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Socio-Economic Progress of Shrimp Farming in Punjab

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***Abstract*:** COVID-19 pandemic devastated the world with unprecedented economic crisis, leaving everyone confused and apprehended, including the livestock sector. As a resilience measure, shrimp farmers of Punjab were advised some remedial adaptations. Expecting good results, socio-economic evaluation of shrimp farmers from 3 south west districts (Fazilka, Sri Muktsar Sahib and Mansa) of the state was carried out. With enthusiastic participation of young (56.7% ≤ 35 years of age) and educated (50% graduates) farmers, overall 86.6% of the farmers followed the advisories. The pandemic delayed stocking of ponds, however 66.7% of farmers harvested 6.5 to 8.75 t shrimp ha^{-1} $crop^{-1}$. Non-availability of water testing facility within approachable distance emerged as the major constraint (80%), while only 6.66% farmers each reported marketing and seed related problems. With culture period of 101-120 (40%) and >120 (36.7%) days, 66.7% farmers obtained feed conversion ratio <1.2. Further, 43.3 and 36.7% farmers harvested shrimp with an average body weight of 31-35g and 26-30g, respectively and 100% farmers marketed shrimp at the farm site @ Rs. 301-400 (53.3%) and >Rs. 400/- (40%) kg^{-1}, corresponding to net profit of >12.5 lakh (60%) and 7.6-12.5 lakh (26.7%) ha^{-1}. The adopted resilience plan helped the farmers to realize optimal economic returns from shrimp farming in Punjab.

***Keywords*:** COVID, Inland, Performance, Punjab, Saline, Shrimp, Vannamei

Inland salt affected areas in Punjab, Haryana and Rajasthan are being potentially utilized for aquaculture, including fresh water carp culture in low saline areas and shrimp farming in low to high saline waters, due to innovative research and development (R&D) drive of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) in Punjab and Regional Center of ICAR- Central Institute of Fisheries Education (CIFE) in Haryana (Pathak et al 2013, Dhawan et al 2016, Ansal and Singh 2019, Bist 2019 and Debroy et al 2020). It has converted underproductive/ unproductive zero earning salt affected waste lands into a remunerative resource, converting adversity to prosperity in the region. Since 2014, when first pilot shrimp farming commercial trial was conducted in Punjab in Village Painchawali (district Fazilka), area under Pacific white shrimp (*Litopenaeus vannamei*) farming increased from 0.4 hectare (ha) in 2014 to 130 ha in 2019 (Ansal and Singh, 2019). Unlike coastal states, cold sensitive shrimp/prawn species are cultured only during the summer months (April to October) in north-western region of the country. Farmers in Punjab generally stock their ponds during April to June for rearing 100-120 days crop. Some farmers also retain their stock for > 120 days to harvest bigger sized shrimp as per market demand (Singh et al 2020). However, owing to COVID-19 lockdown led suspension of international flights and restricted interstate transport, import of SPF (specific pathogen free) shrimp brood stock by shrimp hatcheries in India was adversely affected (CIBA 2020). Consequently, production and supply of shrimp seed by the coastal states hatcheries was impeded and stocking got delayed, especially in the non-coastal states including Punjab, Haryana and Rajasthan. Under the said unprecedented condition, shrimp farmers of Punjab felt apprehensive, fearing financial losses owing to unforeseen marketing problems, being predominantly dependent on export to the United States, China and Europe (Ravishankar et al 2018). Eventually an estimated total area of 158.6 ha was stocked in 3 south west districts (Fazilka, Sri Muktsar Sahib and Mansa) with adaptive measures (delayed stocking at lower stocking density), recommended by the GADVASU, Ludhiana (Punjab) to curtail unforeseen economic hardship. No socio-economic survey has been conducted so far to appraise the socio-economic condition of shrimp farming in Punjab. Hence, the present study was taken up to evaluate the socio-economic status of shrimp farmers and to assess impact of COVID pandemic on the economic performance of shrimp farming in the above listed districts of the State during 2020.

