Effect of stocking density of *Labeo rohita* (Rohu) for the production of stunted yearling in cage culture conditions

Abstract

The present experiment evaluated the Optimization of *Labeo rohita* (Rohu) stocking density for the production of stunted yearling in cage culture conditions. Fingerlings were stocked at three different stocking densities i.e., 100, 200 and 300 (T1, T2, and T3, respectively) and reared for 180 days in cage culture condition. Water quality and growth parameters of all treatments were compared during the experiment. A significant ($p<0.05$) decrease in growth and survival concentration relative to the higher stocking density was observed. Though some of the parameters showed significant ($p<0.05$) differences among the treatments, the water quality remained within an optimum level, throughout the experiment. An increase in stocking density led to a significant reduction ($p<0.05$) in ABW and survival of fingerlings. Treatment T1 (100 nos/cage) recorded significantly higher growth than treatment T2 (200 nos/cage) and treatment T3 (300 nos/cage) of both locations during all the years. Among the treatments, T1 recorded significantly higher values of body weight (38.12 g) as compared to T2 (30.87 g) and T3 (27.19 g) but treatment T3 (27.19 g) was at par with T2 (30.87 g). Treatment T1 recorded higher average body weight at both locations during all the years 2013-14 (L1-31.30g and L2-35.98g), 2014-15 (L1-30.91 g and L2- 60.23 g) and 2015-16 (L1-26.37 g and L2-43.93 g) as well as in pooled results (L1-29.53 g and L2-46.72 g) as compared to rest of the treatments. The fish survival data revealed that at both locations and during all the years, there was little variation. As per the survival rate in different treatments, T3 is found most economical.

Keywords: *Cage culture, Growth, Survival, Labeo rohita, Stocking density*

INTRODUCTION

Globally aquaculture is one of the fastest-growing industries [1] (Tacon, 2020) and has been playing a significant role in the economic development front on account of its contribution to food security, national income, employment opportunities as well as generating source of revenue (Kumar and Shivani, 2014) [2]. It is the main source of animal protein for billions of people Worldwide, where capture fishery and aquaculture serve the livelihoods of >10% of the overall population (Anonymous, 2020b) [3].

India plays a pivotal role in global fisheries, contributing significantly to both inland and marine capture production. The country accounts for 16.7% of the global inland aquatic animal capture, with an output of 1,890 thousand tonnes, and 4.5% of the global marine animal capture, producing 3,597 thousand tonnes. While India demonstrates remarkable performance in capture fisheries, its contribution to global aquaculture production remains relatively modest at 10 thousand tonnes, compared to the world inland aquaculture production of 9 thousand tonnes. The fisheries and aquaculture sectors, recognized as critical components of India’s "Blue Economy," have experienced substantial advancements, underscoring their importance in ensuring food security, employment generation, and economic growth. (SOFIA-FAO, 2024) [4].

Inland aquaculture presently contributes 12.1 million tonns (in 2021-22) of fish annually with the three Indian major carps viz., catla (*Labeo catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) constituting 51.96% of the production. Cage culture and pen culture are those activities that can be helpful to supplement aquaculture production in areas with limited land-based resources for aquaculture (Dept of Fisheries, 2022) [5].

In India, carp culture forms the backbone of freshwater aquaculture generally dominated by Indian major carp, namely catla, rohu, and mrigal which contribute a majority of the total Indian aquaculture production (Anonymous, 2020b) [3]. At present Indian Major Carp production from village pond is very low (500-1000 kg/ha/year) in the context of the potential production of 10,000 kg/ha/year. Indian fish culture has witnessed rapid development in the last 2-3 decades. As the farmers became well-known with the technology of different fish culture systems, they modified the technology to suit their requirements. Among the different modifications adopted by the farmers to suit their needs, the use of stunted carp fingerling around the year is important (Veerina et al., 1993) [6].

The present study was conducted to evaluate the growth performance and survival rates of stunted fish fingerlings under varying stocking densities in cage culture conditions. The objective was to optimize the stocking density required to produce economically viable stunted yearlings at the pond site while determining the optimum range of stocking density for achieving favorable growth and survival rates, thereby ensuring economic feasibility.

