Original Article

Experiences on the utilization of inland-saline water for aquaculture

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Abstract
The availability of fresh water is steadily decreasing in many parts of the world due to climate change and anthropogenic factors. At the same time, the occurrence of inland saline water is increasing at an alarming rate due to both natural and human-induced factors. Agriculture of commercially important marine and brackish-water fish species are practiced in many regions of the world. This study discusses the suitability of inland saline water, with and without potassium supplementation, for the survival and growth of various culturable finfish and shellfish species, including tiger shrimp.

Keywords: Inland-saline water, ground water, *Penaeus monodon, Fenneropenaeus merguiensis*

Introduction

More than half of the total ground water is saline in the world and the availability of fresh water is continuously decreasing in many parts of the world due to climatic changes and anthropogenic causes. [1] In the semi-arid and arid climates, there is always a crisis of fresh water, but saline water is abundant. The salinization of land and water resources in inland regions has exerted a serious pressure on the availability of fresh water for drinking, agriculture, industries and fisheries. Agriculture production is reduced by 40-100% as also the biodiversity of both aquatic and terrestrial flora and fauna. In many developing nations, where the per capita availability of land is less and agriculture provides the largest contribution to national GDP, the salinization of land and water resources has challenged the socio-economic sustainability of farming communities. These factors are especially relevant to most of the countries in Asia and Africa. Therefore, freshwater-based farming activities need diversification to facilitate the use of saline water.

In India too, the occurrence of inland-saline water is increasing at alarming rates due to both natural and man-induced factors. Around 6.1 million hectares of Indian agricultural land have been ruined by increasing soil salinity and salinization of ground water. [2] The inland states of Haryana, Uttar Pradesh, Punjab and Rajasthan contribute about 40% to this. At the same time, 41-84% ground water is saline or alkaline in these states. Most of these resources are lying unutilized or underutilized as most of the lands are either confined to marginal farmers who are resource poor, or the cost of reclamation is too high.

The development of irrigation facilities has been a major cause of salinization at sub-surface and surface levels due to prolonged water logging in the command areas of irrigation projects. The total extent of waterlogged lands in India is about 8.53 million hectares. In the command area of major and medium irrigation projects, 15-20% of the area is reported to have become afflicted with water logging. The average rate of water table rise in most canal-irrigated areas is 45 cm per year. [3]

In the state of Haryana, 52% of the total geographical area is confronted with a rising water table with 455,000 ha of salt-affected area. This land is lying fallow or defunct without any agricultural activity. In the command area of Indira Gandhi Nahar Pariyojna in the State of Rajasthan, 45,000 ha area is reported to be waterlogged and saline, which is expected to increase a few folds soon, if not controlled. Gujarat has 1,214,400 ha of salt-affected area. Most of the salt-affected land is situated in the southern districts in the state. The highly fertile agricultural lands became saline due to water logging. The Government of Gujarat has made a special amendment to convert these defunct agricultural lands into *kharlands* for the development of aquaculture.

The fertile agriculture lands of the districts of western Maharashtra, *i.e.*, Sangli, Satara and Kolhapur, have been becoming saline since the 1980's. The rate of salination is constantly on the rise due to which the farmers of the region are stripped of their livelihood. Socio-economically, the people of the region, especially the weaker sections of the population, are in a very dire state. These districts have perennial sources of water and also plenty of ground water, which means that these saline lands could be utilized for various aquaculture activities on a commercial scale. About 50,000 ha of fertile sugarcane fields have become saline and the area is increasing by 200 ha every year. Another significant feature is that the marginalised population, who have very small land holdings (0.5-1.0 ha), is also high in these districts. All these lands became saline, and the small farmers became agricultural labourers because of the lack of alternatives for their day-to-day livelihood.