MATERIAL AND METHODS

During the present study, 30 shrimp farmers were selected, including 10 each from Fazilka, Sri Muktsar Sahib and Mansa districts (Table 1), where shrimp farming has developed very fast in last 4-5 years (Ansal and Singh 2019, Singh and Ansal 2021), and socio-economic profile of shrimp

farmers was recorded with the help of predesigned questionnaire-based survey and group discussions (Holloway 1997), by visiting the farmers personally at their farms. The socio-economic profile of farmers, including name, location, gender, age, educational profile, family size, total land holdings, land under shrimp farming, occupation, training, farming skills, labour and finance was recorded. The technical information in terms of water source, salinity, bio-security measures, seed quality, stocking, aeration, water quality monitoring, feeding management, health management, survival, disease outbreak, culture period, feed conversion ratio (FCR), consultancy, harvest size, post-harvest management, marketing, effluent management etc. was collected to evaluate technological gaps, constraints and output. Economic estimation in terms of capital investment, production (operational/recurring) cost, productivity, gross income, net profit and benefit cost (BC) ratio was carried out to assess economic viability of shrimp farming in inland saline water of the State. A total of 22 independent socio-economic variables were measured and analysed, by classifying the respondents into categories. Adoption level and performance efficiency of shrimp farmers was estimated through 25 dependent management practice variables, ranging from pond preparation to culture, harvesting and marketing. The respondents were classified into suitable categories for each variable depending on respective range recorded during the survey. Statistical techniques like percentage analysis and cumulative frequency were used for analysis of data.

RESULTS AND DISCUSSION

Gender, age and education status: The demographic profile is given in Table 2.

Land holdings and occupation: Out of the total land holdings, <0.8, 0.8-2.0 and >2.0 ha was used for shrimp farming by 10.0, 53.3 and 36.7% farmers, respectively. In terms of total land of surveyed farmers under shrimp farming, Sri Muktsar Sahib was the top district (34.6 ha) followed by Mansa and Fazilka (Table 2). In terms of ownership, 70, 90 and 50% farmers developed shrimp farms in their own land in Fazilka, Sri Muktsar Sahib and Mansa districts, respectively, while rest were on lease. As compared to southern states, more percentage of farmers in Punjab (70%) reared shrimp in their own farms. The said percentage in Maharashtra, Andhra Pradesh (Nellore district) and Tamil Nadu (Nagapattinam district) has been documented as 35.59, 11.66 and 0.67%, respectively (Naik et al 2020, Swathilekshmi et al 2005). The differences among the States may be attributed to availability of salt affected waste lands with the farmers of the south west districts of the state. Among all, only 1 shrimp pond (3.33%) was poly-lined to prevent seepage in Sri Muktsar Sahib. In contrast, most of the farmers in Haryana (Rohtak), Rajasthan (Churu) and Western UP (Mathura & Hathras) have poly-lined their ponds with HDPE 50 µ thick poly-sheet to prevent seepage loss (Bist 2019). Overall percentage of farmers in the 3 districts involved in aquaculture; agriculture and aquaculture; and business and aquaculture were 10, 83.3 and 6.7%, respectively. Shrimp farming appeared as second major occupation after agriculture for Punjab shrimp farmers (83%), with 73.3% having total land holdings between 2-8 ha; and 53.3% and 36.7% farmers rearing shrimp in 0.8-2.0 and > 2.0 ha of farm area, respectively. As compared to Punjab, percentage of farmers having shrimp farming as primary occupation in coastal states is high i.e., 100% in A.P., 83.33% in T.N. and 34.3% in Gujarat (Vadher and Manoj 2014 , Swathilekshmi et al 2005). Chittem and Kunda (2018), observed that 61.06% of shrimp farmers in A.P. are only engaged in shrimp farming; while 20.5% were involved in both shrimp farming and agriculture; and remaining 12.2% were engaged in other aquaculture practices along with shrimp farming, indicating dependence of over 70% shrimp