MATERIAL AND METHODS

Experimental site

The present experiment was conducted for a period of six months (180 days) from August to January 2013, 2014 and 2015 in the freshwater pond of L1 - SWMRU (Soil and Water Management Research Unit) NAU in Navsari District and L2 - CSSRS (Coastal Soil Salinity Research Station) Danti-Umbharat, NAU Navsari.

The size of the cage was 15 m^3 (2 m x 4 m x 2.5 m). Cages were made with PVC pipe material with a thickness of 75 mm and mesh size of 8 mm knotless. Cages were settled in one floating bamboo frame. Nine floating cages were set up at once using bamboo (*Bambusa spinosa*), coir, kuralon nylon ropes plastic barrels, etc.

Cage construction and installation

In this experiment, 9 floating net cages each having an area of Outer dimension of 200 cm x1 00 cm x 200 cm (2 m^3) and an Inner dimension of 200 cm x 100 cm x 90 cm (1.8 m^3) made of synthetic nylon net (mesh size 1.1 cm) were installed in the pond of both the locations. Every net cage was fixed and hung with a bamboo pole frame and enclosed at the top with another piece of plastic net (mesh size 2.5 cm) to prevent the runaway of fish by jumping and bird predation. The bamboo poles were enclosed with long pieces of wooden raft for trouble-free movement, feeding to fish and sampling of the experimental fish on the cage structure. The structure of the cage was fixed with anchors at both shore sides by nylon rope to make easy floating and moving of the whole cage structure with 9 individual cages depending on the water level.

Fish stocking:

In the present study, we tested three different stocking densities of rohu like 100, 200 and 300 fish per cage designated as T1, T2 and T3 respectively, in triplicates for each treatment group. In short, hatchery-produced *Labeo rohita* (5.39±0.15 g) (mean±SD) were transported to the experimental site by oxygenated polyethene bags and they were kept in cages after proper acclimation with the environment and the initial length and weight of fish were measured individually in 'cm' and 'g' with the help of a scale and a digital electronic balance respectively. Finally, the cages were randomly stocked with fish fry and the number of fish stocked in each cage as per the treatments were recorded simultaneously.

During the experimental period, mortality was recorded and removed quickly. All the cages were lifted from the water at every 15-day interval to make sure the net was not damaged and also for cleaning purposes. All experimental units (Cages) were cleaned with a soft brush to eradicate algae, sponges and other organisms. Loose-fitting, net mesh torn by predators was checked regularly and instantly mended or replaced as required.

Sampling and data analysis:

Physico-chemical parameters of water such as temperature (°C), pH, hardness (mg/l) and total alkalinity (mg/l) were monitored weekly in the morning between 7 and 8 a.m. during the whole culture period APHA (1992). Water temperature was recorded with a glass Celsius thermometer, pH was measured using a digital pocket pH meter. Other chemical parameters were measured using a titration method.

After 180 days of trial, the whole cage structure was moored to the shore of the pond and all fish were harvested by repeated scoop netting and then fish were counted, measured and weighed for each cage. To determine the growth response, yield and survivability of experimental fish, the following parameters were calculated:

Weight gain (WG) = final fish weight (g)-initial fish weight (g)
Weight gain (%) = (final weight-initial weight) × 100/initial weight
Average daily weight gain (ADWG) = (final fish weight-initial fish weight)/days

The used stocking density for *Labeo rohita* was 100, 200 and 300 fry per cage. Fish fry was obtained from a private hatchery in Navsari. The fry was stocked in the morning hours. The rearing period for *L. rohita* was 6 months.

The fry was fed twice a day at a rate of 0.5% of body weight with the respective feed types. The amount of feed in respective feed types was mixed with water and prepared as dough. The feed dough was provided to the fish using a feeding tray hung inside the cages 60 cm below the water surface.