The saline water-based agriculture is being practised in many parts of the world.[4] The suitability of such water for the culture of many commercially valuable finfish and shellfish species has been evaluated at experimental scale[5-11], but only those of Nile tilapia (*Oreochromis niloticus*) and Pacific white shrimp (*Litopenaeus vannamei*) have achieved commercial success, though rainbow trout (*Oncorhynchus mykiss*), silver perch (*Bidyanus bidyanus*), milkfish (*Chanos chanos*) and grey mullet (*Mugil cephalus*) survive well in moderate to high salinity inland waters.[12,13] Moreover, poor survival or total mortality has been reported in Asian seabass (*Lates calcarifer*), Australian snapper (*Pagrus auratus*), western king prawn (*Penaeus latisulcatus*) and tiger shrimp (*Penaeus monodon*). [7,9,14-17] The water of up to about 4‰ salinity only is recommended for use in aquaculture, while in many regions, specifically in the semi-arid and arid parts, the salinity of inland water is like that of sea water or even much higher. It restricts the use of such an abundant resource.

The culture of commercially important brackish water fish species, like milkfish (*Chanos chanos*), grey mullet (*Mugil cephalus*),Asian seabass (*Lates calcarifer*), pearlspot (*Etroplus suratensis*), tiger shrimp (*Penaeus monodon*),etc., was considered to be an economically viable proposition to utilize the inland-saline water resources of the country. The research and development efforts that were initiated in this direction more than three decades ago have demonstrated the suitability of inland-saline water for aquaculture development and thus the socio-economic upliftment of the affected sections of the population spread in these areas. However, inland-saline water differs from sea water in chemical characteristics and has location-specific variations. It is generally low in potassium, and potassium supplementation has been found to greatly enhance the survival and growth of cultured animals. [7,9,11,16] In the present study, the suitability of inland-saline water with and without potassium supplementation was evaluated in terms of survival and growth of many culturable finfish and shellfish species including tiger shrimp.

Materials and Methods

Study location

The Central Institute of Fisheries Education under the Indian Council of Agricultural Research initiated activities on inland-saline aquaculture at Sultanpur in Haryana in 1982 in collaboration with the Haryana State Fisheries Department with two specific problems on carp seed production in semi-arid zone, and utilization of saline soils and ground-saline water for aquaculture. After getting encouraging results and with an aim to extend the activities utilising better infrastructure, the institute shifted its project activities to Lahli (Rohtak District) in 1996 and started functioning as a full-fledged centre of the Institute. The centre is located at about 8 km from Rohtak on the Rohtak – Bhiwani road. The centre has a total area of 14.6 ha with inland-saline soil and wells to extract saline water. The farm has nurseries and rearing ponds of various sizes to conduct experiments on rearing of finfish and shellfish under varying levels of salinity as also hatcheries.

Preliminary studies

One of the greatest problems with inland-saline soils is the high rate of seepage in ponds which enhances the cost of filling water on one hand and nutrient loss on the other, and thus, affects overall culture economics. So, the ponds were lined with polyvinyl chloride sheets to overcome this problem (Figure 1). These ponds had shown insignificant differences in growth in comparison to earthen ponds in the case of *C. chanos* and *M. cephalus*; however, significant differences in survival had been noticed.

To verify the observations, the study was carried out to assess the survival and growth of *C. chanos* in poly-lined and earthen ponds using 16‰ inland-saline water with the fry procured from Tamilnadu. Nursery rearing was carried out in the earthen ponds of size 0.1 ha for two months. Fish were fed with a mixture of rice bran and mustard oil cake (50:50) at 100% of the body weight for initial 15 days and later on, gradually reduced to 10% of the total body weight. A total of 5 ponds of size 0.1 ha were used for the experiment. Each pond was stocked with 2000 fingerlings. Out of the five

Figure 1: Poly-lined ponds to reduce the seepage loss

ponds, two were poly-lined and three were without lining. Average length and weight at the time of stocking into grow-out ponds were 5.4 cm and 7.4 g, respectively. Water quality and growth monitoring was done regularly. Feed was provided from the second day of stocking with a mixture of rice bran and mustard oil cake (50:50) at 3% of the total body weight, and the rearing was continued for 120 days.

