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Production Cost and Productivity Analysis of Singhi (*Heteropneustes fossilis*) under Advance and Low Cost Recirculatory Aquaculture Systems (RAS) of Haryana

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ABSTRACT

The study focuses on the economic feasibility of cultivating Singhi (*Heteropneustes fossilis*) in RAS farms in Haryana, India. The research involved an analysis of data collected from 14 RAS farms, encompassing both nursery and grow-out operations, with the aim of evaluating the economic feasibility of Singhi farming in RAS. The results show that the majority of farmers prefer advanced RAS systems due to their superior filtration capacity, which is attributed to the use of more advanced filtration equipment compared to low-cost RAS systems. A comparison between low-cost and advanced RAS systems revealed that while the stocking density was slightly higher in low-cost RAS, advanced RAS achieved better survival rates (77.92% vs. 70%) and similar FCRs (1.39 vs. 1.50). Additionally, the production per tank was substantially greater in the advanced RAS (1273.12 kg) than in the low-cost RAS (882 kg). Consequently, the total production per crop was higher in the advanced RAS (₹ 16,70,308) than in the low-cost RAS (₹ 16,80,000). Furthermore, the harvest size was larger in the advanced RAS (86.20 g) in contrast to the low-cost RAS (70 g). However, it's worth noting that the study's results revealed that the total net profit per year was higher in low-cost RAS (₹ 17,34,470) compared to the advanced RAS (₹ 13,89,032). This discrepancy can be attributed to the higher operational costs associated with the advanced RAS, including expenses related to electricity, labour, expensive filtration equipment, and maintenance. Furthermore, it is worth noting that 13 out of 14 RAS farmers favored grow-out RAS over nursery RAS, primarily because of the lower profitability associated with the latter.

Keywords: Singhi, Haryana, Economic feasibility, Low cost RAS, Advance RAS

One of the most rapidly expanding areas of food production worldwide is aquaculture. The demand for and profit margin for farmed species like tilapia, catfish, salmon, trout, oysters, and clams are quite high (Appiah-Kubi, 2012). A significant contribution to improving the socioeconomic standing of farmers is made by commercial catfish. The Heteropneustidae family, which includes the air sac catfishes found in India, Bangladesh, Myanmar, Pakistan, and Thailand, includes the stinging catfish *H. fossilis*, also known as "Singhi." India reported cases of *H. fossilis* (Ali *et al.* 2016). It is widely regarded for its nutritional and therapeutic qualities in addition to its delectable

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flavor and market worth. In comparison to many other freshwater fish, the species has a very high iron level (226 mg/100 g) and a very high calcium content (Saha and Guha, 1939). The commercial, subsistence, and recreational fisheries, ornamental fish trade, and aquaculture all place a great deal of value on catfish (Gisbert *et al*. 2021). In 2018, a total of 5,781,235.1 t of catfish were produced globally, according to the FAO's aquaculture data (FAO, 2020). On other side, Water and dissolved nutrients are recycled in aquaculture food production systems called recirculating aquaculture systems (RAS) (Mugwanya *et al*. 2022). In contrast to open aquaculture systems like ponds, RAS offers the option to undertake intensive aquacultural techniques with high stocking densities to obtain maximum net output and significant profits.

In the realm of recirculatory aquaculture systems (RAS), several species have proven to be highly suitable choices. These species include Barramundi (*Lates calcarifer*), Cobia (*Rachycentron canadum*), Silver Pompano (*Trichinotus Blochii/ Trichinotus mookalee*), Tilapia (*Oreochromis niloticus*), Pearl Spot (*Etroplus suratensis*), Pangasius (*Pangasianodon hypophthalmus*), and Rainbow Trout (*Oncorhynchus mykiss*) etc (NFDB, 2022) These aquatic champions are well-known for their adaptability to the controlled environments offered by RAS, making them excellent choices for sustainable and efficient fish production. Arifa *et al*. (2021) also reared Ompokpabda and *Heteropneustes fossilis* to evaluate the economic feasibility of these species in RAS.