RESULT AND DISCUSSION:

Average Body Weight:

The year-wise results related to the growth (weight) of stunted yearling of *L. rohita* at two locations and different stocking densities are reported in Table 1. The results presented in Table 1 revealed that all the treatment's effects were significant on average body weight (g) during individual years as well as in pooled analysis. Treatment T1 50/m^3 (100 nos/cage) recorded significantly higher growth than treatment T2 100/m^3 (200 nos/cage) and treatment T3 150/m^3 (300 nos/cage) of both locations during all the years. Among the treatments, T1 recorded significantly higher values of body weight (38.12 g) as compared to T2 (30.87 g) and T3 (27.19 g) but treatment T3 (27.19 g) was at par with T2 (30.87 g). Treatment T1 recorded higher average body weight at both locations during all the years 2013-14 (L1-31.30 g and L2-35.98 g), 2014-15 (L1-30.91 g and L2-60.23 g) and 2015-16 (L1-26.37g and L2-43.93 g) as well as in pooled results (L1-29.53 g and L2-46.72 g) as compared to rest of the treatments. Statistical analysis in relation to the individual growth also supports in favour of 50/m^3 ($p< 0.01$) than that of 100/m^3 and 150/m^3. This is possibly due to low stocking density, enough natural live food and breathing space as well as fewer struggles prevailing in the condition. Lembi *et al.* (1968) [7] and Kilambi *et al.* (1977) [8] showed that decreasing individual growth with increasing stocking density might be due to more struggle during feeding at heavily populated cages.

In the present study, lower stocking density 50/m^3 (100 fish/cage) of stunted *L. rohita* in cages showed superior growth performance in terms of higher final body weight, which indicates that at lower stocking density stunted fish have superior growth potential. On the other side, higher 150/m^3 stocking density (300 fish/cage) negatively affected the growth performance of stunted rohu. In broad-spectrum, at higher stocking densities, individual fish get reduced breathing space which affects social interaction and increases stress. In stressed situations, fish spend additional energy for stress mitigation which reduces the regular growth of fish (Biswas *et al*., 2015[9]; Ofor and Afia, 2015 [10]). Similar growth pattern was reported in catla fish (Sukumaran *et al*., 1986 [11]; Govind *et al*., 1988 [12]) Rohu fish (Kohli *et al*., 2002 [13]; Chattopadhyay *et al*., 2013 [14]; Biswas *et al*., 2015[9]) hybrid catfish (Ofor and Afia, 2015 [10]) *catla catla* and *Labeo rohita* (Kohli, 2002) [13].

High stocking density is accepted as a stressor by many scientists for a number of species (Wedemeyer, 1976 [15]; Klinger *et al*., 1983 [16]; Gatlin *et al*., 1986 [17]; Vijayan *et al*., 1990 [18]). Veerina *et al*. (1993) [6] stated that the fish farmers in Andhra Pradesh generate stunted carp fish fingerling by stocking early fingerling at higher stocking densities with sub-optimal levels of feeding and rearing them for 6 to 12 months. Puttaswamy and Ramesh (1995) [19] have reported the production of stunted Indian major carp fingerling of 28 to 30 g size by stocking fry at one lakh/ha and rearing for 6 months, with sub-optimal level of feeding and fertilization. Vijayan and Leatherland, (1988) [20] have shown a significant decrease in food consumption and feed gain ratio of fish stocked at high stocking densities indicative of a decrease in the metabolic efficiency. Dimitrov (1976) [21] stated that the best production of carp in floating cages was achieved at higher stocking densities (80 and 50 fish/m^2) than the lower one (25 fish/m^2). Backiel and Le Cren (1967) [22] show that the growth and production of fish are to a certain extent, dependent on the population density. Powell (1972) [23] mentioned the harmful effects of higher stocking density on the culture of fish were the decline of growth rate, increase of FCR and low survival rate. A higher survival rate in the present study was obtained in low stocking density (50/m^3) cages.