Table 1. GPS coordinates of selected shrimp farmers in different districts

Fazilka	Sri Muktsar Sahib	Mansa
30.332830°N 74.311125°E	30.264501°N 74.502707°E	29.835667°N 75.299683°E
30.117833°N 74.157999°E	30.263978°N 74.501741°E	29.868070°N 75.27895°E
30.905751°N 75.813065°E	30.264412°N 74.503781°E	29.860855°N 75.403290°E
30.075570°N 74.05600°E	30.287234°N 74.415714°E	29.867371°N 75.205635°E
30.104062°N 74.363053°E	30.292122°N 74.384201°E	29.864113°N 75.403397°E
30.135650°N 74.185870°E	30.073023°N 74.255659°E	29.860255°N 75.242790°E
30.104255°N 74.364191°E	30.291287°N 74.385320°E	29.868807°N 75.278950°E
30.142377°N 74.113811°E	30.201366°N 74.568040°E	29.871283°N 75.246816°E
30.107869°N 74.355824°E	30.287125°N 74.416010°E	29.866270°N 75.271210°E
30.104619°N 74.363551°E	30.111378°N 74.322471°E	29.876900°N 75.346092°E

farmers on aquaculture for their livelihood. While in South Konkan region of Maharashtra and Gujarat, aquaculture and business is reported as the major occupation in case of 76.27 and 65.7% of shrimp farmers, respectively (Vadher and Manoj 2014, and Naik et al 2020). Hence, unlike Punjab, majority of shrimp farmers in the southern part of the country are either involved in other aquaculture activities or are having any other business for financial security. These regional occupational differences are attributed to regional agriculture, livestock and industrial requirements in reference to available resources and historic expertise.

Start-up initiative and financial assistance: Although, majority of farmers-initiated shrimp farming during 2018-19 in Fazilka (60%), Sri Muktsar Sahib (70%) and Mansa (80%) districts. However, district Sri Muktsar Sahib was the first to adopt shrimp farming (before 2017), followed by Fazilka and Mansa; with 40, 20 and 40% farmers availing start-up financial assistance (subsidy and loan) under various promotional schemes, respectively (Table 2). In general, successful adoption of technology by the farmers serves as a chain reaction to motivate others to follow the footsteps. In Punjab, the progressive farmers also inspired about 80% of the farmers/entrepreneurs to adopt shrimp farming. According to the farmers of Fazilka (50%) and Sri Muktsar Sahib (80%) districts, shrimp farming helped in economic utilization of their salt affected waste lands, while in district Mansa, 100% farmers adopted shrimp farming as an opportunity for higher income, as explained further on. All the shrimp farms surveyed in district Mansa were developed in economically utilized agriculture land (18.4 ha) by extracting underground saline water available at the depth of 100-200 feet.

Training and skills in shrimp farming: With an overall percentage of 96.7%, all the farmers (100%) surveyed in Fazilka and Sri Muktsar Sahib Districts and 90% farmers in district Mansa had acquired practical training for capacity building in shrimp farming (Table 2). High investment cost involved in shrimp farming had been the prime factor that

Table 2. Socio-economic profile of shrimp farmers in different districts

Variable/ Categories		Fazilka	Sri Muktsar Sahib	Mansa	Total
Gender	Male	100	100	100	100
	Female	0	0	0	0
Age (yrs.)	<25	10	0	10	6.7
	26-35	30	50	70	50.0
	36-50	50	50	20	40.0
	>50	10	0	0	3.3
Education status	< Matric	10	10	0	6.7
	Matric	40	30	60	43.3
	Graduate	50	60	40	50.0
Total land holdings (ha)	<2	20	0	0	6.7
	2-4	40	30	40	36.6
	>4	40	70	60	56.7
Land under shrimp farming (ha)	<0.8	0	30	0	10.0
	0.8-2.0	80	10	70	53.3
	>2.0	20	60	30	36.7
Occupation	Aquaculture	30	0	0	10.0
	Aquaculture + Agriculture	70	90	90	83.3
	Aquaculture + Business	0	10	10	6.7
Training/Capacity building	Yes	100	100	90	96.7
	No	0	0	10	3.3
Exposure visits	A.P./T.N./Haryana/Gujarat	10	10	10	10.0
	Haryana	30	40	70	46.7
	No Visit	60	50	20	43.3
Access to technologies	Department of Fisheries	0	20	0	6.7
	GADVASU	70	40	90	66.7
	GADVASU & Media	30	30	10	23.3
	Any Other	0	10	0	3.3
Year of shrimp adoption	Before/During 2017	30	30	10	23.3
	2018	20	50	30	33.3
	2019	40	20	50	36.7
	2020	10	0	10	6.7
Reason of adoption	Utilization of Waste Land	30	70	0	33.3
	Higher Income	50	20	100	56.7
	Both	20	10	0	10.0
Credit source	Own Resources	60	80	60	66.7
	Subsidy/Loan	40	20	40	33.3