Locally known as Singhi (*Heteropneustes fossilis*) holds significant economic value due to several key factors. It is in high demand in countries like India and Bangladesh for its delicious taste and highly nourishing and well preferred due to its less spine, less fat and high digestibility (Noor Khan *et al*. 2003). They are extremely resilient fish, and their supplementary respiratory organs allow them to survive for a short period of time without water (Chakraborty and Nur, 2012). Its fast growth rate allows for quicker harvests and increased revenue. Singhi can be cultivated in various sustainable methods, benefiting both the environment and rural communities. This farming generates multiple income streams, including fingerling sales, breeding, and fish meal production (Obwanga *et al*. 2020). Export opportunities add to its economic value, and value-added products like fillets and snacks command higher prices. Cultivating *Heteropneustes fossilis* within a Recirculatory Aquaculture System (RAS) presents a promising economic venture. The controlled environment of RAS allows for precise management of water quality, temperature, and feeding schedules, optimizing growth rates and feed conversion efficiency, which in turn reduces operational costs (Bregnballe, 2015). Additionally, RAS reduces the need for water, prevents the spread of illness, serves as a water treatment system, enhances feed conversion, and shortens the production cycle (Balami, 2021). The ability to maintain year-round production and accommodate high stocking densities within RAS maximizes production efficiency (Leingang, 2020). Singhi farming in RAS aligns with environmentally conscious practices, reducing its environmental impact. Overall, Singhi farming in RAS not only offers economic sustainability to farmers but also promotes resource efficiency and responsible aquaculture practices, making it a compelling choice in the evolving landscape of fish production.

MATERIALS AND METHODS

For this comprehensive study, a total of 14 Recirculatory Aquaculture System (RAS) farms in Haryana were meticulously chosen as the study sites. The selection was based on in-person survey conducted to ensure representation across different RAS farming practices. The research team gathered crucial data pertaining to average production and operational costs through a meticulously designed questionnaire proforma. RAS farmers in Haryana predominantly focus on the cultivation of Singhi fish (*Heteropneustes fossilis*) for both grow-out and nursery culture. A comprehensive cost and productivity analysis was conducted individually for each operational expense to gain insights into the production costs associated with *H. fossilis* grow-out and nursery culture. To assess the performance of the RAS systems and the economic viability of Singhi fish cultivation, several key metrics were calculated:

Survival Rate = Total number of fishes harvested / Total number of stocked × 100

Feed Conversion Ratio (FCR) = Feed given (dry weight) / Body weight gain (wet weight)

The economic evaluation of the RAS systems for intensive *H. fossilis* culture was conducted using the following parameters:

Total production (in kg) = Number of animals × Average weight ÷ 1000

Total profit = Total production (in kg) × Cost of fish (in ₹)

Annual fish seed cost = number of fish seed stocked during year in culture cycle × average price of fish seed

Total seed cost = Average price of fish seed/kg × per crop quantity of fish feed utilized for production

Annual fish feed cost = Average price of fish feed/kg × per crop quantity of fish feed utilized for production × number of culture cycles

Total fish feed cost = Number of fish seed stocked/culture cycle × average price of fish seed

Net profit = Total profit – Expenditure

This meticulously structured methodology allowed for a comprehensive assessment of Singhi cultivation within RAS, offering valuable insights into its economic viability and performance across different farm practices and systems.

RESULTS AND DISCUSSION

Different practices of Fish farming under RAS

The study presents a comprehensive overview of the various fish farming practices adopted by Recirculating Aquaculture System (RAS) farmers in Haryana. It identifies which RAS farmers are involved in nursery RAS and grow-out RAS activities. Notably, only one farmer (Kaithal I) is involved in nursery RAS. Table 1 complements this information by categorizing the same set of RAS farmers into low-cost RAS and advanced RAS users. Majority of the farmers adopted Advance RAS for culturing the fishes. However, only one farmer (Fatehbad I) encompasses low cost RAS for singhi culture.

Table 1: Different types of farming practices under RAS farms of Haryana

Sl. No.	RAS Farmer	Types of fish farming	
		Nursey RAS	Grow-out RAS
1	Ambala 1		✓
2	Bhiwani 1		✓
3	Fatehbad 1		✓
4	Fatehbad 2		✓
5	Gurgaon 2		✓
6	Hisar 2		
7	Kaithal 1	✓	✓
8	Karnal 1		✓
9	Karnal 2		✓
10	Rewari 2		✓
11	Rohtak 1		✓
12	Rohtak 2		✓
13	Sonipat 1		✓
14	Sonipat 2		✓

