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Semi-intensive Carp Culture in Saline Water-Logged Area: A Multi-Location Study in Shorkot (District Jhang), Pakistan

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Abstract.- The saline water-logged area of Shorkot (District Jhang) along the Trimmu-Sidhnai Link and Haveli Canals is an excellent site for fish culture. Fish culture not only plays an important role in human nutrition but also in the rural economy of the country. The main purpose of present study was to identify the primary production and fish production patterns in villages under different management practices. Soil and water samples of seven selected fish farms were collected and analyzed for some physico-chemical and biological parameters such as pH, electrical conductivity (EC), dissolved O_2, free CO_2, sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soil texture and plankton density. The costs and returns of carp culture in such saline water-logged areas were also calculated. Results indicated that all the six carp species were well adapted to different supplemental feeds along with salt-tolerant forages in saline environments. The net carps production ranged from 1198 to 1410 kg ha^{-1} $year^{-1}$ and plankton density 565 to 1608 organisms L^{-1}. The net profit obtained was Rs. 14652 to 19417 per acre with benefit-cost ratio 1.37 to 1.51 in brackish groundwater (EC 1.80 to 3.93 dS m^{-1}), indicating the influence of environmental and management factors. The average fish yield was about 32.5% less than the yield obtained from freshwater pond culture. It may be concluded that saline aquaculture has potential to meet the demand of fishery products, generate income and contribute to sustainable food supplies.

Key words: Indian major carps, Chinese carps, polyculture, supplemental feed, brackish water.

INTRODUCTION

In Pakistan, aquaculture is relatively newly introduced activity and is still in its growing phase; there are large numbers of opportunities to strengthen this sector. The country has vast fresh, brackish and marine water resources where only carp culture is practiced in earthen ponds by adopting extensive farming technique with very little inputs. Pakistan is very rich in fish fauna but only nine species (7 warm water and 2 cold water) are being cultured on commercial scale (FAO, 2008).

Saline aquaculture is one of the profitable options for income generation by utilization of more than one billion hectares of abandoned salt-affected lands world-wide and underlain brackish water resources. Apart from marine fisheries, inland fisheries (rivers, ponds, etc.) are also important sources of cheaper animal protein with high biological value (96%) and protein efficiency ratio (3.55). The consumption of fish is very low *i.e.* 1.7 kg per capita annually in Pakistan. Only 26% of total production is consumed domestically, 19% being exported and 55% used for fishmeal (Wasim, 2007). The fisheries sector as a whole contributes to about one percent to the country's GDP and provides jobs for about one percent of the country's labour force. Freshwater carp farming is the major aquaculture activity in three of the country's four provinces, *i.e*. Punjab, Sindh and Khyber Pakhtoon Khawa (Sultana, 2004).

Good nutrition in animal production systems is essential to economically produce a healthy and high quality product. In fish farming, nutrition is most critical factor as it represents 40-50% of the production cost (Craig and Helfrich, 2002). Semi-intensive type of fish culture is based on natural food as the main source of protein while energy requirements are fulfilled by carbohydrates from raw cereals as supplementary feed (Markovic and Mitrovic-Tutundric, 2003). It is necessary to utilize all the available resources to develop fish industry through simple agriculture practice. Among the new trends in fish culture, integrated semi-intensive system is more acceptable because various agricultural wastes and low value feedstuff can be utilized as a cost-effective source of fish feed (Ahmed *et al*., 2005).

In ponds, the required nutrients for proper

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growth of fish are limited because of nutrient loss in pond sediments. This loss can be reduced through the addition of fertilizers and supplemental feed in semi-intensive culture system. Fertilizers increase the primary productivity, dissolved O_2, pH and total phosphorus while supplemental feeds fortify the naturally available diet with extra protein, carbohydrates and/or lipids (Azaza *et al.*, 2009).

Phytoplankton and zooplankton can be used as bio-indicators to assess water quality of carp ponds (Dulic *et al.*, 2009). Zooplankton respond quickly to the environmental changes and may be an effective indicator of subtle alterations in water quality (Zakaria *et al.*, 2007). Phytoplankton are integrated extensively into water quality monitoring programs worldwide and are highly responsive to nutrient loadings due to rapid reproduction and short life cycles (Dulic *et al.*, 2010). Fish growth is strongly correlated with increase in phytoplankton and zooplankton productivity. Under polyculture system, organic and inorganic fertilizers provide basic nutrients required for the production of plankton which serve as a major source of food for fish (Rehman and Hussain, 2008).