Table 1. Effect of different treatments on mean final body weight (g) of *L. rohita* fish (Mean of 10 nos)

FINAL WEIGHT												
Treatments	**YEAR-1**			**YEAR-2**			**YEAR-3**			**POOLED**		
	L1	**L**	**MEAN**	**L1**	**L2**	**MEAN**	**L1**	**L2**	**MEAN**	**L1**	**L2**	**MEAN**
T1	31.30	35.98	**33.64**	30.91	60.23	**45.57**	26.37	43.93	**35.15**	29.53	46.72	**38.12**
T2	24.53	27.37	**25.95**	27.00	49.80	**38.40**	22.65	33.88	**28.27**	24.73	37.02	**30.87**
T3	22.97	19.15	**21.06**	20.32	46.73	**33.53**	22.33	31.61	**26.97**	21.87	32.50	**27.19**
MEAN	**26.27**	**27.50**	**26.88**	**26.08**	**52.26**	**39.17**	**23.78**	**36.48**	**30.13**	**25.38**	**38.74**	**32.06**
	SEm±	**CD at 5%**		**SEm±**	**CD at 5%**		**SEm±**	**CD at 5%**		**SEm±**	**CD at 5%**	
L	0.8115	NS	**L**	2.3665	7.79	**L**	0.4289	1.32	**L**	5.0973	NS	
T	0.9939	3.06	**T**	2.8983	8.93	**T**	0.5253	1.62	**T**	1.0115	**2.89**	
LxT	1.4056	4.33	**LxT**	4.0988	NS	**LxT**	0.7428	2.29	**LxT**	1.4330	NS	
CV%	9.06			15.13			4.27		**YL**	1.4654	**4.51**	
									YT	1.7948	NS	
									YLT	2.5382	NS	
									Y	1.4050	NS	
									CV%	12.71		

Average Body Length:

The results revealed that treatment effect on final length of *L. rohita* fish was not significant at both the locations during second and third years, as well as treatments were also recorded as non-significant during third year. Effect of stocking density was significant on body weight. But it was not so in the case of body length. In all the cases treatment T1 (50/m^3) showed superiority over treatment T2 (100/m^3) and T3 (150/m^3).

In all the years, the effect of locations and treatments on the number of fish stocked was significant during second and third year in length of fish. In all the treatments, stocking densities of *L. rohita* fish @ 50/m^3 (100 nos/cage) showed superior over 100/m^3 (200 nos/cage) and 150/m^3 (300 nos/cage) at both locations. During all the years, the L x T interaction effect was significant in the stocking density of *L. rohita* fish. Treatment T1 recorded higher average fish body length at both locations during all the years 2013-14 (L1-12.37 cm and L2-14.42 cm), 2014-15 (L1-14.01 cm and L2 17.30 cm) and 2015-16 (L1-13.43 cm and L2- 15.99 cm) as well as in pooled results (L1-13.27 cm and L2-15.91 cm) as compared to rest of the treatments. Here also, T1 recorded significantly higher length of fish than T2 and T3 but T3 was at par with T2 of the combinations.

Table 2. Effect of different treatments on mean final body length (cm) of *L. rohita* fish (Mean of 10 nos)

FINAL LENGTH												
Treatments	**YEAR-1**			**YEAR-2**			**YEAR-3**			**POOLED**		
	L1	**L2**	**MEAN**	**L1**	**L2**	**MEAN**	**L1**	**L2**	**MEAN**	**L1**	**L2**	**MEAN**
T1	12.37	14.42	**13.40**	14.01	17.30	**15.66**	13.43	15.99	**14.71**	13.27	15.91	**14.59**
T2	13.00	13.51	**13.26**	13.34	16.72	**15.03**	12.55	14.68	**13.62**	12.96	14.97	**13.97**
T3	12.70	11.74	**12.22**	13.87	16.19	**15.03**	12.90	14.40	**13.65**	13.16	14.11	**13.63**
MEAN	**12.69**	**13.23**	**12.96**	**13.74**	**16.74**	**15.24**	**12.96**	**15.03**	**13.99**	**13.13**	**15.00**	**14.06**
	SEm±	**CD at 5%**		**SEm±**	**CD at 5%**		**SEm±**	**CD at 5%**		**SEm±**	**CD at 5%**	