Results and Discussion

Significant differences were not found in terms of growth rate between poly-lined and earthen ponds. Survival in the case of earthen ponds was around 60%, whereas it was around 40% in the case of poly-lined ponds. A total of 500 kg (Figure 2) was harvested form 0.5 ha area (1 t/ha). Mortalities due to sudden temperature fluctuations and toxic gases (ammonia and hydrogen sulphide) were higher in the case of poly-lined ponds. Earthen ponds were found to be more suitable for *C. chanos* rearing probably due to the higher oxidative bacterial activity. It was concluded that if poly-lined ponds have to be used for the rearing of *C. chanos*, these should be provided with proper water exchange facilities.

In the light of the earlier experiments and the realization that inland-saline water needs amendment with respect to the potassium content, the water was amended for shrimp farming. Inland saline water of salinity 10‰ was pumped from a bore-well and allowed to settle for a week, which was then filtered through a 100-µm filter-bag and stored in three 1000-l tanks where it was disinfected with bleaching powder at 15 mg/l and vigorously aerated with a portable air blower for >48 hours before use. One of the tanks was maintained as control. One tank was supplemented with muriate of potash (KCl containing 49% K^+) to a K^+ concentration of 50% that in seawater (57

Figure 2: A haul of milkfish produced using inland-saline water

mg/l) and another to 100% (114 mg/l) of seawater after Fielder *et al.*, (2001), Ingram *et al.*, (2002), and Boyd and Thunjal (2003). Calcium and magnesium were measured according to standard methods,[20] and sodium and potassium with a microprocessor-based flame photometer (Model 1381E, Electronic India); salinity was measured with a handheld refractometer (Atago). Water amended this way was used for the indoor experiments. For rearing, well water was diluted with canal water to the appropriate salinity and treated with muriate of potash to have a potassium content of 50% of sea water at the corresponding salinity unless specifically mentioned.

Experiments were conducted to assess the survival, growth and suitability of inland-saline waters for the culture of kuruma shrimp (*Marsupenaeus* *japonicus*); 10,000 post-larvae of *M. japonicus* procured from Tamil Nadu were reared at a stocking density of 1/l in indoor tanks with 18‰ ground-saline water with potassium fortification (100% equivalent to the sea water level of potassium) up to the juvenile stage. The initial survival up to the juvenile stage was found to be around 64%. The initial results suggested that the inland-saline water is suitable for the culture of *M. japonicus.* The juveniles obtained from the indoor rearing experiments were stocked in two adjacent outdoor ponds of size 0.1 ha at a density of $3/m^2$. The pond culture was carried out using 18‰ ground-saline water amended with potassium. However, the experiments had to be terminated due to the failure of water source. Indoor and outdoor experiments were conducted to assess the suitability of inland-saline waters for the culture of banana shrimp (*Fenneropenaeus merguiensis*). This experiment was carried out mainly because this particular shrimp naturally matures under pond conditions and hence, hatchery technology could be easily developed for inland areas. The post-larvae were obtained from the Central Institute of Brackishwater Aquaculture, Chennai. The post-larvae were stocked in six indoor tanks at 1/l density and the indoor rearing was carried out using 18‰ ground-saline water with potassium fortification (100% equivalent to the sea water potassium) up to the juvenile stage. The survival up to the juvenile stage was found to be around 40%. The juveniles obtained from the indoor rearing experiments were stocked in two adjacent outdoor ponds of size 0.1 ha at $1/m^2$. The pond culture was also carried out using 18‰ ground-saline water amended with potassium. However, the experiments were terminated due to water supply issues. These initial results suggest that the inland-saline waters can be used for the culture of *F. merguiensis*.

Experiments to analyze the suitability of inland-saline waters for the culture of Indian white shrimp (*Fenneropenaeus indicus*) were also conducted. The outdoor experiments were not successful due to the high level of calcium hardness in the high-saline tube well water (hardness 7000 ppm $CaCO_3$; calcium level 1200 ppm). Indoor experiments to find out the optimum water quality conditions required for the rearing of *F. indicus* in inland-saline waters were taken up subsequently using water passed through ion-exchangers to reduce the calcium content. A total of 30,000 post-larvae (PL-5) were procured from the Matsyafed Hatchery at Mopla Bay, Kannur. The post-larvae were initially conditioned using potassium supplemented inland-saline water of salinity 10‰ inside the wet laboratory for 15 days to attain a better size to stock into the outdoor ponds. After the attainment of the suitable size, around 18,000 post-larvae were stocked in a poly-lined pond of size 0.1 ha for the nursery rearing and 6,000 post-larvae maintained under indoor conditions. These animals were also reared using inland-saline water of salinity 10‰ and fed with commercial shrimp feed (CP brand). The animals had grown to an average size of 5 g in 2 months (Figure 3) proving that indigenous species that mature under pond conditions can be cultivated using inland-saline water and that the production of seed using shrimp maintained entirely under captive conditions in such waters is possible sooner than later. This would do away with the need for seed production using wild-caught brood and transportation of the seed from the coastal areas to inland-saline areas.