The saline water-logged areas which are no longer used for crop producing can be developed for fish culture. There is a need to examine the fish growth rate, net production, economics and problems of carp culture in such areas to convince and educate the farmers to engage more and more in saline aquaculture.

MATERIALS AND METHODS

A general survey of the fish farms in Shorkot, District Jhang (latitude 30° 45' 35 N and longitude 72° 16' 58 E) was conducted and seven managed fish farms from different villages were selected on the basis of management practices and productivity. These farms are located in the field area of "Saline agriculture farmer participatory development project (SAFPDP) in Pakistan" along Trimmu-Sidhnai Link and Haveli Canals which originate from Head Trimmu and extend up to Head Sidhnai covering a distance of 45 km (Fig. 1).

The climate of Shorkot site is dry subtropical. The main feature of the climate is two well-defined seasons, a hot summer with late monsoon rains and a relatively milder winter. Average rainfall per year is around 250 mm. Main water source used for fish culture is seepage water of Trimmu-Sidhnai Link and Haveli Canals but when there is no water supply in these canals, brackish tube-well water is used as an alternative source.

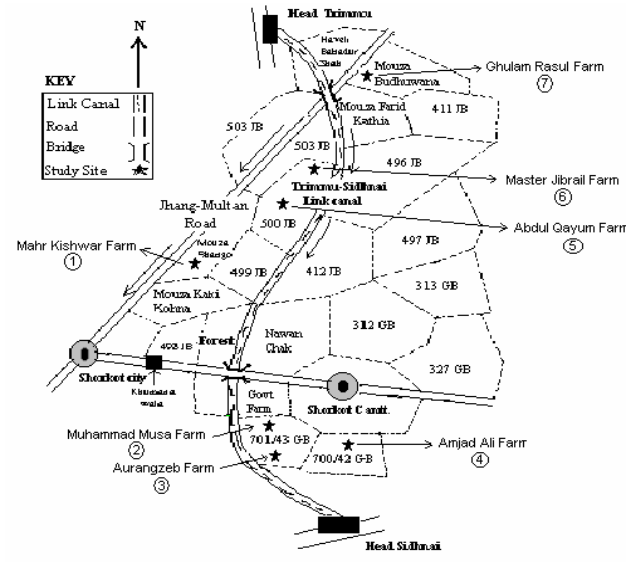

Fig. 1. Fish farms selected for study at Shorkot (District Jhang).

In Shorkot, fish farmers cultured Indian major and Chinese carps in semi-intensive polyculture system with different combinations, depending upon the availability of fish seed from government fish hatcheries. They use maximum their on-farm resources like cow-dung, poultry waste, goat droppings as organic manure and fodder crops like barseem, sorghum and kallar grass as supplemental feed to get good economic return.

Soil and water samples collected from the selected fish farms were analyzed by using methods of USDA Handbook-60 (Richards, 1954). The water samples for planktonic density were preserved in plastic bottles with 4% formalin solution (Battish, 1992). The planktonic population was estimated by using Sedgwick Rafter Cell. Different growth parameters, *i.e.* weight gain, survival rate, specific growth rate and net fish production of all selected fish farms were recorded at the time of harvesting by the actual harvests. The economics including capital cost, operational cost, net profit and benefit-cost ratio (BCR) were also calculated and found the

major constraints which become major hindrances to farmer's economic growth. The statistical analysis was carried out to find significant relationship among different fish farms by using MSTATC program (1989, Michigan State University, USA).

RESULTS AND DISCUSSION

In Pakistan, water-logging and salinity is decreasing the production potential with an ever increasing pace for more than three decades, threatening our agriculture. Severely water-logged soils have gone out of production, whereas slightly/moderately affected lands are producing much lower yields (Kahlown *et al.*, 2001). Salinity and water-logging coupled with drought and aridity is causing large scale poverty in Pakistan.

In the study area, different farmers use different management practices to produce marketable sized fish at minimum cost. There are many factors that affect productivity and cost of fish production. Water quality, stocking rate and the quality and quantity of food are most important factors that influence fish growth rate and production. The characteristics of fish farms selected in saline water-logged area of Shorkot, are presented in Table I.

