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Litopenaeus vannamei (whiteleg shrimp) farming in Indian inland saline ecosystem

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Abstract
Inland saline shrimp farming has been growing rapidly due to increase of higher profits than traditional agriculture or fishery in the inland saline water areas and it has been playing important roles on the socio-economic development in Haryana, Punjab, Uttar Pradesh, Rajasthan and Maharashtra. Increasing demand for aquaculture has led to the development of new production systems. Inland saline water shrimp farming, defined here as land-based aquaculture using saline groundwater, occurs in several countries including Israel, the USA, India and Australia. Characteristics of saline-affected land are described, with particular focus on Australia and India. Saline groundwater can differ in chemistry compared with coastal seawater and adjusting the chemistry or choosing species that are tolerant to the differences is one of the major challenges for expansion of inland saline ecosystem. The chemistry of different sources of water is described and common methods of adjusting the chemistry described. The Pacific whiteleg shrimp (*Litopenaeus vannamei*) is the leading farmed shrimp globally, representing one of the most common aquaculture species. It is widely favoured due to its superior flesh quality, delicious taste and nutritional properties, as well as its ease of cooking. *L. vannamei* is an adaptable to a wide range of salinities shrimp species suitable for high-density cultivation in diverse salinities. Inland saline shrimp farming is needed to increase aquaculture production and meet increasing demands for seafood and help to encourage the farmers to get involved in *L vannamei* farming and socio-economic status of the people.

Keywords: Inland saline farming, ecosystem, *Litopenaeus vannamei*, aquaculture, shrimp socio-economic status

Introduction
Litopenaeus vannamei farming offers the potential to increase production of euryhaline and marine species. Inland saline shrimp farming is defined here as land-based aquaculture using saline groundwater. Expansion of coastal aquaculture is limited in many areas because of other land and water use activities. Inland aquaculture already makes the greatest contribution to total aquaculture (approximately 60%: FAO, 2007) [13]. *L. vannamei* is a decapod crustacean which is native to the eastern Pacific coast of Central and South America from Tumbes, Peru in the south to Mexico in the north. It has been introduced widely around the world since the 1970s, but especially since 2000, as it has become the principle cultured shrimp species in Asia. *L. vannamei* (Boone, 1931) [8] is the most important penaeid shrimp species cultured worldwide (Alcivar- Warren *et al*., 2002) [2]. Among all species of shrimp, *L. vannamei*, which represents over 90% of shrimp culture in the western hemisphere, is the most commonly cultured shrimp in Central and South American countries, China and Thailand (McGraw *et al*., 2002) [21]. Globally, an estimated 380 million ha of land is unusable for agriculture because of salinisation of soils and groundwater (Lambers, 2003) [18]. There are numerous other imbalances in ionic composition and possible contaminants in saline groundwater. For many of these ions, site-specific studies will be needed. Most studies have focussed on large deviations of single ions but, as production from saline groundwater sources increases, it is likely that chronic effects will become apparent. Research to understand how to construct artificial mixed-salt environments and physiological responses of aquaculture species in low-salinity water will be valuable in helping to understand these relationships (Cheng *et al*., 2005) [10]. This type of wasteland is being used for farming of fish, crustaceans, molluscs, etc. especially in the USA, China, India, Israel, and Australia (Allan, 2009) [3]. In India, nearly 8.62 million ha of land area is affected by soil salinity and 2.8 million hectares of salt-affected soils are present with in the Indo-Gangetic alluvial plain. Within 8.62 million ha, 40% of the salt-affected area is concentrated in the north-western, semiarid/arid states of Haryana, Punjab, Uttar Pradesh, and Rajasthan (Allan, 2009) [3].

Across the globe, more than 1,300 million ha of land has been documented as salt affected, severely impacting the agricultural productivity and rural economies of many developing countries including India (Ansal and Singh, 2019) [4]. Out of total 6.74 million ha salt affected areas including coastal saline areas in India, around 1.20m ha is located in the non coastal Indo-Gangetic plains of Northern India. These areas are distributed among seven states *viz.*, Punjab, Haryana, Rajasthan, Bihar, Uttar Pradesh, Madhya Pradesh and Jammu and Kashmir (Ansal and Singh, 2019) [4].