farmers attained technical skills to rear shrimp without any management failure. Since, farmers had acquired technical skills through trainings (96.7%), exposure visits (56.7%), interaction with shrimp farmers (100%) and consultancy with R&D institutes like GADVASU (73.3%), no farm manager or technician has been deployed on their farms. At 86.7% of farms skilled labor was hired, including 76.7% permanent manpower, to manage the shrimp farms in a scientific manner as per recommended BMPs.

Bio-security awareness and management: Biosecurity measures, including seed quality (SPF), net fencing, foot/hand dips and farm entry restrictions, were adapted by 93.3-100% of farmers in all the districts, while nylon thread network over the pond (protection against predatory birds) was used only by 40, 90 and 60% farmers in Fazilka, Sri Muktsar Sahib and Mansa districts, respectively. Overall, majority of the farmers were well aware and vigilant of bio-security measures, so as to prevent any kind of disease outbreak leading to mortality or quality compromise. Anticipating pandemic driven marketing problems and stringent quality control for export, the farmers were more watchful to prevent any added financial loss due to disease or poor quality of harvest. In contrast, only 14% farmers in the neighboring states (Haryana, Rajasthan and Western UP) were using bird nets, which was less than reported in the present study (Bist 2019).

Seed and stocking: All the farmers procured shrimp seed from the hatcheries in Andhra Pradesh and Tami Nadu registered with Coastal Aquaculture Authority (CAA) of India. In terms of seed supply, A.P. and T.N. supplied 90 and 70% seed in Mansa and Sri Muktsar Sahib districts, respectively, while no specific dominance was observed in case of district Fazilka (Table 3). Owing to COVID-19 pandemic, stocking of ponds got delayed by 2 to 3 months in all districts and 83.3% farmers procured seed (PL) @ Rs. 0.61-0.80 PL^{-1} (43.33% @ Rs. 0.71-0.80 PL^{-1}). Overall, 76.7% of the farms were stocked in the month of June and rest in July, 2020. Vannamei seed was however, procured on an average seed rate of Rs. 0.65

Table 3. Management profile of shrimp farms in different districts

Variable/ Categories		Fazilka	Sri Muktsar Sahib	Mansa	Total
Water depth (Feet)	4-5	100	100	20	73.3
	>5	0	0	80	26.7
Seed source	A.P.	50	30	90	56.7
	T.N.	50	70	10	43.3
Stocking size	<PL10	70	90	30	63.3
(PL size)	PL10-12	30	10	70	36.7
	>PL12	0	0	0	0.0
Seed cost	<0.60	20	10	0	10.0
(Rs. PL^{-1})	0.61-0.70	50	40	30	40.0
	0.71-0.80	20	50	60	43.3
	>0.80	10	0	10	6.7
Stocking rate	< 1.00	0	20	10	10.0
(Lakh PL per m^2)	1.00-1.25	50	20	30	33.3
	1.26-1.50	40	40	50	43.3
	>1.50	10	20	10	13.3
Seed survival (%)	<70	30	60	70	53.4
	71-80	40	20	10	23.3
	>80	30	20	20	23.3
Feed used	<7.5	50	0	20	23.3
(t ha^{-1} $Crop^{-1}$)	7.6-10	50	90	80	73.3
	>10	0	10	0	3.3
Feed cost	70-75	0	20	0	6.6
(Rs. kg^{-1})	76-80	0	80	60	46.7
	81-85	100	0	40	46.7
Health management	Aeration	100	100	100	100.0
	Disinfection	90	100	100	96.7
	Sanitizers	80	70	60	70.00
	Mineral Supplements	100	100	100	100.0
Farm management	Permanent Labor	80	70	80	76.7
	Hired labor	20	10	0	10.0
	Self- Management	0	20	20	13.3
Farm labor	Skilled	100	80	80	86.7
	Non-Skilled	0	20	20	13.3
Farm technician	Yes	0	0	0	0
	No	100	100	100	100

