

India has the largest aquaculture sector in the world. The shrimp culture also plays a significant contribution to the economy. Due to natural and anthropogenic activities, salinization and groundwater have been affected and resulted in reduced productivity, loss of fertility thus possess a serious threat to agriculture in India. The water reserve could be used for the production of fish and shellfish. The inland culture of particularly Litopenaeus vannamei is becoming more widespread in some parts of India. Marine shrimp are generally cultured in coastal waters with 15 to 40ppt salinities. Now, shrimp farming of white leg shrimps is being done by successfully using low to medium saline waters (0 to 10 ppt). This inland low saline water requires supplementation of minerals to achieve desired productivity. The ionic supplementation was found effective in improving the growth and normal survival of various marine species.

Keywords: Litopenaeus Vannamei; Minerals; Salinization; Inland Low Saline Water; Supplementation

Introduction

India has the largest aquaculture sector in the world. According to FAO, India was the leading country with about 10.79 million tons of production [14]. It has vast resources due to its long coastline area and hence offers great species of aquatic organisms in different ecological regions of the country. The shrimp culture also plays a significant contribution to the world economy. During the seventies, fishermen were mainly concentrated on catching shrimps due to their export value. Brackish water shrimp farming was started during 1991-94 especially in the coastal districts of India [14]. Now *Litopenaeus vannamei* is pilot-scale species in India that alone contribute more than 80% of aquaculture production. Due to the short culture period, high growth rate and great export value *Litopenaeus vannamei* rapidly expanded in the country [15]. The *Litopenaeus vannamei* is euryhaline can tolerate a wide range of 0.5 to 40 ppt of salinity.

The Physico-chemical parameters of water often limit the production of shrimp. Due to natural and anthropogenic activities, salinization and groundwater have been affected and resulted in reduced productivity, loss of fertility and reduced productivity thus possess a serious threat to agriculture in most parts of India [1]. These water reserves which are affected could be used for the production of fish and shellfish. The inland culture of particularly *Litopenaeus vannamei* is becoming more widespread in some parts of India. Marine shrimp are generally cultured in coastal waters with 15 to 40 ppt salinities. Now, shrimp farming of white leg shrimps is being done by successfully using low to medium saline waters (0 to 10 ppt) from irrigation drains, rivers, etc. [20]. There are different sources of water available for shrimp culture with different salinities and thus possess different ionic compositions. This inland low saline water requires supplementation of minerals to achieve desired productivity [20].

Minerals are important organic substances that play a significant role in an animal body. These are required for maintaining various metabolic activities and provide the raw material for bones, teeth, and exoskeleton of animals [27]. There are about 20 minerals that are essential for the physiological functioning of shrimp. They can be categorized as macro, micro, and trace minerals. Macro mineral mainly include calcium, phosphorus, magnesium, sodium, phosphorous, and chlorines that are required in large quantities in the diet as well as in water. Micro minerals are copper, cobalt, iron, manganese, selenium, iodine, molybdenum, and zinc are required in a small amount. Trace minerals include arsenic, mercury, and vanadium, etc. are required in very few amount. *Litopenaeus vannamei* is cultured in inland low saline water in many areas which have a relatively low amount of minerals thus external supplementation mineral is necessary [25]. The micronutrients have a great effect on immunity, enhance disease resistance and reduce stress in shrimp [40]. They are important constituents of hormones and enzymes. The requirement of these minerals is taken care of through feed, farmers need not to apply them separately.

The mineral composition mainly depends on salinity. Minerals like Calcium, magnesium, sodium, and potassium are more in water with high salinity as compared with low saline water [32]. The Mineral composition of bore-well waters depends on the location and the depth from which water is extracted. Bore wells in coastal areas contain high saline water [37]. Now, shrimp culture has spread to inland saline regions of the country like Rajasthan and Haryana in groundwater. The groundwater is deficient in potassium and Magnesium, unlike coastal area groundwater. Anorexia, poor feed intake, reduced vigor, body cramps, and white muscles in juveniles are common symptoms of mineral deficiency in shrimp [33].