Farming of whiteleg shrimp *L. vannamei* farming was found to be profitable owing to high density stocking and more adaptability of this shrimp to saline conditions. In recent times in the last few years fast few years

the *L. vannamei* farming is in leaning in Haryana, Punjab Punjab and in Maharashtra with technical support from various Central and State Government Organisations. Encouraging growth have been reported from these different parts of India and it has proved that the White leg shrimp *L. vannamei* cultivation is commercially feasible provided the farmers are trained, strict bio-security measures followed and Best management practices (BMPs) adopted.

Litopenaeus vannamei farming in Indian inland saline ecosystem

There is little published information about the growth and survival of *L vannamei* in well-water or inland surface water in India. Central Institute of Fisheries Education (CIFE) had initiated studies on the use of salt affected inland saline soils and ground saline water for aquaculture under ICAR sponsored Operational Research Project (ORP) during 1986 at Sultanpur, Haryana. Later this project shifted to Lahli fish Farm, Rohtak, and Haryana during 1996. With the experience of Sultanpur, various programmes have been initiated for the culture of finfish and shellfish species locations of Rajasthan (Bist, 2019) [33]. Simultaneously research programmes were undertaken to find out the suitability of ground saline water of Rajasthan for aquaculture laboratory trails on tiger shrimp, *Penaeus monodon* were undertaken. Having observed the potassium deficiency in ground saline water, trials were made on culture of tiger shrimp and larval rearing of giant freshwater prawn by fortifying it by adding potassium chloride at various levels and achieved successful results (Barman *et al.*, 2012) [7].

Table 1: Species introduced/experimented for culture in Inland saline aquaculture

S. N	Species	References
1	*Litopenaeus vannamei*	Davis *et al.*, 2004 [11]; Samocha *et al.*, 1998 [30]; Pathak, 2013 [25]; Reddy and Harikrishna, 2014 [17], Jahan, 2016 [15]
2	*Penaeus monodon*	Antony, 2013 [35]; Reddy and Harikrishna, 2014 [17]; Antony *et al.*, 2015 [6]; Raizada *et al.*, 2015 [28]
3	*Penaeus latisulcatus*	Prangnell and Fotedar, 2006 [27]
4	*Macrobrachium rosenbergii*	Raizada *et al.*, 2005 [28], *Jain et al.*, 2007 [16]

The Central Institute of Fisheries Education (CIFE), Rohtak Centre has taken up aquaculture of *Penaeus monodon* and *Litopenaeus vannamei* using inland saline ground waters at farmers' field for the first time in the country. The CIFE, Rohtak Centre initiated *Penaeus monodon* culture during 2009 in high saline area of Baniyani farm where the production ranged from 400-1600 kg/ha/120 days. Later *P. monodon* and *L. vannamei* were stated in low saline area of Lahli farm (2.0-5.0) and high saline unit of Baniyani (12-15) during 2012. In low saline waters, a much higher production of 2,700kg/ha/120 days was obtained for P. monodon and *L. vannamei* respectively during 2013. Consequently, *L. vannamei* farming has been successfully taken up by two farmer groups at Baniyani and Meham villages in Rohtak district of Haryana during 2014. The production of *L. vannamei* in farmers' ponds is expected to be 8.0 -10.0 tonnes/ha in 120-130 days with a net profit of Rs. 8-10 lakhs/ha/crop. The technology has immense potential for its further propagation in Haryana, Punjab and Uttar Pradesh enhancing fish productions for inland states towards blue revolution.