PL^{-1} in Haryana, Punjab, Rajasthan and Western U.P during the previous years (Bist 2019), indicating significant hike in seed cost (up to 23%) during 2020. Similar seed hike was recorded in the southern states during 2020 (CIBA 2020), where the seed prices increased by 15-30% affecting production cost significantly and the farmers had to spend Rs. 62,500-75,000/- more on every ha of stocking.

The districts also differed in terms of PL stocking size. In Fazilka and Sri Muktsar Sahib, 70% and 90% farmers stocked their ponds with PL size <10, while in district Mansa 70% farmers stocked PL size 10-12. Available database indicates that PL 10-14 was commonly stocked in Haryana, Rajasthan and Western U.P (Bist 2019), while in Punjab PL 10-12 sized seed was stocked during 2019 (Singh et al 2020). About 43.3% farmers followed the GADVASU advisory to restrict stocking between 20-30 PL per m^2 (<2.5 – 3.0 lakh ha^{-1}) to mitigate any unforeseen marketing issues owing to COVID -19 pandemic restrictions on international flights and export. Maximum seed survival (>70%) was reported from district Fazilka, while it was only 40% and 30% in Sri Muktsar Sahib and Mansa districts, respectively. It can be attributed to differences among the districts in respect to seed quality, seed size and stocking rate. With only 13.3% farmers exceeding stocking limits of 3.5 lakh ha^{-1}, most of the farmers (76.7%) were able to retain the stock for an extended period and sell the produce in a phased manner at competitive prices. According to early reports, in Mansa (Punjab), Rohtak (Haryana), Churu (Rajasthan) and Hathras and Mathra (Western UP) districts, shrimp seed stocking @ 25-50 PL per m^2 had been a common practice during previous years (Bist 2019, and Singh et al 2020). Besides seed quality, both seed size and stocking density affects seed survival in relation to carrying capacity of the pond, which in turn depends on water depth, water quality and management. Differences in respect to listed factors are hence, responsible for lower survival rates recorded in Sri Muktsar Sahib and Mansa districts.

Water quality and health management: As per scientific recommendations, 100% farmers in all the districts had installed wheel aerators in their ponds @ 10 aerators ha^{-1} to keep the ponds well aerated and overall water depth between 4-5 feet was maintained by 73.3% farmers, while 26.7% maintained it >5 feet (Table 3). Shrimp farmers of neighboring inland states (Haryana, Rajasthan and U.P.) have also been reported to maintain 5 feet water depth with 10 wheels aerators installed ha^{-1} (Bist 2019). Salinity of water of shrimp ponds varied from 7-16, 9-16 and 12-15 ppt in Fazilka, Sri Muktsar sahib and Mansa districts, respectively. Majority of farmers in Fazilka (90%) and Sri Muktsar Sahib (100%) districts got their samples tested from ICAR-CIFE Centre, while in district Mansa majority of the farmers (90%) got the water samples tested from GADVASU. Although, many chemicals and supplements were used by farmers for maintaining the water quality, but application of salts (calcium, magnesium and potassium), soil/water sanitizers and disinfectants like BKC (Benzalkonium Chloride), $KMnO_4$ (Potassium Permanganate) were most commonly used by the farmers in all the districts. However, the most common chemicals/ supplements used in other inland states like Haryana, Rajasthan and Western UP (Bist 2019) are reported as mineral supplements, zeolite, oxygen enhancers, ammonia reducing compounds, disinfectants and probiotics.