Table 2: Different types of RAS farms in Haryana

Sl. No.	RAS Farmer	Types of RAS	
		Low-cost RAS	Advance RAS
1	Ambala 1		✓
2	Bhiwani 1		✓
3	Fatehbad 1		✓
4	Fatehbad 2	✓	
5	Gurgaon 2		✓
6	Hisar 2		✓
7	Kaithal 1		✓
8	Karnal 1		✓
9	Karnal 2		✓
10	Rewari 2		✓
11	Rohtak 1		✓
12	Rohtak 2		✓
13	Sonipat 1		✓
14	Sonipat 2		✓

Cost and Productivity data of Singhi (*Heteropneustes fossilis*) under grow out RAS farms of Haryana

A total of 13 RAS farmers of Haryana are producing *H. fossilis* on their farms with average stocking density of17846 pieces per production tank, average seed price of ₹ 2.10/ piece and 77.31 percent harvest survival (Table 3). The farmers purchased singhi fish feed with average value of ₹ 55.38/ kg during production cycle and the total average fish feed cost was ₹ 3,34,913/- (Table 4). The average fish production from individual tank was 1243.08kg with harvesting size of 84.92 g, feed conversion ratio was 2.1 and farmers generated the revenue of ₹ 15,53,638/- from singhi culture on their RAS farms with average sale price of was ₹ 342.31/kg in Haryana (Table 3 & 4).

In term of individual farm revenue, Karnal farmer got ₹ 55,44,000/- from singhi culture in two tanks with 90 percent average survival on initial stocking density (40,000 fish/ tank) and sale price of ₹ 350/ kg on harvest size of 110 g (Table 3 & 4). Besides this, Gurgaon farmer received ₹ 25,20,000/- as revenue from singhi culture, 90 percent survival on initial stocking density (14000 fish/ tank), 100 g harvest size and ₹ 400/kg sale price from 5 tanks (Table 3 & 4). Fatehabad and Hisar farmers cultured singhi in 8 tanks of their RAS unit and got 50 and 80 percent survival on initial stocking density of 15000 fish/ tank. They received the sale price of ₹ 350/kg and generated revenue of ₹ 16,80,000/- and 26,88,000/-, respectively. Sonipat farmer generated revenue of ₹ 5,95,000/- with initial stocking density of 25,000 fish/ tank, 85 percent survival, 80 g harvest size and 1700 kg production/ tank (Table 3 & 4). The other Sonipat farmer used low stocking density of 8000 fish/ tank and was able to get 512. kg production from the tank with a harvest size of 80 g, ₹ 300/kg as sale price and ₹ 1,53,600/- as revenue (Table 3 & 4). The findings of Olaoye *et al*. (2013) revealed that the average total revenue (TR) of fish farmers was 4,873,521.29 with a gross margin (GM) of 2,376,616.36 from catfish farming and the average cost of fish feed for farmers was 2,158,456.01 accordingly. This demonstrated that catfish fish farming was successful in his research location.

The other farmers from Karnal, Fatehabad and Rewari used two culture tanks for singhi culture with an initial stocking density of 15000, 18000 and 20000 fish/ tank and got 85, 70 and 75 percent survival with 1020, 882 and 1200 kg production from their culture tanks generating revenue of ₹ 7,14,000/-, 6,17,400/- and 8,40,000/- respectively (Table 3 & 4). From three culture tanks, Ambala and Rohtak farmers generated ₹ 12,28,500 /- and 14,28,000/- as revenue on 104 g and 80 g harvest size with 1170 kg and 1360 kg production respectively (Table 3 & 4). The average sale price in Haryana fluctuated between ₹ 300 and 400/kg with majority of farmers sold their produce for ₹ 350/kg (Table 4). According to Tunde *et al.* (2015), the overall revenues from the production of catfish and tilapia fish were (Nigerian currency)

Table 3: Productivity data of Singhi (*Heteropneustes fossilis*) under RAS farms of Haryana

RAS Farmer	Singhi (*Heteropneustes fossilis*) stocking and production related data					
	Stocking rate	**Number of tanks**	**Survival at harvest (%)**	**FCR**	**Production per tank (kg)**	**Harvest size (g)**
Ambala 1	15000	3	75	1.4	1170	104
Bhiwani 1	12000	6	60	1.6	576	80
Fatehbad 1	15000	8	50	1.3	600	80
Fatehbad 2	18000	2	70	1.5	882	70
Gurgaon 2	14000	5	90	1.4	1260	100
Hisar 2	15000	8	80	1.44	960	80
Karnal 1	15000	2	85	1.4	1020	80
Karnal 2	40000	4	90	1.3	3960	110
Rewari 2	20000	2	75	1.4	1200	80
Rohtak 1	15000	4	80	1.4	960	80
Rohtak 2	20000	3	85	1.3	1360	80
Sonipat 1	25000	1	85	1.4	1700	80
Sonipat 2	8000	1	80	1.3	512	80
Mean	**17846.2**	**3.7**	**77.31**	**1.39**	**1243.08**	**84.92**