Culture of tiger shrimp

Survival and growth of tiger shrimp (*Penaeus monodon*) in inland-saline water at three salinity levels 5, 10 and 15‰ were investigated with and without potassium supplementation. [21] Shrimps reared in potassium-supplemented media survived whereas, total mortality occurred in control water. Survival levels of 72.6% in 45 days and 63.3% in 60 days at 5% salinity; 90.0% in 45 days and 88.0% in 60 days at 10% salinity; and 81.3% in 45 days and 78.6% in 60 days at 15% salinity were recorded. Growth parameters indicated that there is significant difference in lengths and weights attained amongst the various treatments and growth was found to be the best at 10% salinity. The study indicated that the inadequate level of potassium in inland-saline water is mainly responsible for the mortality of shrimp, and that supplementation of potassium can raise the survival and growth of *P. monodon* to a level normally obtained in commercial production. For commercial-level production of *P. monodon*, hatchery-produced post-larvae (PL-10) were procured from Kakinada, Andhra Pradesh. The PCR-screened post-larvae for white spot syndrome virus (WSSV) prior to dispatch by air to the experimental site at Rohtak were acclimatized to 10‰ salinity in natural seawater. The post-larvae (average weight 10±1 mg) were then acclimatized to artificial seawater of

10% salinity for 48 hours before randomly stocking at a rate of 50 post-larvae in each of the nine cylindro-conical FRP tanks of 300-l capacity for the survival trial.

Figure 3: White shrimp juveniles

Stocked tanks were randomly assigned to one of the three treatments: control (ISW), potassium supplementation to 50% seawater (ISWK+50%) and potassium supplementation to 100% of that in seawater (ISWK+100%). Tanks were continuously aerated and ~25% of water exchanged daily at the time of tank cleaning. Experimental animals were fed commercial shrimp diet (CP Brand), *ad-libitum.* All the post-larvae died by the sixth day in ISW. In the other treatments, survival rates were 85.3% to 88.0% up to the sixtieth day. The post-larvae under potassium supplementation exhibited normal locomotion and body pigmentation; muscle tissue opaqueness, appendage deformity or untimely moulting were not observed. As there were no significant ($p < 0.05$) differences in mortality amongst the potassium treatments, pond trials were conducted at 50% potassium supplementation rate.

The post-larvae were acclimatized to pond water conditions for one hour in plastic tubs and at 4.4/m^2 stocking rate in two earthen ponds of 56 x 46 m (0.25 ha) lined with LDPE geo-membrane (thickness 200 µm) with cement tiles on the sides and a soil bottom. These ponds were filled with ISW (10% salinity) to a depth of 120 cm and were supplemented with muriate of potash to get a K^+ concentration equivalent to 50% of seawater at 10‰ salinity. The required quantity of salt was added based on measured potassium concentration fortnightly. Both the ponds were initially manured with semi-rotten rice polish (200 kg/ha) and diammonium phosphate (25 kg/ha). Subsequent manuring with rice polish and diammonium phosphate was carried out whenever the transparency of water was >40 cm. On the appearance of algal blooms, around 10% of the pond water was replaced. The ponds were aerated using two mechanical aerators in each pond in opposite directions (Figure 4). The post-larvae were fed graded commercial shrimp diets (CP brand) initially at 10% body weight, reduced to 1% as shrimp became larger. To measure growth, 50 specimens were measured and weighed on days 50, 60, 70, 80, 95 and 110. Survival rate, specific growth rate and feed conversion ratio were calculated according to standard formulae.