Out of total 6.74 million ha salt affected (including coastal saline soil) areas in India, around 1.20m ha is located in the non-coastal Indo-Gangetic plains of Northern India. These areas are distributed among seven states *viz*., Punjab (1.51 lakh ha), Haryana (2.32 lakh ha), Rajasthan (3.75 lakh ha), Bihar (1.53 lakh ha), Uttar Pradesh (1.37 lakh ha), Madhya Pradesh (1.39 lakh ha), and Jammu and Kashmir (0.17 lakh ha) (Ansal and Singh, 2019) [4].

Table 2: State-wise Indian Inland Sodic soils, Saline soils and Coastal saline soils.

State	Sodic soils	Saline soil	Coastal saline soils	total
Gujarat	14.3	71.2	37.1	32.9
Uttar Pradesh	35.6	1.3	-	20.3
Maharashtra	11.2	10.4	0.6	9.0
West Bengal	-	-	35.4	6.5
Rajasthan	4.7	11.4	-	5.6
Tamil Nadu	9.4	-	1.1	5.5
Andhra Pradesh	5.2	-	6.2	4.1
Haryana	4.8	2.9	-	3.4
Bihar	2.8	2.8	-	2.3
Punjab	4.0	-	-	2.2
Karnataka	3.9	0.1	-	2.2
Orissa	-	-	11.8	2.2
Madhya Pradesh	3.7	-	=	2.1
Andaman & Nicobar Islands	-	-	6.2	1.1
Kerala	-	-	1.6	0.3
Jammu & Kashmir	0.5	-	-	0.3
Total	100(3.78)	100(1.71)	100(1.25)	100(6.74)

Source: Adapted from Mandal *et al.*, (2018) [19] The presence of an excess of sodium salts and the predominance of sodium in the exchangeable complex are divided into the two main groups: 1. Saline soils and 2. Alkaline soils. Saline soils contain an excess of sodium salts, but its colloidal material is not yet sodiumises. In the case of alkali soils, the exchange complex contains appreciable quantities of exchangeable sodium. Such soils may or may not contain excess salts. Salt affected soil mainly occur in Gujarat, West Bengal, Rajasthan, Panjab, Maharashtra, Haryana, Orissa, Delhi, Kerala and Tamil Nadu. Almost 2.8 million hectare of salt affected soils are present within the Indo Gangetic alluvial plain occupying parts of Punjab, Haryana, Utter Pradesh, Delhi, Bihar and Rajasthan States (Abrol *et al.*, 1971) [1].

The culture of *L. vannamei* mostly occur in the coastal water of salinity range from 1 ppt to 40 ppt (Bray *et al*., 1994) [9], and this is the major species of penaeid shrimp cultured in the eastern hemisphere (Pe'rez-Farfante and Kensley, 1997) [26]. Although many investigations on the effects of salinity on shrimp growth have been conducted, most of them studied on the effects of constant salinities (Palacios *et al*., 2004; Wang *et al*., 2004) [24, 34], and no work on the effects of fluctuating salinity on the growth and energy budget of *L. vannamei* has been carried out. In Maharashtra pilot scale project with the finance from Marine Products Export Development Authority (MPEDA) is in trend in Akivat village of Western Maharashtra. In all the three states the pond water quality is suitable for L. vannamei culture, except that, the K level and Ca:Mg ratio needs to be maintained in the pond. The shrimp production in these different states varied from 8.36 to 10 tonnes ha-1 and the farming duration ranged from 120 to 140 days. For successful and sustainable production of the shrimp better Management Practices (BMPs) adoption and the K level and Ca:Mg ratio maintenance are the most vital factors. The water parameters of Haryana, Punjab and Maharashtra are quite suitable for the shrimp.