The inland ground low saline water is quite different than seawater mainly in ionic concentration. Potassium concentrations are very low, calcium levels are high and magnesium is highly variable in inland water in comparison to natural seawater. Potassium is the primary cation, plays important role in the activation of the Na^+-K^+-ATPase Pump. Magnesium is also an essential mineral needed for the normal survival and growth of crustaceans. The supplementation of these minerals is necessary to achieve a standard concentration for salinity. The amount of potassium and magnesium required for standard seawater is 320-340 ppm and 590-600 ppm (Davis., *et al.,* 2005). The ionic supplementation was found effective in improving the growth and normal survival of various marine species. The appropriate ratio of calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentration in water is very essential for *Litopenaeus vannamei*. The magnesium level must be three times more than the calcium level. The calcium and magnesium concentration should follow the formula that

- **Calcium (ppm):** Salinity x 11.6
- **Magnesium (ppm):** Salinity x 39.1[14]

Magnesium plays an important role in the metabolism of protein, carbohydrates, and lipids. It is used as cofactors for various enzymes and forms specific enzyme complexes that are necessary for the osmoregulation of shrimp to lower salinity water [16]. Calcium plays an important role in the exoskeleton formation and hardening of the cuticle. It is absorbed from the external environment with the help of gills or gut and transferred to the cuticle by the epidermis. Shrimp undergoes continuous molting, in which they shed their outer shells throughout life as they grow. Molting affects the metabolism, behavior, and reproductive cycle of shrimp directly or indirectly [30]. Calcium ions play a central role in molting and shrimp growth and help to maintain homeostasis [13]. Most farmers in India use the bore well water for shrimp culture. Bore well water contains a high concentration of calcium and magnesium which contribute to the high hardness of water [21]. Excess absorption of calcium by shrimp leads to deposition of minerals on carapace that delays the molting [21]. The mineral deposition on shrimp made the shell rough, stunt the growth, and increase the mortality of shrimps during culture [23]. The growth of shrimp is more affected by ratio differences between the important minerals (Na, K, Ca, and Mg). Mineral deficiency generally occurs in either presence of a lesser amount or not inappropriate. The mineral composition of water is also related to the pH. At neutral pH, mineral availability is maximum [36]. The shrimp farmers have to check water quality parameters fortnightly.

Thus, supplementation of minerals in inland low saline water is required to maintain the culture medium at par inadequate mineral level to shrimp.

- **Importance of minerals for shrimp growth:** Minerals are important organic substances that play a significant role in an animal body. In shrimp culture calcium, magnesium, potassium, and sodium are major ions that play a key role [28]. These are required for maintaining various metabolic activities, osmoregulation, and molting, new shell formation and provide the raw material for bones, teeth, and exoskeleton of animals [2]. The mineral profile of water is very important for shrimp culture. It is difficult to analyze the actual mineral requirement of shrimp due to the variable ionic composition of pond water as the availability of minerals for shrimp is the function of the mineral concentration in water. In pond water, the level of minerals has to be similar to the seawater diluted to the same salinity [6]. The proper ratio of minerals is quite an important factor for preventing mineral deficiency and toxicity in pond water. Generally, the ratio of calcium to magnesium and sodium to potassium is very significant in shrimp culture [3]. Imbalance in proper ratio leads to osmotic stress, reduce growth and survival of shrimp. The preferred ratio of Magnesium to calcium (Mg: Ca) and Sodium to potassium (Na: K) are 3.4:1 and 28:1. In pond water where the ratio of calcium to potassium and Sodium to Potassium is high, the addition of Potassium in low saline water can enhance shrimp growth.