Table 4: Operation cost data of Singhi (*Heteropneustes fossilis*) under RAS farms of Haryana

RAS Farmer	Operational cost					
	Seed price/piece (₹)	**Total seed cost (₹)**	**Feed price/ kg (₹)**	**Total Feed cost (₹)**	**Sale price (₹/kg)**	**Revenue generated (₹)**
Ambala 1	1.8	81000	55	270270	350	1228500
Bhiwani 1	2.5	180000	56	309657.6	300	1036800
Fatehbad 1	2.5	300000	58	361920	350	1680000
Fatehbad 2	2.5	90000	55	145530	350	617400
Gurgaon 2	2.5	175000	56	493920	400	2520000
Hisar 2	2	240000	57	630374.4	350	2688000
Karnal 1	2	60000	54	154224	350	714000
Karnal 2	1.5	240000	50	1029600	350	5544000
Rewari 2	2	80000	54	181440	350	840000
Rohtak 1	2	120000	57	306432	300	1152000
Rohtak 2	2	120000	57	302328	350	1428000
Sonipat 1	2	50000	55	130900	350	595000
Sonipat 2	2	16000	56	37273.6	300	153600
Mean	**2.1**	**134769**	**55.38**	**334913**	**342.31**	**1553638**

Table 5: Comparative grow out productivity analysis of low-cost and advanced RAS with Singhi (*Heteropneustes fossilis*) in Haryana

Fish production related data	Low-cost RAS	Advanced RAS
Number of Farmers	1	12
Average number of tanks	2	3.92
Average number of fish species	1	1
Average stocking density/ tank	18000	17833.33
Average seed price/piece (₹)	2.5	2.10
Average total seed cost/ crop (₹)	90000	138500
Average feed price (₹)	55	55.42
Average total feed cost/ crop (₹)	145530	350695
Average Feed Conversion Ratio (FCR)	1.5	1.39
Average Survival rate (%)	70	77.92
Average production per tank (kg/crop)	882	1273.12
Average total production/ crop (₹)	1680000	1670308
Average sale price (₹)	350	341.67
Average harvesting size (g)	70	86.20
Number of culture/ years	1.5	1.5

244,363.30 k every cycle, and the total profit margin was 114984.78K per cycle.

Out of 13 farmers, single built low-cost RAS and preferred to culture singhi as a high vale fish species on their units, while 12 farmers were also culturing the same fish species (both grow-out and nursery) in advanced RAS systems. Average stocking density was greater under low-cost RAS (18000 fish/tank) than it was under advanced RAS (17833.33 fish/ tank), however survival was better under advanced RAS (77.92 %) than it was under low-cost RAS (70%). The FCR was discovered to be nearly same for both low-cost (1.50) and advanced RAS (1.39).

In comparison to the advanced RAS (₹ 2.10, 1273.12 kg, ₹ 1670308 and 86.20 g, respectively), the seed price (₹ 2.50), production/tank (882 kg), total production/crop (₹ 1680000), and harvest size (70 g) were all significantly lower under the low-cost RAS (Table 5). In both RAS systems, low-cost RAS farmers were able to achieve about 1.5 fish culture cycles

Table 6: Comparative operational cost and production analysis of distinct RAS systems of Haryana

Items	Cost in Low-cost RAS		Cost in Advanced RAS	
	Amount (₹)	**Total cost (%)**	**Amount (₹)**	**Total cost (%)**
Operational Cost or Variable or Production cost				
Annual average fish feed cost	145530	25.29	350695	35.42
Annual average fish seed cost	90000	15.64	138500	13.99
Annual average labour cost	140000	24.33	220000	22.22
Annual average fuel cost	33333.33	5.792	50000	5.05
Annual average electricity bill	120000	20.85	180000	18.18
Farm maintenance cost/year	20000	3.475	26470.59	2.674
Miscellaneous expenses/year	26666.67	4.633	24411.76	2.466
Total annual variable cost (₹)*	785530	100	1116430	100
Production data				
	Cost in Low-cost RAS		**Cost in Advanced RAS**	
Average fish production per tank (kg/year)	1323		1909.68	
Average total production/Year (₹)	2520000		2505462	
Total production cost (₹) [A]	785530		1116430	
Total Production profit (₹) [B]	2520000		2505462	
Total net Profit (B-A)	1734470		1389032	

*Per year a Single farmer taking 1.5 crops (Single crop of Singhi includes 8 months in a year).