Water quality

Mean values of physico-chemical parameters of pond water from all study sites are presented in Table II. The pH of pond water ranged from 7.15 to 8.20. There was slight variation in pH values at all sites but were found within limits, *i.e.*, 7.5 to 9.0 (Pailwan *et al.*, 2008). Low pH interferes with oxygen uptake and reduces the feeding activity (Matthews, 1998). The EC of pond water at seven sites varied greatly due to mixing of seepage water in some ponds and ranged from 1.80 to 3.93 dS m^{-1}. The values for electrical conductivity were high during summer that may be due to high evaporation rates and salt concentrations (Bhatnagar and Singh, 2010). The maximum value of dissolved O_2 was observed at site-3 (6.2 mg L^{-1}) whereas minimum value was found at site-6 (4.1 mg L^{-1}). Pond water with 5 to 10 mg L^{-1} dissolved O_2 is considered ideal for fish production (Banarjee and Lal, 1990). Free CO_2 was recorded maximum at site-6 (9.1 mg L^{-1}) and minimum at site-5 (7.1 mg L^{-1}). Free CO_2 showed inverse relation with dissolved O_2. Chlorides, calcium and magnesium were high in all ponds that may be due to addition of farmyard manure, since these parameters are usually taken as an index of pollution (Bhatnagar *et al.*, 2009).

The plankton density varied from 565 to 1608 L^{-1}. The biological characteristics of pond water clearly indicated that salinity grossly affected the primary pond productivity in the form of Phytoplankton density; it was maximum (1260 L^{-1}) at conductivity 1.80 dS m^{-1} and minimum (488 L^{-1}) at conductivity 3.92 dS m^{-1}. Similarly, zooplankton also varied in the same proportions *i.e.* maximum (356 L^{-1}) at conductivity 1.81 dS m^{-1} and minimum (77 L^{-1}) at 3.92 dS m^{-1}, as presented in Table III. The plankton density was comparatively high in those ponds having mixed water of tube-well and canal water indicating the environmental effect. Pond fertilization is used to stimulate both the autotrophic and heterotrophic levels which increase fish production (Grag and Bhatnagar, 2000). According to Bhatnagar and Singh (2010) the optimum plankton population is approximately 3000 to 4500 L^{-1} in freshwater ponds.

Soil characteristics

The soil properties of all selected fish ponds depicted that they were less to highly salt-affected having conductivity 3.38 to 15.2 dS m^{-1} and pH 7.62 to 8.85 (Table III). Boyd (1995) argued that aquaculture pond soil should have pH above 7.0. The maximum sodium adsorption ratio (33.3) with highest Na^+ concentration (117 meq L^{-1}) was found at site-7 while minimum SAR 4.74 with lowest Na^+ concentration (17.9 meq L^{-1}) was found at site-4. The maximum concentration of Ca^{2+}+Mg^{2+} was 46.4 meq L^{-1} at site 6 and minimum 14.1 meq L^{-1} at site-3. The maximum K^+ concentration (19.5 meq L^{-1}) was found at site-5. The texture of pond soil receiving canal water was sandy loam to loam, while others receiving no canal water were sandy clay loam in texture. The overall soil quality was better at Mauza Bhango (Site 1), Chak No. 701/43 GB (Sites 2 & 3) and Chak No. 700/42 GB (Site 4) as compared to Chak No. 500 JB (Sites 5 & 6) and Mauza Budhuwana (Site 7).

Table I.- Characteristics of fish farms selected for study in Shorkot (District Jhang).

Site No.	Name of farm / village	Area (hectare)	Water sources	Breeds cultured*	Fertilizers used	Supplemental feed used
1	Mahr Kishwar Farm Mauza Bhango	1.21	Tube-well	Five (R, M, T, GC, SC)	Cow-dung, Poultry waste, Gypsum, DAP	Rice polish, barseem, *Sorghum*, kallar grass
2	M. Musa Farm Chak No. 701/43 GB	2..82	Canal/ Tube-well	Six (R, M, T, GC, SC, CC)	Cow-dung, Poultry waste, Nitrophos	Rice polish, gluten, fish meal, molasses, sunflower meal
3	Aurangzeb Farm Chak No. 701/43 GB	4.86	Canal/ Tube-well	Six (R, M, T, GC, SC, CC)	Cow-dung, Poultry waste	Dry bread pieces, cottonseed oil cake, molasses
4	Amjad Ali Farm Chak No. 700/42 GB	2.43	Canal/ Tube-well	Six (R, M, T, GC, SC, CC)	Cow-dung, DAP	Rice polish, sunflower meal, kallar grass
5	Abdul Qayum Farm Chak No. 500 JB	1.21	Tube-well	Five (R, M, T, GC, SC)	Cow-dung, Goat droppings, Gypsum	Rice polish, chokar, kallar grass
6	Master Jibrail Farm Chak No. 500 JB	1.62	Tube-well	Five (R, M, T, GC, SC)	Cow-dung, Gypsum	Rice polish, chokar, kallar grass, *Sorghum*
7	Ghulam Rasul Farm Mauza Budhuwana	3.24	Tube-well	Six (R, M, T, GC, SC, CC)	Cow-dung, Poultry waste	Rice polish, barseem, kallar grass