- **Calcium:** Calcium is a divalent cation essential for exoskeleton formation and is mainly sequestered from pond water and feed. It affects the breeding process, digestion, level of oxygen, and proper functioning of muscles, nerves, and heart of shrimp [5]. Calcium and Magnesium mainly contribute to the hardness of water and prevent diurnal variation in the pH of pond water. Calcium ion is not acting as a limiting factor in saline water at salinity 5 ppt to 10 ppt but water with less than 3 ppt salinity generally becomes calcium deficient. The multiplication coefficient for determining the optimum calcium level is 11.6 [14]. The calcium levels in shrimp farms should be monitored regularly as calcium may get settled in the bottom sediments. Calcium supplementation in shrimp farms is generally done by using agricultural lime [8].
- **Magnesium:** Magnesium plays an important role in the metabolism of protein, carbohydrates, and lipids. It is used as cofactors for various enzymes and forms specific enzyme complexes that are necessary for the osmoregulation of shrimp to lower salinity water [16]. Magnesium is also an essential mineral needed for the normal survival and growth of crustaceans. The supplementation of these minerals is necessary to achieve a standard concentration for salinity [19].
- **Potassium:** It is generally present in fewer amounts often ten times low as compared to seawater diluted to the same salinity in inland low saline water. Potassium is an important intracellular cation that play important role in osmoregulation in shrimp by Na+/K+ atpase activity [24]. The multiplication coefficient to quantify the optimum potassium levels at any salinity is 10.7 Potassium ion in the water is absorbed by bottom sediments and potassium level in water gradually drops as days of culture increase [7]. In low saline water, high levels of potassium are maintained as it gets absorbed by bottom sediment. Such a sudden decrease in potassium levels may affect shrimp growth and survival at low salinities.
- **Sodium:** Sodium is the major monovalent ion of extracellular fluids in an animal body and plays a key role in the regulation of osmotic pressure and the maintenance of acid-base balance. It also affects muscle contraction and play important role in the absorption of carbohydrate [9]. Sodium concentration in saline groundwater is not a limiting factor in shrimp farming but the ratio of sodium to potassium is the most important factor for shrimp growth. Shrimp farming in inland low salinity requires the Na+/K+ ratio above 30:1. Antony., *et al.* (2015) [1] had found the Na+/K+ ratio ranges between 25:1 and 45:1 as ideal for shrimp culture at 10 and 15 ppt and a Na+/K+ ratio of 25:1 optimum for farming at 5 ppt.

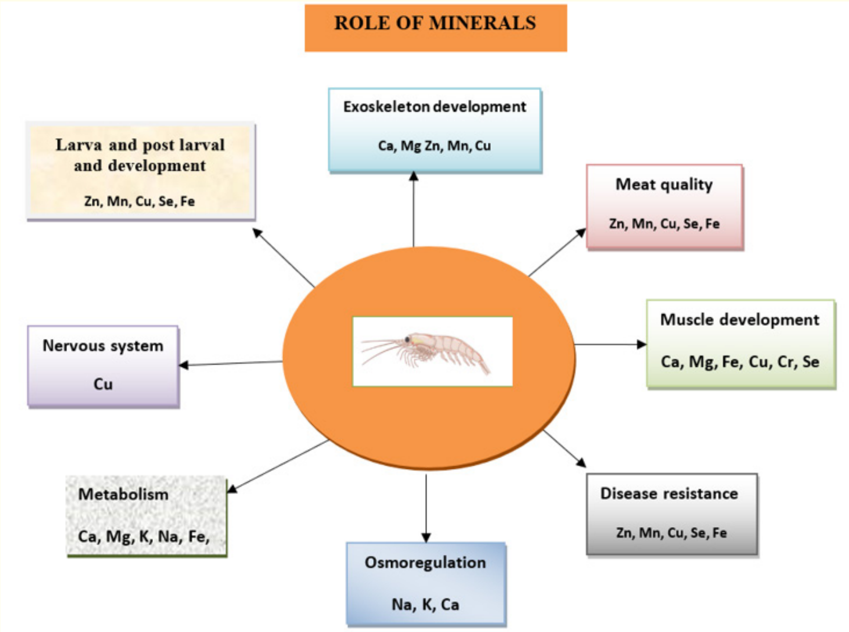

Figure 1: Show Role of different mineral in shrimp growth.

- **Effect of mineral deficiency in vannamei:** In the coastal area there is no need for mineral supplementation in culture. But it was reported that vannamei in low saline water become lethargic and stressful even under normal conditions.
- **Effect of sodium and Potassium deficiency:** The post-larval stage is more tolerant to a wide range of salinity. It was noted that in *L. Vannamei* post larva activation of Na^+/K^+-ATPase activates in less time of about 1 to 3 hours. However, in juvenile shrimp, it takes more time about 3 weeks [17]. The Na^+/K^+-ATPase pump of shrimp is similar to all other animals as it also consists of α-subunit on the upper part and β- subunit on the lower part of the transmembrane protein [42]. With the help of magnesium as a cofactor and, ATP three sodium ion leaves the cell and replace two potassium ions as shown in figure 2. Therefore, it maintains intracellular high potassium and low sodium [26]. The sodium gradient created by the pump acts as a driving force for the sodium-potassium channel that is responsible for the transportation of ions from hemolymph to gills. When shrimp were exposed to low salinity, they hyper-osmoregulate their hemolymph by increasing enzymatic activity of Na^+/K^+-ATPase and gene expression α - subunit increase in the tissues. The level of Na^+/K^+-ATPase activity in shrimp was found to be correlated with their ability to adapt to estuarine habitats [35]. If the ratio of Na/K higher or lower than the optimum level proportion of fat gradually decreased and the consumption of protein increased [12]. Ammonia nitrogen, uric acid, and urea nitrogen content and arginase activity get decreased with decreasing salinity. Arginase is an important enzyme of the ornithine cycle from which urea is produced [18].