Feed and feeding management: Different brands (total 6 brands) of commercial feed were used in different districts. Mansa and Sri Muktsar Sahib had specific preferences for feed brands, while no such preference was observed in Fazilka district. The crude protein content (dry matter basis) in the said feed brands varied between 35 to 38%, which is expected to effect shrimp growth and productivity and is discussed in the following section. The BMPs in respect to feed check-tray, feeding rate, feeding frequency and feeding methods were followed by 96.7% of the farmers (Table 3). Overall, 73.33%, farmers used 7.6-10 t feed ha^{-1} for rearing one crop of shrimp, with maximum no. of farmers recorded in Sri Muktsar sahib (90%) followed by Mansa and Fazilka. As compared to Fazilka, more feed was used by the farmers of Sri Muktsar Sahib and Mansa districts, which is attributed to higher seed stocking rate and subsequent higher feed requirement of standing crop biomass in these districts. Further, culture period (<100 to >120 days) differences also played a major role in quantity of feed used in different districts, as discussed in following section. Cost of feed varied with the feed brand, costing Rs. 76-80kg^{-1} (46.7%) and Rs. 81-85kg^{-1} (46.7%) to most of the farmers, which was 7-9% higher than previous years (Singh et al 2020) owing to pandemic affected supply chain. However, little less hike (6-7%) was reported in case of coastal states during 2020 (CIBA 2020), probably due to added transport charges for feed supply to the northern states.

Culture period, weight gain and productivity: Culture period varied among different districts, which is attributed to delayed stocking due to seed procurement hassles faced by the farmers amidst COVID-19 pandemic. In district Fazilka, 60% of farmers harvested shrimp after 101-120 days of culture. In district Sri Muktsar Sahib, 40% farmers harvested the crop in less than 100 days of culture, while 50% reared the stock for > 120 days (Table 4). However, in district Mansa 50 and 40% farmers reared shrimp for 101-120 and > 120 days, respectively. Due to differences in crop duration,

shrimp harvested in different districts differed in terms of size and count (no. kg^{-1} of shrimp). In district Fazilka, 50 and 30% of farmers harvested shrimp weighing 26-30g and >30g, respectively. In Sri Muktsar Sahib 40 and 60% and in Mansa 20 and 50% farmers harvested shrimp weighing 26-30g and >30g, respectively (Table 4). Higher average shrimp weight in districts Sri Muktsar Sahib and Mansa is attributed to higher percentage of farmers rearing the shrimp crop for > 120 days (40-50%) as compared to farmers in district Fazilka (20%) and maintenance of water depth >5 feet by 80% farmers in district Mansa.

Productivity of the shrimp farms in different districts also appeared to vary in respect to salinity, stocking size, stocking rate, survival, feed quality and management differences at farmer's level. In terms of productivity, 70, 60 and 70% farmers in Fazilka, Sri Muktsar Sahib and Mansa districts harvested 6.5 to 8.75 t shrimp ha^{-1}, respectively; while one farmer in district Sri Muktsar Sahib harvested > 8.75 t shrimp ha^{-1}. Although, the shrimp productivity recorded in all the districts was less as compared to previous years, probably due to low stocking rates (Singh et al 2020), but as per recent report (MPEDA 2021), it was still higher than the average productivity (t ha^{-1}) reported in most of the southern states during 2020-21 viz., A.P. (8.82), T.N & Pondicherry (5.20), Kerala (2.67), Karnataka (2.25), Maharashtra (3.59), W.B. (5.84), Odisha (4.10) and Gujarat (5.60). Among all, productivity of 7.5 t ha^{-1} was achieved by 40% of the shrimp farmers in Punjab, indicating the potential of shrimp farming in inland saline areas and its prospective role in food security and export earnings for the State.