Table 7: Productivity of Singhi (*Heteropneustes fossilis*) under nursery RAS farms of Haryana

RAS Farmar	Singhi (*Heteropneustes fossilis*) stocking and production related data					
	Stocking rate*	**Number of tanks**	**Survival at harvest (%)**	**FCR**	**Production per tank (kg)**	**Harvest size (g)**
Kaithal 1	25000	2	75	0.8	37.5	2

annually. Additionally, Table 5 shows that low-cost RAS farmers were able to sell their crops at a higher price (₹ 350) than advanced RAS farmers (₹ 341.67).

Cost and Productivity data of Singhi (*Heteropneustes fossilis*) nursery RAS farms of Haryana

During survey, it was observed that few farmers are utilizing their production tanks of RAS units as nursery tanks for seed supply purpose for better profitability within short period of time. The nursery of *H. fossilis* being raised at different RAS units. Only 1 RAS farm of Haryana was utilizing its production tanks as nursery tanks for *H. fossilis* seed supply purpose. With an initial stocking density of 25000 fish/tank, he generated ₹ 187500 from two tanks of singhi seed (2 g harvest size) (Table 7 & 8). The survival at harvest, FCR and total feed cost was 75 percent, 0.80 and ₹ 3240/- respectively. He was able to receive a sale price of ₹ 2500/ kg in Haryana for 37.5 kg production/tank (Table 7 & 8). According to Bailey and Vinci (2020), when the infrastructure facility of the RAS unit improved, the capital cost of the salmon fish producing land-based RAS unit generated dropped. The stated price difference from 3600 to 1200 MT was $14/kg. Annual output of salmon at the land-based RAS farm ranged from 1000 to 22000 MT, with FCRs of 0.85 for salmon fry, 0.90 for smolt, and 1.0 for pre-grow out, respectively.

CONCLUSION

Singhi farming in RAS systems in Haryana is economically viable, offering substantial profits and contributing to the sustainability of the aquaculture industry. The prevalent preference for Advanced RAS among farmers is driven by its remarkable filtration efficiency, owed to its state-of-the-art equipment. While Advanced RAS showcases superior production based on growth

Table 8: Operation cost and production data of Singhi (*Heteropneustes fossilis*) under nursery rearing RAS units of Haryana

RAS Farmer	Operational cost					Revenue generated (₹)
	Seed price/piece (₹)	Total seed cost (₹)	Feed price (₹/kg)	Total Feed cost (₹)	Sale price (₹/kg)	
Kaithal 1	2	100000	54	3240	2500	187500
* Per year a farmer taking 4 crops as a seed supplier with nursery rearing of Singhi in RAS						
Annual seed production revenue generated (₹)		187500 × 4 = 750000				

Operational Cost or Variable or Production cost

Items	Amount (₹)	Total cost (%)
Annual average fish feed cost	12960	1.81
Live-feed supplement cost/year	30000	4.19
Annual average fish seed cost	400000	55.87
Annual average labour cost	108000	15.08
Annual average fuel cost	30000	4.19
Annual average electricity bill	115000	16.06
Farm maintenance cost/year	20000	2.793
Total annual variable cost (₹)	715960	100
Total production cost (₹) [A]	735960	
Total Production profit (₹) [B]	750000	
Total net Profit (B-A)	14040	

and survival metrics while Low-Cost RAS takes the lead when revenue generation is the primary focus. The increased operational costs associated with Advanced RAS can be attributed to heightened electricity consumption, greater labour requirements, increased fuel and increased maintenance expenses of the farm. Moreover, Grow-out RAS stands out as the preferred choice over Nursery RAS due to better growth and survivability of fish. The assessment of economic feasibility is calculated based on the singhi culture tanks under RAS which is closely tied to the number of production tanks employed by farmers in Singhi farming within RAS. In Low-Cost RAS, farmers typically utilize a single tank, while in Advanced RAS, farmers make use of approximately four tanks. This research underscores the potential for sustainable and profitable aquaculture practices, promoting economic growth and resource efficiency in the sector.

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