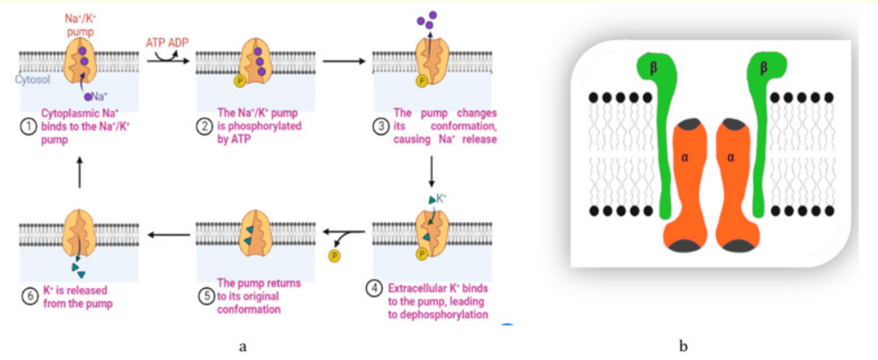

Figure 2: Show Structure and Na+/K+-ATPase activity.

- **Effect of Calcium and Magnesium:** Calcium is required for calcification and hardening of cuticle. Calcium ions are absorbed from the food and water then transferred to the cuticle of the shell by the epidermis or may be stored in the hemolymph and hepatopancreas. Shrimp continually molt their outer shells throughout their lives. Metabolism, growth, and behavior are affected by periodic ecdysis. Calcium regulation is also affected by the molting cycle. The mechanisms of calcium absorption are explained in figure 3. Calcium deficiency generally leads to softening of shell, cramps, improper muscle growth, whitening of muscles, etc. [29].

Magnesium plays an important role in the metabolism of protein, carbohydrates, and lipids. It is used as cofactors for various enzymes and forms specific enzyme complexes that are necessary for the osmoregulation of shrimp to lower salinity water [16]. The deficiency of magnesium leads to osmotic imbalance and reduces the activity of various enzymes that play important role in the metabolism of shrimp [10].

Mineral deficiency leads to osmotic imbalance, cramping, softening of shell, pailing of a tail, spotted body, stunted growth, less feeding rate, and mortality [4]. Softening of shell and stunted growth may increase cannibalism in shrimp because soft shells take a long time to become hard but in this time another active shrimp can attack them [11]. Shrimp cultured in low saline water would not get adequate minerals from feed and water as there is no specific commercial feed for them [22]. Potassium is the monovalent ion that is necessary for the survival and growth of post larval and its threshold value is 1ppm. The survival of shrimp is enhanced by mixed salt-containing chlorides of Na^+, K^+ Ca^{2+}, and Mg^{2+} supplementation of minerals equal to their level in seawater.

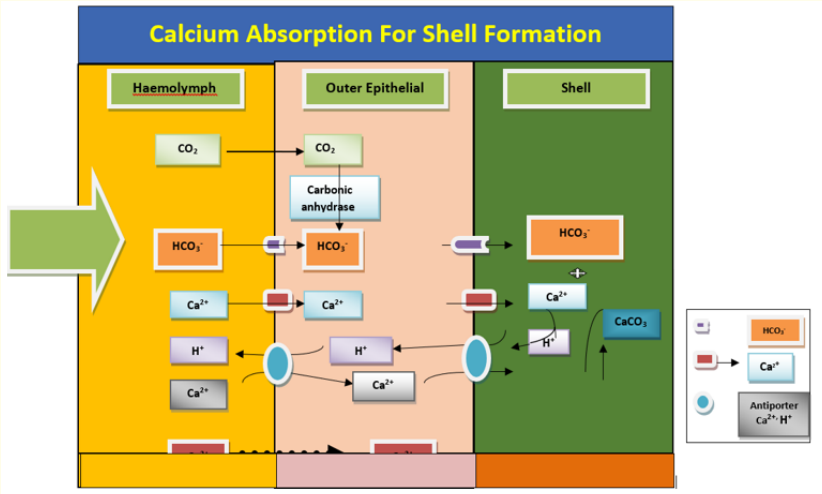

Figure 3: Show Mechanism of Calcium absorption.