L	0.5090	NS	**L**	0.7392	3.5757	**L**	0.1556	0.48	**L**	0.3176	0.90	
T	0.6234	NS	**T**	0.9054	NS	**T**	0.1905	0.59	**T**	0.3582	NS	
LxT	0.8816	NS	**LxT**	1.2804	NS	**LxT**	0.2695	NS	**LxT**	0.5050	NS	
CV%	11.78			14.55			3.34		**YL**	0.5259	NS	
									YT	0.6441	NS	
									YLT	0.9109	NS	
									Y	0.2962	NS	
									CV%	11.22		

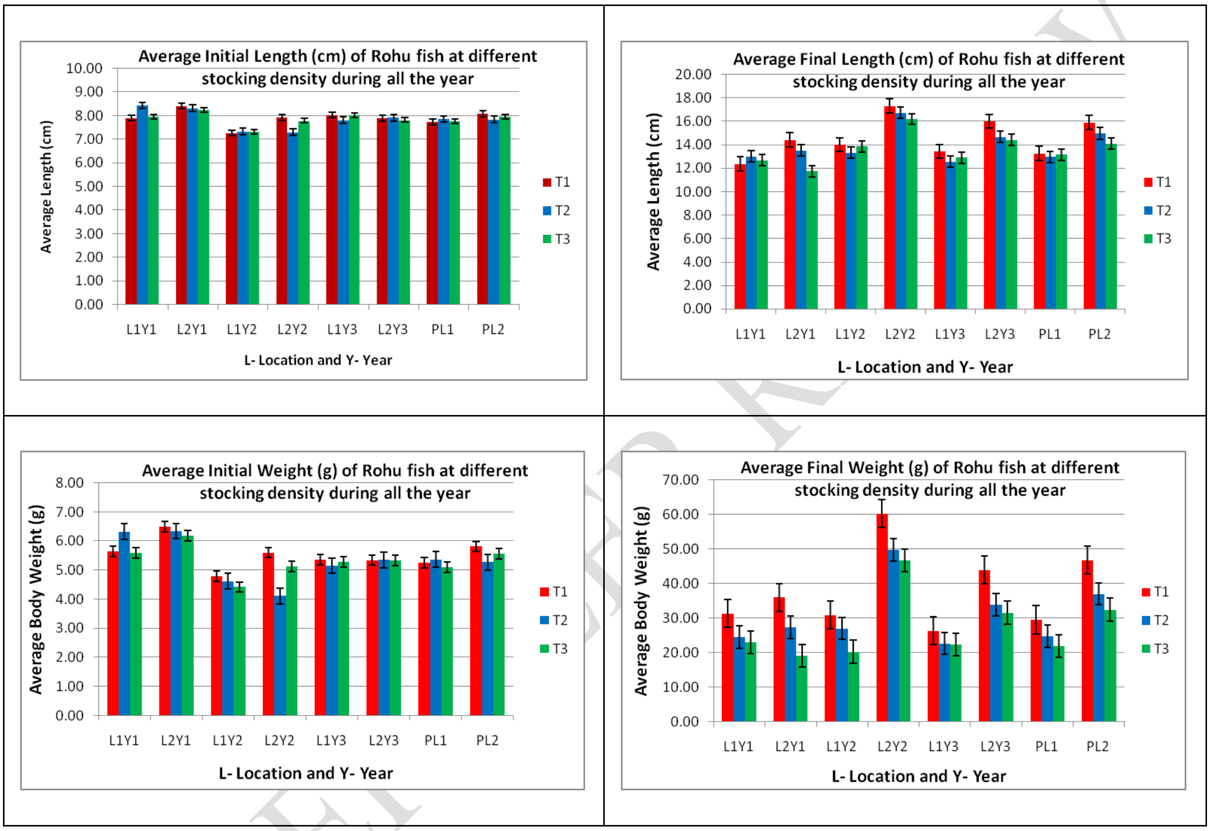

Fig. 1. Growth performance, of *L. rohita* fingerlings, reared in cages under different stocking densities

Survival rates:

The fish survival data revealed that at both the locations and during all the years did not show much variation (Table 3). As per the survival rate in different treatments, T3 (150/m^3) is found most economical (Table 5). The results pertaining to the year-wise and pooled yield of *L. rohita* are reported in Table 1. The results revealed that during individual years as well as in pooled analysis, only the main effect of stocking density was found to be significant on the growth of *L. rohita*. In all cases, the Danti location (L2) recorded significantly higher average body weight in comparison to the SWMRU location (L1), but in pooled results, the difference between L1 and L2 was not significant.