Table 3: Water parameters of Haryan, Punjab and Maharashtra

Parameter	Haryana	Western Panjab	Akiwat village of Maharashtra
	Value	Range	Value
Water salinity (ppt)	13 - 15	5.3 ± 0.3	0.50 - 2.0
pH	7.8 - 9.0	8.3 ± 0.4	7.5 - 8.0
Dissolved Oxygen	5.4 - 8.2	-	6.0 - 9.4
Total alkalinity (ppm)	200 - 230	370.5 ± 10.2	-
Hardness (ppm)	3200 - 3700	1270 ± 22.8	560 - 680
Sodium (ppm)	-	1312 ± 17.3	257 – 401
Potassium (ppm)	80 - 100	24.4 ± 1.2	6.5 - 18
Magnesium (ppm)	610 - 695	10.3 ± 4.5	73 - 88
Calcium (ppm)	235 - 270	165 ± 7.4	88 - 152

India has approximately 9.38 million hectares' area which in occupied by salt-affected soils in which 5.5 million ha are saline soils (including coastal) and 3.88 million ha alkali soils (I A Is, 2002). Total area nearly 8.62 million ha is affected with the problem of soil salinity and 1.93 million km2 area is under laden with ground saline water. Salt affected soil mainly occur in Gujarat, West Bengal, Rajasthan, Panjab, Maharashtra, Haryana, Orissa, Delhi, Kerala and Tamil Nadu. Almost 2.8 million hectare of salt affected soils are present within the Indo Gangetic alluvial plain occupying parts of Punjab, Haryana, Utter Pradesh, Delhi, Bihar and Rajasthan States (Abrol *et al.*, 1971) [1].

Litopenaeus vannamei farming in Haryana, Punjab and, Maharashtra

Haryana is the first Land Locked State in the country to utilize Inland Underground Saline water for culture of white shrimp *Litopenaeus vannamei*. Fisheries play an instrumental role in the socio-economic development of the country, as it is a valuable source of livelihood for a huge section of economically backward population. Among the different fisheries enterprises, aquaculture is the fastest growing food sector in the world. Over the last few decades, aquaculture has taken off in India from a mere subsistence to a profitable commercial enterprise.

Punjab, thousands of acre of land in south western part has turned water logged and saline in nature and unfit for agriculture activities. About 1.90 lakh ha brackish water area have been developed for Tiger shrimp *Penaeus monodon* culture in the country spread over all the coastal states including Punjab and Haryana. Since 1995, culture of P monodon was affected by White Spot Syndrome Virus and the development of shrimp farming has become stagnant. Fisheries Department of Punjab has started initially with one acre land during - 2016 encouraged for pilot scale attempt in 37.5-acre area in 2017 which has spread in about 410 acre in 2019 resulting in so far 750 ton shrimp production. Many of the farmers are doing shrimp farming and earning double the income. The shrimp farming is bound to bring prosperity to farmers whose lands have become saline and are unfit for cultivation of any agricultural crop.

Maharashtra, the third largest state in the country in terms of area and population, with a coastline of 720 km and continental shelf area of over 0.11 million sq km, offers rich resources for marine fish production. Maharashtra has about 80 thousand hectare of brackish water area suitable for shrimp farming. At present, approximately 12,445 ha land is suitable for brackish water culture in Maharashtra, out of which 1,056 ha area is developed. In Western Maharashtra saline lands are available in long stretches and the farmers are ready to adopt new culture practices.

Huge capital investment is required to be made in inland saline water shrimp farms for construction of ponds and equipment; during initial years. All these issues have direct bearing on the profitability and economics of shrimp farming operations. As such, development of shrimp farming industry is considerably growing in Haryana and Punjab as compared to other states.

Socio-economic feature of *Litopenaeus vannamei*

Shrimp farming in inland saline waters is playing an excessive part on the socio-economic development in India especially in Punjab, Haryana and Maharashtra. Indian inland saline water shrimp farming is more profitable as compared to agricultural crops because it raises higher returns to farmers in a short span of 100-120 days. Further, utilizing the groundwater/seepage water for shrimp culture prevents water logging, improves soil texture and at the same time reduces secondary salinisation. Cluster Farming of a large saline area dividing into two clusters and producing two crops per year may result in increase of profit as well as employment generation. *L. vannamei* shrimp farming may reduce the production cost and improve the socio-economic status of farmers living in those areas suitable for aquaculture.

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