- **Mineral supplementation through the feed:** In inland low saline water concentrations of minerals are very low and shrimp is unable to absorb macro minerals like Na, Mg, K, etc from the medium. Fertilizers are added for minerals supplementation but they may be very costly. Thus this problem is encountered through the addition of these minerals along with the feed. The inclusion of these minerals through feed enhances the growth of shrimp [39]. Mainly the major minerals like calcium (Ca), Potassium(K), and Magnesium (Mg) are supplemented with the diet of the shrimps and the same is proved successful in yielding good survival and good growth in shrimps [34]. Other than minerals, components like carbohydrates, stress releasers like astaxanthin, highly unsaturated fatty acids (HUFA), immunity boosters like betaine, amino acids are also incorporated through the feed to tolerate the salinity variation. But excessive inclusion of either of the minerals will not yield a good result.
- **Mineral supplementation through water**: The physical-chemical parameters of water are very crucial for shrimp growth. Mineral supplementation through water is more effective compared to diet modification [29]. But the cost of ionic modification has become high when the culture area is large. The ionic profile of water is more important than salinity as it determines the physiology of the shrimps.

It is reported that *Litopenaeus vannamei* can grow in water that contains less than 140 ppm of cation [41]. In inland low saline waters, potassium and magnesium are highly low and it varies from area to area especially while using groundwater. It has been reported that the growth of shrimp is inversely proportional to the ratio of Na and K. Calcium is mainly absorbed by the shrimp especially after molting as it does not have internal calcium reserves as other freshwater crustaceans[31]. Magnesium is also an important mineral that plays a key role in shrimp metabolism. The composition of these ions varies from water to water and they cannot be maintained as required. Thus, the ratio of these minerals is considered to be a significant one. The ratio of these ions should be maintained in low saline waters as present in coastal water [31]. The ratio of Calcium and Potassium is 1:1 in coastal water; any changes in the inland low saline water can be restored by the addition of potassium instead of calcium. Other ions being maintained in inland low saline waters are sodium: potassium and Magnesium: calcium is 28:1, it might be up to 40:1 and 3.4:1 respectively [29]. Minimum ionic compositions for vannamei are Na: 4000 ppm Ca: 160 ppm, Mg: 525 ppm, K: 150 ppm, Cl: 7500 ppm, and Nitrate: 0.03 ppm. The ionic concentration of pond water will vary from time to time and crop to crop [38]. Thus, frequent analysis of ionic profile in inland low saline waters will give clues about the number of minerals to be supplemented to maintain the required ionic ratios. Potassium and Magnesium will be adsorbed largely in the pond soil so it is necessary to determine mineral profile frequently [29]. The growth of vannamei is more in the water containing a high concentration of ions sodium and potassium than Calcium and Magnesium. The requirement of ionic concentration or minerals can be calculated by multiplying existing salinity with their multiplication factor. The multiplication factor for sodium, potassium, Magnesium, Calcium, Chloride, and Sulphate is 304.5, 10.7, 39.1, 11.6, 551, and 78.3 respectively. For example 7 ppt salinity water required potassium is 7 x 10.7 = 74.9 (75ppm) [14].

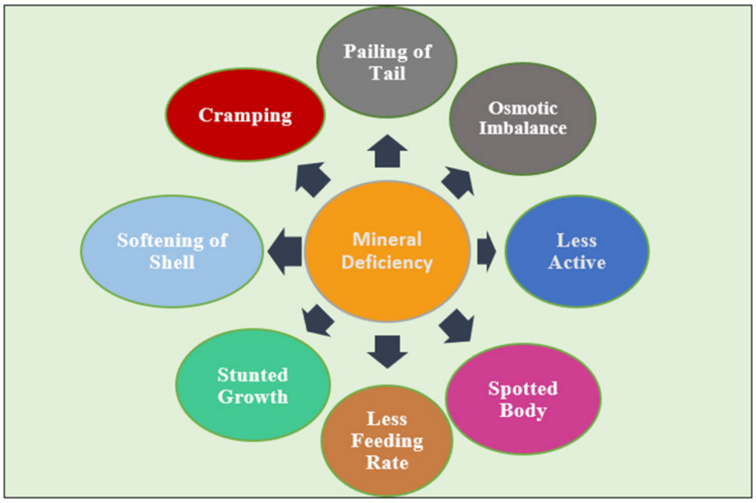

Figure 4: Show various symptoms of Mineral deficiency in Shrimp.