* R, Rohu (*Labeo rohita*); M, Mori (*Cirrhinus mrigala*); T, Thaila (*Catla catla*); GC, Grass carp (*Ctenopharyngodon idella*); SC, Silver carp (*Hypophthalmichthys molitrix*) and CC, Common carp (*Cyprinus carpio*).

Table II.- Water quality parameters (±SD) of selected fish farms located at Shorkot (District Jhang).

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
pH	7.52±0.02	7.47±0.01	7.46±0.01	7.53±0.03	7.15±0.02	7.97±0.02	8.20±0.01
EC (dS m^{-1}) *	2.31±0.01	1.80±0.02	1.93±0.01	2.98±0.01	3.93±0.02	2.75±0.02	1.81±0.01
Dissolved O_2 (mg L^{-1})	5.5±0.1	4.3±0.05	6.2±0.08	5.9±0.07	4.8±0.03	4.1±0.01	4.7±0.02
Free CO_2 (mg L^{-1})	7.2±0.12	8.9±0.11	8.6±0.10	8.4±0.09	7.1±0.11	9.1±0.08	8.4±0.10
Cl^{-1} (mg L^{-1})	65.4±1.5	359±3.9	209±2.5	58.6±1.1	12.4±0.9	280±2.7	1.0±0.1
Na^{+} (meq L^{-1})	13.9±0.5	15.7±0.4	13.5±0.5	6.47±0.1	37.9±0.3	33.3±0.2	1.6±0.1
K^{+} (meq L^{-1})	0.46±0.05	0.01±0.00	0.06±0.01	0.06±0.01	0.28±0.02	0.01±0.00	0.04±0.01
Ca^{2+}+Mg^{2+} (meq L^{-1})	7.6±0.01	11.0±0.01	12.6±0.02	6.4±0.01	9.6±0.02	3.6±0.01	2.0±0.01
CO_3^{2-} (meq L^{-1})	Nil	Nil	Nil	Nil	Nil	Nil	Nil
HCO_3^{-} (meq L^{-1})	8.0±0.02	8.2±0.01	6.4±0.02	8.2±0.03	14.1±0.02	14.0±0.03	2.5±0.01
SAR**	7.16	6.72	5.38	3.62	17.3	24.8	8.72
RSC (meq L^{-1}) ***	0.4	Nil	Nil	1.6	4.4	10.6	0.5
Plankton density L^{-1}	676±21.5	1608±52.6	1245±26.3	1052±29.8	565±19.6	1420±38.4	1431±59.8
Phytoplankton L^{-1}	573±12.7	1260±38.4	1045±21.7	854±15.6	488±14.4	1106±23.6	1075±33.5
Zooplankton L^{-1}	103±9.5	348±11.8	200±11.5	198±8.7	77±6.7	314±15.5	356±24.6

* EC, electrical conductivity; ** SAR, sodium adsorption ratio; *** RSC, residual sodium carbonate.

Pond construction

In order to reduce the capital costs for better economic benefits, farmers used low cost pond construction technique. By this technique, about 35% construction cost can be saved by digging of the pond up to two feet depth only and raising the pond dykes with excavated soil. Almost all the ponds at selected fish farms were constructed by adopting this technique in rectangular shape with 6-7 feet depth.

Stocking rate

Stocking of fish seed is considered as prime input; depends on species, size of fingerling and pond conditions as fish pond can support a certain quantity of fish in its limited space and natural food.

Table III.- Soil characteristics (±SD) of selected ponds located at Shorkot (District Jhang).