Table 3. Average survival rate (%) of *L. rohita* fish (Stunted yearlings)

Treatments/Location	Year-1	Year-2	Year-3	Mean
L1T1	72.33	99.33	98.33	90.00
L1T2	81.00	97.00	97.17	91.72
L1T3	67.83	97.78	96.56	87.39
Mean	73.72	98.04	97.35	89.70
L2T1	76.50	99.33	99.33	91.72
L2T2	71.44	97.67	98.17	89.09
L2T3	88.78	96.56	97.11	94.15
Mean	78.91	97.85	98.20	91.65

Disease has been a major problem in aquaculture which is mostly due to its intensification (Gopal Rao *et al*., 1992 [24]; Robinette and Noga, 2001 [25]). The obtainable information suggests the improved performance of stunted carp fingerling in terms of growth and survival when stocked in rearing ponds with the most favorable environment. In the present study, the survival rate recorded for stunted rohu (87-94%) was slightly higher compared to normal mrigal (84.87%). Similar results with regard to stocking densities and survival rates has been reported by earlier workers (Refstie, 1977 [26]; Trzebiatowski *et al*.,1981[27]; Holm *et al*., 1990 [28]). Veerina *et al*. (1993) [6] reported that in Andhra Pradesh, farmers obtained a mean survival rate of 70% when fish reared under high density. So, in the present rearing system of rohu at high stocking density with sub-optimal level of feeding, the survival rate obtained can be considered to be economical.

Quality parameters:

Fortnightly water samples were collected from both ponds (locations) and analyzed for pH and alkalinity. Water temperature data like air temperature, surface and bottom were taken on the pond site Physico-chemical parameters at both locations did not have significant variations and were within the optimum range (table 4).

The water quality parameters measured at both SWMRU Pond (L1) and Danti Pond (L2) were within the suitable range for *Labeo rohita* growth under cage culture conditions. Air and water temperatures showed variation, with slightly higher averages at L1 compared to L2 across the years. Alkalinity levels were moderate to high, with slightly increasing trends observed over the study period. The pH levels remained stable and slightly alkaline, indicating favourable conditions for fish growth and health.

Table 4. Water temperature and quality parameters (Mean ±SD)

Location	Parameters			2013	2014	2015
				Mean		
L1 (SWMRU Pond)	Air Temp (°C)	Max	Range	23-34	23-30	24-27
			Avg±SD	29.0±3.40	26.4±2.42	25.9±1.24
		Min	Range	12-25	13-22	17-25
			Avg±SD	20.0±4.74	17.5±2.77	21.7±25
	Water Temp (°C)	Surface	Range	21-31	20-28	23-27
			Avg±SD	27.0±2.82	24.3±2.70	25.3±1.15
		Bottom	Range	24-32	25-32	25-29
			Avg±SD	29.3±2.34	27.9±2.30	27.0±1.28
	Alkalinity (ppm)		Range	132-169	130-244	152-208
			Avg±SD	151.5±14.00	179.7±39.16	188.3±18.28
	pH		Range	7.9-8.3	7.12-8.54	7.64-8.59
			Avg±SD	8.12±0.16	8.08±0.36	8.02±0.26
L2 (Danti Pond)	Air Temp (°C)	Max	Range	23-32	21-31	26-31
			Avg±SD	28.9±2.92	26.5±3.63	28.1±1.51
		Min	Range	13-25	14-21	20-27
			Avg±SD	21.6±4.17	17.6±1.98	23.3±2.27
	Water Temp (°C)	Surface	Range	21-29	20-31	20-26
			Avg±SD	26.9±2.59	24.9±3.82	24.3±1.91
		Bottom	Range	22-33	25-33	23-29
			Avg±SD	28.4±3.10	28.1±3.37	26.1±1.73
	Alkalinity (ppm)		Range	139-206	129-286	157-274
			Avg±SD	168.3±18.09	209.5±47.71	201.2±29.49
	pH		Range	7.7-8.5	7.5-8.7	7.9-8.7
			Avg±SD	8.11±0.19	8.05±0.34	8.38±0.21