There is no standard rule for determining the level of mineral requirement because there are many interactions between minerals in inland low saline waters [17]. The alkalinity of water also the determine kind of minerals to be added. If alkalinity is less, agricultural lime, calcium carbonate is to be used whereas in the case of high Calcium sulfate ($CaSO_4$) or Gypsum [38]. If deficiency of Na, K, or Mg is found, many agricultural products like Potassium sulfate, Magnesium sulfate (Epsom), Murate of Potash, Potassium chloride, Magnesium chloride, Sodium chloride (Rock salt), Potassium Magnesium sulfate (K-Mag).

Mineral	Mineral salt	Common name	Typical composition
For Calcium	Calcium sulfate $CaSO_4$	Gypsum	22% Ca, 53% SO_4
For Potassium	Potassium chloride KCl	Muriate of potash	50% K ,45% Cl
	Potassium sulfate K_2SO_4	Sulphate of potash	41.50% K, 50.9% SO_4
For Magnesium	Magnesium sulfate heptahydrate $MgSO_{4.}\,7H_2O$	Epsom salt	10%Mg, 39% SO_4
For Sodium	Sodium chloride NaCl	Rock salt	39% Na, 61% Cl

Table 1: Show composition of different salt.

Mineral	Optimum level at 1 ppt (Mg\lt)	Optimum level at 5 ppt (Mg\lt)	Optimum level at 10 ppt (Mg\lt)	Optimum level at 15ppt (Mg\lt)	Optimum level at 35ppt (Mg\lt)
Calcium	11.6	58	116.0	174	406
Potassium	10.7	53.5	107	160.5	374.5
Magnesium	39.1	195.5	391	586.5	1368.5
Sodium	304.5	1522.5	3045	4657.5	10657.5
Chloride	551	2755	5510	8265	19285
Sulphate	78.3	391.5	783	1174.5	2740.5

Table 2: Show optimum level of minerals at different salinity [29].

S.no	Mineral	Optimum concentration in water
1	For Calcium	150-200mg\lt in water and 1.25-2.00% in feed
2	For Potassium	150-200 mg\lt in water and 0.5-1% in feed
3	For Magnesium	300-400mg\lt in water and 0.2% in feed
4	For Sodium	In feed 0.5%
5	For Phosphorous	In feed 1-1.5%
6.	For Chlorine	Depends on salinity

Table 3: Show Requirement of minerals in feed and water [35].

Feed Chart for the Shrimp	
DOC (Days of culture)	Amount of feed per individual (gm)
3-5th	2.00-3.00
5-7th	3.00-3.90
7-11th	3.90-4.80
11-18th	4.80-5.80
18-28th	5.80-6.20
28-45th	6.20-7.00
45-65th	7.00-7.60
65-100th	7.60-10.0

Table 4: Show feed chart for optimum growth of shrimp [38].

S.no.	Water parameter	Optimum range	Measuring unit
1	Dissolved oxygen	>4	ppm
2	Temperature	26-30	Degree Celsius
3	pH	7.5-8.5	
4	Total alkalinity	>120	ppm
5	Total hardness	>1000	ppm
6	Ammonia	<1.0	ppm
7	Nitrate	<0.5	ppm
8	Hydrogen Sulphide	<0.01	ppm
9	Calcium	>150	ppm
10	Magnesium	>450	ppm
11	Chloride	>500	ppm
12	Total dissolved solid	>150	ppm
13	Salinity	10-35	ppt
14	Sodium	>2000	ppm
15	Potassium	>150	ppm
16	Phosphorous	<0.03	ppm
17	Secchi Disc	30-40	cm
18	BOD	<10	ppm
19	COD	<70	ppm
20	Ratio of phytoplankton to zooplankton	10:1	
21	CO2	<10	ppm
22	Total suspended soild	>100	ppm

Table 5: Show optimum water parameter for Shrimp culture [6].

Conclusion

It has been proved in many areas that the culture of *L. vannamei* is remarkably successful in freshwater or low saline water also. With a quality seed and pollution-free environment, the culture of vannamei will be promising. Survivability of seed depends on the selection of PL stage and proper acclimatization. Modification of nutritional/dietary and environmental is feasible and economically.

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