Shrimps survived well in both the ponds at 55.8% and 64.3% in ponds 1 and 2, respectively (Figures 5-7), resulting in the total biomass of 157.70 kg (630.8 kg/ha) and 172.25 kg (691.0 kg/ha). Average length was 15.43 and 15.15 cm, and weight 25.69 and 24.44 g in ponds 1 and 2, respectively. FCR was 1.9 in both the ponds. Production of 631 kg/ha and 691 kg/ha at a stocking density of 4.4/m^2 (PL-10) with limited exchange of water is good enough for commercial production in India. Athithan *et al.,* (2001) reported a total length of 14.5 cm and weight 25.0 g with 58% survival in 110 days while culturing *P. monodon* in a freshwater pond containing hard water (total hardness 786.25 ± 232.67 mg $CaCO_3$/l) at a low stocking density of 15,000/ha (PL-35). Growth rate, gross biomass production (208.8 kg/ha), and FCR (2.43) at 58% survival were worse than in the present study. Earlier, Guru *et al.,* (1993) obtained growth of 26.30 g in 135 days at a stocking density 3/m in seawater of 4.0-10.8% salinity. The survival and growth were found to be sufficiently high for obtaining a commercial crop from inland-saline water, which is a wasted resource. [24]

In continuation of the initial success on commercial production of tiger shrimp in potassium-supplemented inland-saline water, trials were repeated to study the economic feasibility of the technology developed. The trials were conducted at higher stocking de nsities to increase the total production and the profitability margin.

Figure 4: One of the ponds under the culture of tiger shrimp

A total production of 1340 kg/ha with a net survival of 94.5% was obtained in 110 days of culture period at a stocking density of 6/m^2 with judicious management. The production obtained was at par with the production in the

Figure 5: A portion of the harvested tiger shrimp

commercial culture in coastal areas at the same stocking densities. These experiments have not only proved the technical feasibility of the technology but also its economic viability.

The grow-out culture of *P. monodon* using inland-saline waters was repeated with an objective to produce two crops in a year (despite the severe winter) and to confirm the economic feasibility of the technology developed. The first crop was successfully harvested by the last week of June with a total production of 1680 kg/ha with a

Figure 6: Tiger shrimp harvest

Figure 7: Specimens of harvested tiger shrimp

net survival of 82% in 96 days of culture period at a stocking density of 10/m^2. As in the previous year, the production obtained was at par with the production obtained through commercial culture in coastal areas at the same stocking densities. The second crop was completed by the second week of November and a total production of 650 kg/ha was obtained with a net survival of 60% in 90 days of culture period at 6/m^2 stocking density. A repeat experiment completed by the second week of October resulted in a total production of 1280 kg/ha with a net survival of 70% in 110 days of culture duration at a stocking density of 10/m^2.

Health monitoring of the shrimp in the farm trials revealed that the general health of the shrimp in potassium-amended inland-saline water is as good as in any ideal coastal tiger shrimp culture operation. Although inland-saline water is a novel habitat to the shrimp, it did not pose any disease susceptibility issues or health problems, provided water quality parameters were maintained. It was also found that the potassium level of inland-saline water has direct correlation with disease susceptibility and the general health status of the shrimp. An optimum of 53 ppm potassium is required in 10‰ inland-saline water for the maintenance of ideal health conditions. As *P. monodon* cannot withstand the extremely low temperature at Rohtak, polyhouses (Figure 8) were established for the overwintering of the stock and the results have been successful.

Conclusion

Unlike coastal farms, inland farms need to be operated with either zero or very little exchange of water due to the difficulty of finding suitable places for the disposal of water with high salt content. In addition, since ISW is pumped from wells, the chances of pathogens are fairly remote, and the lack of naturally occurring crustaceans that can serve as carriers of pathogens present a pathogen-free atmosphere for the rearing of brood stock and seed production. Both argue for the increased assessment of the potential of ISW for marine shrimp farming that could turn a waste resource into a viable industry. It is also expected to provide sustainable means of livelihood to the target population.

Figure 8: Inside a polyhouse fabricated for the overwintering of shrimp brood stock

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Conflict of interest
There are no conflicts of interest.

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