With an overall percentage of 66.7%, Fazilka appeared at the top in terms of FCR (90% farmers achieving FCR < 1.2), followed by Mansa and Sri Muktsar Sahib. This can be attributed to differences in type of feed used by the farmers, besides variations in stocking rate (<2.5 to > 3.75 lakh PL ha^{-1}) and crop period (<100 to >120 days). The feed conversion efficiency decreases with progress of culture period with increase in size of shrimp (Lee and Lee 2018) and hence, higher FCR values were recorded in Sri Muktsar Sahib, where 50% farmers reared shrimp for > 120 days and 100% farmers produced bigger sized shrimp (26-40g), followed by Fazilka and Mansa. Garza de Yta et al (2004) recorded FCR of 1.97, 2.03 and 2.12 during nursery rearing of *L. vannamei* for 1-10 days, 10-20 days and 20-30 days, respectively. Lee

Table 4. Economic performance of shrimp farms in different districts

Variable/ Categories		Fazilka	Sri Muktsar Sahib	Mansa	Total
Culture period (Days)	<100	20	40	10	23.3
	101-120	60	10	50	40.0
	>120	20	50	40	36.7
Disease outbreak	Yes	0	0	10	3.3
	No	100	100	90	96.7
Average shrimp Wt. Harvested (g)	<25	20	0	30	16.7
	26-30	50	40	20	36.7
	>30	30	60	50	46.6
Productivity	<5	10	0	20	10.0
(t ha^{-1}Crop^{-1})	5.1-6.25	20	30	10	20.0
	6.3- 8.75	70	60	70	66.7
	>8.75	0	10	0	3.3
FCR	<1.2	90	40	70	66.7
	1.3-1.5	10	50	10	23.3
	>1.5	0	10	20	10.0
Marketing	On-Farm	100	100	100	100
	Market	0	0	0	0
Operational cost	<7.5	10	0	0	3.3
(Lakh ha^{-1} Crop^{-1})	7.6-12.5	10	40	10	20.0
	12.6-17.5	70	50	80	66.7
	>17.5	10	10	10	10.0
Post-harvest management/ Marketing	On-Farm Sale	100	100	100	100
	Processing	0	0	0	0
	Storage	0	0	0	0
Average sale rate	<300	0	0	20	6.7
(Rs. kg^{-1})	301-400	70	60	30	53.3
	>400	30	40	50	40.0
Net income	<7.5	10	0	30	13.3
(Lakh ha^{-1} Crop^{-1})	7.6-10.0	20	10	10	13.3
	10.1-12.5	20	10	10	13.3
	>12.5	50	80	50	60.0

and Lee (2018) reported FCR of 1.32 in *L. vannamei* juveniles (0.65g) fed for 36 days and 1.55 in adult (10.5g) fed for 48 days on same diet (CP 35%) and recorded reduced FCR with increase in diet CP level from 35 to 40%. CP levels of feeds used by the farmers of the state is also expected to have played a significant role in combination to culture period and size of shrimp in respect to FCR recorded in the 3 districts during the present study.

Post-Harvest management and marketing: All the farmers marketed their produce directly to traders at the farm site and could fetch competitive prices for every size they harvested from < 15 g to >40 g (65-25 count kg^{-1}). Overall, 93.3% farmers could sell their produce @ >Rs. 300 kg^{-1} (including 40% @ > Rs. 400 kg^{-1}), while as per NABARD report (Bist 2019), shrimp produced in inland states was sold @ Rs. 250-400 kg^{-1} during previous years, depending on size and quality (Table 4). No farmer was involved in any kind of processing or storage activities. Shrimp harvest was lifted by traders from A.P., Haryana, New Delhi and Gujarat, but stock from maximum farms (83.3%) was lifted by traders/lifting parties from A.P., indicating strong linkages of the farmers with the processing industry and demand of shrimp, which attracted traders/processors to Punjab from a far of state.