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
pH	7.62±0.01	8.85±0.01	8.55±0.04	7.64±0.03	7.84±0.02	7.91±0.01	8.14±0.04
EC (dS m^{-1})	3.54±0.04	4.38±0.03	5.86±0.02	3.38±0.03	14.1±0.01	15.2±0.04	14.8±0.05
Na^+ (meq L^{-1})	32.7±0.02	41.2±0.01	45.6±0.02	17.9±0.01	108.5±0.55	106.6±0.65	117±0.15
K^+ (meq L^{-1})	0.41±0.01	0.72±0.02	0.65±0.02	0.46±0.02	19.5±0.15	2.83±0.01	1.08±0.02
Ca^{2+}+Mg^{2+} (meq L^{-1})	42.5±0.11	18.5±0.08	14.1±0.15	28.6±0.11	38.2±0.05	46.4±0.15	24.6±0.05
SAR	7.09	13.6	17.1	4.74	24.8	22.1	33.3
Sand (%)	19.1	44.6	38.7	56.5	60.4	48.4	41.6
Silt (%)	49.0	36.0	40.0	26.0	12.0	20.0	21.0
Clay (%)	31.9	19.4	21.3	17.5	27.6	31.6	37.4
Textural class	Silty clay loam	Loam	Loam	Sandy loam	Sandy clay loam	Sandy clay loam	Clay loam

Table IV.- Costs and returns (in Rs.) from different fish farms at Shorkot (District Jhang).

Inputs	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
A. Capital cost							
Lease amount	-	42000	-	30000	-	-	-
Pond construction	42200	87500	153600	72500	42500	54400	103200
Fish seed	7650	17850	32400	17850	8925	12600	20400
B. Operational cost							
Supplementary feed	17550	82800	154900	45400	15600	21580	63400
Fertilizer	8200	27400	51000	18300	10900	10500	21300
Diesel expenses	16500	13000	26800	17500	15900	18500	22500
Labour charges	18000	8800	24000	18000	12000	18000	24000
Misc. expenses (electricity, etc.)	3680	4400	9550	5880	4250	3900	8850
Total expenses	113780	283750	452250	225430	110075	139480	263650
C. Production							
Net fish production (kg ha^{-1} $year^{-1}$)	1322	1380	1410	1290	1273	1284	1198
Total revenue	159962	389442	685260	313470	154033	208008	388152
Net return (Profit)	46182	105692	233010	88040	43958	68528	124502
Profit per acre	15394	15098	19417	14673	14652	17132	15562
D. Benefit-Cost Ratio	**1.40**	**1.37**	**1.51**	**1.39**	**1.40**	**1.49**	**1.47**

A fertile fish pond produces a number of different kinds of fish food organisms; therefore, stocking different kinds of fish will efficiently utilize the space as well as food. Several stocking rates and rearing practices are in use in different areas of the world. In the study area, a combination of five or six of the three indigenous species of Indian major carps (*Labeo rohita, Cirrhinus mrigala, Catla catla*) as well as three exotic species of Chinese carps (*Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyprinus carpio*) is cultivated with stocking rate 2000 to 2500 per hectare. Chinese carps are contributing as much as 60% of total stocking density as their growth rates are high as compared to Indian major carps.

Fertilization of ponds

Semi-intensive carp polyculture is mostly based on fertilization and supplementary feeding to improve the fertility rate of fish pond. The commonly used organic fertilizers were cow-dung, poultry wastes and goat dropping where as

inorganic fertilizers used were urea, diammonium phosphate and nitrophos. The average doses of organic and inorganic fertilizers were applied at the rate of 6000 kg ha^{-1} and 7.5 kg ha^{-1}, respectively. Types and doses of fertilizers were different at different locations even at same location. They dump manure in a corner of pond to supply the decomposed organic matter for plankton production. In the study area, the planktonic density varied from 565 to 1608 L^{-1}. Minimum planktonic diversity was observed in those ponds receiving brackish groundwater permanently while maximum in those ponds receiving canal water as an alternative source.