Economics

As the L x T interaction was not significant, the economics was calculated based on pooled results under investigation. Considering the seed yield of *L. rohita* fish and cost of cage culture, cost of feed, cost of labour, per yearling cost, gross income, net income and BCR were computed. The results showed that among the treatments of T3 (50/m^3), gave a higher net income of Rs. 1906.17 with a benefit-cost ratio (BCR) of 5.90. The cost of production for producing stunted yearlings for T3 (50/m^3) is lower (Rs. 1.01) than those of all other treatments (Table 5).

The total cost increased with increasing stocking density generally due to higher operational costs (cost on fingerlings and feed) incurred at higher stocking density, while the capital cost was the same for all treatments. A similar trend was observed for gross income which was due to maximum yield from higher stocking density. The highest economic stocking density is the one that can get the maximum biomass/unit area, maximum net revenue and the highest BCR. These were achieved at the stocking density of 150 fingerlings/m³. However, an increase in net profit with increasing stocking density was shown in the case of Asian river catfish (Jiwyam, 2011) [29] and African catfish (Hengsawat *et al*., 1997) [30], may be because catfishes can accept high levels of crowding stress and withstand inferior water quality compared to carps. Furthermore, in the above two experiments, growth retardation was not observed even in the higher stocking density tested. Economic production of fish may also be determined by the market value and consumers' preference for fish size (Hengsawat *et al*., 1997 [30]; Rahman *et al*., 2006) [31]. *L. bata* has a very good market price and consumer preference with sizes as small as 15−20 g (Datta *et al*., 1996 [32]; Bhattacharya *et al.,* 2008 [33]). Furthermore, more crops can be produced if the target size is small as in the present case. Large rohu (>100 g) fetches a higher market price, which may be achieved at higher production cost and/ or duration. To produce larger table fish, alternatively, the stocking size of rohu can be increased, which demands additional experiments be conducted in the future.

Table 5: Economics cost of production (per cubic meter basis)

Treatments	Survival	No. of survivors	ABW (g)	Biomass (Kg)	Total feed (Kg)	Total cost of feed (Rs.)	Labor (Rs.)	Total operational cost (Rs.)	Gross income (Rs.)	Net income (Rs.)	BC ratio (Rs.)	Per yearling cost (Rs.)
T1	90.86	91	29.53	2.68	6.71	74	112.5	186.27	636.01	449.74	2.41	2.05
T2	90.41	181	24.73	4.47	11.18	123	112.5	235.46	1265.72	1030.26	4.38	1.30
T3	90.77	272	21.87	5.96	14.89	164	112.5	276.30	1906.17	1629.87	5.90	1.01

Assumptions

1. Feed cost - Rs. 11/kg
2. Labor cost calculated as 1 hr/day
3. Fingerling cost-Rs. 1/no.
4. Yearling market rate- Rs.7/no.
5. Rearing period - 6 months

CONCLUSIONS:

The findings from the three-year study reveal that for achieving optimal growth and production of stunted yearling rohu (*Labeo rohita*) under cage culture conditions, a stocking density of 100 fingerlings per cage is the most suitable. In contrast, a stocking density of 300 fingerlings per cage is recommended for maximizing economic returns. The results also indicate that stunted rohu exhibits superior growth performance at lower stocking densities, with 50/m³ (100 fish per cage) being ideal for rearing. From an economic standpoint, treatment T3, with a stocking density of 150/m³, emerges as the most cost-effective option.

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