Operational cost and income: Operational cost of majority of farms (66.7%) ranged between 12.6 to 17.5 lakh ha^{-1} $crop^{-1}$ and with 90% farmers spending >12.5 lakh ha^{-1} $crop^{-1}$, Mansa emerged as the top district (Table 4) followed by Fazilka and Sri Muktsar Sahib, which is attributed to higher stocking rates and subsequent higher feed requirement, overuse of chemicals and additives for water quality management and power charges thereof. The 60% of the farmers earned a net profit of > 12.5 lakh ha^{-1} $crop^{-1}$ and Sri Muktsar Sahib was the top district with 80% farmers in the said net profit category. In district Fazilka, 40% farmers recorded BC ratio of more than 1.00 (1.28-1.32), while 30% achieved BC ration 0.96 to 0.99. In district Sri Muktsar Sahib, 50% of farmers recorded BC ratio > 1.00 (1.03 – 1.33) and 30% achieved BC ratio 0.91-0.96. Further, in district Mansa, 40% farmers recorded BC ratio > 1.00 (1.15- 1.35) and only 10% achieved BC ration 0.9-1.0. However, 20% farmers in district Mansa suffered loss due poor survival of seed and outbreak of black gill disease. Shrimp farming is a 'High Cost High Risk' aquaculture practices, involving about 10-15 lakh of operational or production cost ha^{-1} $crop^{-1}$of about 100-120 days. Market price of shrimp varies with size and quality, being an export commodity. Hence, net earnings of the farmers depend on both quantity and quality of shrimp harvested from their pond.

No economic study in respect to shrimp farming in inland saline areas of Punjab has been conducted so far. However, in Haryana, Rajasthan and Western UP, productivity levels ranging from 6.25 to 12t ha^{-1} (Bist 2019) were recorded during 2019. While, Joshi (2019) reported shrimp productivity of 13 and 10t ha^{-1} in Haryana, at salinity levels of 13-15 ppt and 0.5-2.0 ppt, respectively. Earlier, Singh et al (2020) reported shrimp productivity of 8.35 t ha^{-1} in district Mansa (Punjab), with stocking rate of 50 PL per m^2 and culture period of 140 days.

Further, if compared with southern states having about 2.40 lakh ha area under brackish water aquaculture (Ravisankar et al 2018), with an average shrimp productivity of 6.85t ha^{-1}, Punjab performed equally well with 66.7% farmers achieving productivity range of 6.5-8.75 t ha^{-1} during 2020.

As compared to inland state Punjab, shrimp farming in southern part of the country witnessed more difficulties and losses due COVID-19 lock down (CIBA 2020) i.e., 15-30% increase in seed cost, 6-7% increase in feed cost, 40% reduction in area, 15-20% increase in production cost. As per latest reports, total shrimp production of India dropped by 29% in 2020 with an estimated loss of 40% (Chase 2021), while world production dropped by 13% (Kumaran et al 2021).

However, in Punjab majority of the farmers could harvest their crops with profit owing to delayed stocking (June-July) at restricted stocking densities (25-30 PL per m^2), with 21.92% increase in area. This could only be possible because complete stocking was done after the lock-down period.

CONCLUSION

Although, COVID-19 pandemic and subsequent restrictions delayed stocking of ponds, besides affecting seed and feed cost in Punjab, but farmers could fare well under the resilience advisory issued by GADVASU and majority of farmers harvested 6.5-8.75 t (66.7%) shrimp ha^{-1}, with net earnings of Rs. 7.6-12.5 lakh (26.7%) and >12.5 lakh (60%) ha^{-1}, without any disease outbreak and major marketing curtailment. The adopted resilience plan helped the farmers to realize the economic benefits of low-density stocking, which enabled them to retain their stocks for an extended period over 120 days (36.7%) and earn more through phased marketing strategy. Although, shrimp farming in Fazilka and Sri Muktsar Sahib has been adopted to utilize under or unproductive salt affected lands, but conversion of good agriculture land for shrimp farming by extraction of underground water (100-200 feet depth) is a matter of great concerns as it may cause serious environmental impact through salinization of adjoining

areas.

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