Supplementary feeding

Artificial feeding is one of the principal methods for increasing pond production. Kabir *et al.* (2009) reported that net fish production can be increased 7.7 times with the use of supplemental feed. Nazish and Mateen (2011) also reported that pond treated with supplemented feed (rice polish) and fertilizer produced 1.26 times greater fish production than with fertilizer only. Considering all locations, it was noticed that mostly farmers used low protein inputs like rice polish, choker, gluten and dry bread pieces along with salt-tolerant plants, *i.e*. kallar grass, barseem and *Sorghum* to reduce the production cost. Khanum *et al.* (2007) carried out the nutritional evaluation of salt-tolerant plants and reported crude protein level only 8 to 11% which is very low for fish. Only at site 2, the farmer used properly formulated feed by mixing different supplemental feed ingredients including fish meal in a specific ratio and applied at the rate of 3% body weight. Fish meal is high quality fish feed but costly, so the majority of the fish farmers cannot afford. Borgeson *et al.* (2006) replaced high concentration (70%) of fish meal with complex mixture of plant ingredients in supplemental feed used for fish growth.

Results indicated that all the six carp species were well adapted to different supplemental feeds and salt-tolerant forages in saline environments. However, significant differences ($p \leq 0.05$) were observed in different growth parameters among different species at different sites. The average net fish production of seven fish farms ranged from 1198 to 1410 kg ha^{-1} $year^{-1}$.

Production and economics

Cost returns to the farmers can be measured in terms of yield, gross return and net return. Moreover, these are interrelated with each other. Gross return is the value of yield and net return is the difference between gross return and cost of production. The value of fish was calculated at prevailing market rate and it varied from Rs. 100 to 120; according to the size, variety, quality and season. In study area, the average net production of fish varied from 1198 to 1410 kg ha^{-1} $year^{-1}$. Chinese exotic species registered weights of over one kg. Jain *et al.* (2008) reported considerable disparity in growth rates and net production in ponds with different salinities. The calculations for total revenue, expenses and net profit of all 7 sites are given in Table-IV. However, no fish farm in this survey area incurred any loss.

The net profit calculated was Rs. 14652 to 19417 per acre with benefit-cost ratio of 1.37 to 1.51 in brackish groundwater (EC 1.80 to 3.93 dS m^{-1}). The maximum profit ratio was obtained by those farmers whose families participated to save labour cost and is land owners as they have to pay no lease money. However, there was significant difference in net fish production and profit ratio due to environmental and management factors which can be further improved by adopting good management techniques to control the hygienic conditions of the pond along with maximum utilization of on-farm resources.

Problems

The major constraints faced by the fish farmers in study area are discussed below:

Increase in lease amount

The consumption of fish in Shorkot area is increasing and the demand for freshwater fish is also increasing from nearby cities like Gojra, Toba Tek Singh, Jhang and Faisalabad. This demand has led a sudden rise in number of persons bidding for more ponds in the area which is seen in a dramatic rise in the lease amounts from Rs. 3000 to 8000 per acre per annum which ultimately reduce the profit ratio. So, the availability of land in the area has become a big constraint.

Multiple use of pond water

Some farmers use the Trimmu-Sidhnai Link and Haveli Canals water to fill their fish ponds and further used this pond water for household or domestic purposes. During dry season, farmers also use this pond water to irrigate their vegetable fields which makes the pond dry and difficult for fish culture.

Lack of technical knowledge

A major requirement of fish culture is the knowledge of modern saline aquaculture technology. In this study, it was found that some farmers had no technical know-how as they failed to get maximum produce as they stocked too small sized fish seed at too high density in ponds that were neither fertilized nor fed on supplemental feed causing high mortality or the fry simply did not grow. Such fish farmers were also unable to maintain the water quality of pond.

Non-availability of good quality fish seed

Non-availability of standard size fish seed is one of the biggest problems for fish pond culture and sometimes it is mixed with undesirable species. The study area is relatively better with respect to the availability of fish seed as there are two government fish hatcheries at Maloo More (District Jhang) and Pir Mahal (District Toba Tek Singh) to meet demand of the area but the availability of good quality fish seed is still a major problem. Normally small size seed is provided by these hatcheries in which it is difficult to identify the desirable species for mixing appropriate ratio suitable for polyculture in saline environments.

Insufficient financial resources

Fish culture requires considerable investment initially for digging new ponds or upgrading old ponds and secondly for the purchase of various inputs like fish seed, feed and fertilizers. In the study area, capital shortage was recognized as a major constraint for the purchase of all these inputs.

CONCLUSIONS

From this field study, it may be concluded that there exists tremendous scope for further expansion of carp culture in saline water-logged areas by managing levels of inputs and monitoring water quality. Consequently, farmers will get more yield and better returns. The study also identified several problems and constraints of saline fish culture which may be helpful in future for the fish farmers, policy makers and extension staff.

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