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Growth performance of Sillago (Sillago sihama) (Forsskål, 1775) stocked at varying densities in hapa in brackishwater pond condition, Gujarat, India

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Abstract:
Effect of stocking density on growth, production and survival of sillago fish were conducted in hapa for 60 days at Aqua Farm Danti, COFS, KU, Navsari. Sillago fish fry (0.076 ±0.00g) were stocked into hapa (2.0 x 1.0 x 1.0 m). Four treatments with five replicates were used: T1-250; T2-500 T3-750 and T4-1000 fry/hapa. Fry were fed twice a daily with pelleted feed (Prawn Feeds) containing protein, 5% of total biomass. After 60 days, the highest growth was determined in T1 (250 nos of fish fry) (0.740 ±0.069g) while in T3 lowest growth (0.512 ±0.043g) was recorded. Production (0.08, 0.16, 0.19 & 0.22 per cubic meter/60days) in T1, T2 T3 and T4 respectively were significantly different ($P<0.05$) to each other. Feed conversion ratio of 1.42, 1.42, 1.46 and 1.48 in T1, T2 T3 and T4, respectively not significantly different ($P>0.05$). Survival was significantly different among treatments ($P<0.01$). Highest survival (88.67%) was attained in T1 with lower stocking density, followed by T2 (87.20%), T3 (83.87%) and T4 (82.57%). Water quality parameters recorded throughout the study period were found within the ranges for fish culture such as temperature 18.00 to 27.30 °C, dissolved oxygen 4.30 to 7.20 mg/l, Salinity 6.90 to 16.80 ppt, pH 8.0 to 8.5, Total Ammonical Nitrogen (TAN) (NH_3-N) from 0.06 to 0.16 mg/l, Nitrite (NO_2-N) 0.012 to 0.11 mg/l and Nitrate (NO_3-N) 0.04 to 0.18 mg/l.

Keywords: Sillago sihama, stocking density, growth performance, survival, hapa

1. Introduction:

Global fish production is estimated to have reached about 178 million tonnes during the year 2020. Out of this; 157 million tonnes were used for human consumption, equivalent to an estimated annual supply of 20.2 kg per capita. Among the world fish production, Sillago fish production increased from 24 tonnes in 2000 to 1,069 tonnes in 2011 (Philipose et al., 2017).

The growth of brackishwater farming system during the last three decades has been spectacular. In India, S. sihama recorded the landings of around 192.83 tonnes (0.05%) during 2018 (Anonymous, 2018) and 89.75 tonnes (0.05%) up to June-2019 (Anonymous, 2019) and it constitutes a minor fishery with considerable economic importance. Sillaginidae family has been recognized as a superior candidate for aquaculture in estuarine areas (McKay, 1992) and the farming possibilities of S. sihama are high in India.

Several attempts were made in coastal ponds and pens to culture sillago fish indicated that this species can be successfully cultured along with many suitable species of milkfish (C. chanos), grey mullets (M. cephalus), rabbit fishes (S. rivulatus), pearl spot (E. suratensis) and prawns (Ramamurthy et al., 1978; James et al., 1982; Nammalwar, 1997). Sillago fish polyculture with shrimps and other brackishwater finfish species is a feasible alternative for enhancing the production and profits in future (Philipose et al., 2017). The quality attributes such as ability to tolerate large fluctuations in ecological situations, rapid growth rate and on top of all their great demand as a tasty table fish make S. sihama ideal candidate species for farming system in coastal sea waters, estuaries and brackishwaters (Vanza et al., 2022).
The present study is aimed to evaluate the optimum stocking density for the nursery rearing, of sillago fish and their economics.

2. Experimental design:

The study was performed in pond (1400 m2) condition. Hapa (2.0 x 1.0 x 1.0 m) (Plate III) were fixed in the pond as experimental units, at Aqua Farm Danti, COFS, KU, Navsari. Four (4) treatments at different stocking densities with 5 replicates each were randomly distributed in the hapa. The culture period lasted for 60 DOC. Growth, survival, feed performance, and cost analyses were determined at the end of the experiment.

2.1 Stocking:

A total of 12,500 fish fry were randomly allocated to 20 experimental hapa. Fish fry were acclimated in 15 ppt salinity by rearing them in hapa net for one week. Fish with an average initial weight of 0.076 ±0.00g were randomly stocked in the hapa at 250 fish fry hapa-1, 500 fish fry hapa-1, 750 fish fry hapa-1 and 1000 fish fry hapa-1 as T1, T2, T3 and T4, respectively in five replicates (Kongkumnerd, 1999). Growth, survival, FCR and benefit cost analysis were determined at the end of the experiment.

2.2 Rearing of Fish:

The fish fry was fed daily using commercial sinking nursery feed diet (Prawn Feeds, CP 35%) at 5% of their body weight (Yousif et al., 2015) during experimental period.

2.3 Fish sampling for growth study:

About 5 numbers of fish fry were sampled randomly on weekly basis to record the growth in terms of length (cm) and weight (g). The weight was measured using top pan electronic balance (0.01g accuracy) in half filled water petri dish to reduce stress (Schreck and Moyle, 1990).

2.4 Growth parameters:

All the growth parameters were recorded same for all the experiment. Individual fish fry was randomly collected on weekly basis for recording growth parameters as below:

Growth parameters such as Length Gain (LG) (cm), Live Weight Gain (LWG) (g), Average Daily Growth (ADG) (g), Feed Conversion Ratio (FCR) and Survival Rate (%) using following formulas of Bandyopadhyay and Mohapatra, 2009.

Length Gain (LG) (cm)

Length Gain (LG) (cm) = Final length (cm) − Initial length (cm)

Weight Gain (LWG) (g)

Weight Gain (LWG) (g) = Final weight (g) − Initial weight (g)

$$\text{Average Daily Growth ADG (g)} = \frac{\text{Live weight gain (g)}}{\text{Time (Days)}}$$

2.5 Feed Conversion Ratio (FCR):

FCR measures the amount of feed utilized to get unit weight gain in flesh. Thus, it is focused on quality of feed and efficiency of fish to convert feed into flesh (USAID, 2011). It was estimated using the following formula (Bengal, 1978; Steffens, 1989; Tok, et al. 2017)

$$\text{FCR} = \frac{\text{Feed offered (dry weight) (g)}}{\text{Body weight gain (wet weight) (g)}}$$

2.6 Survival Rate (SR) (%):

The survival of fish fry was calculated following formula (Tok et al., 2017). The percentage survival rate of fish fry was calculated as:

$$\text{Survival (\%)} = \frac{\text{No. of fish survived after rearing x 100}}{\text{No. of fish stocked}}$$

2.7 Yield (Fish production) (kg/m3):

Fish yield was measured in kg/m3. All the fish of each experimental unit were weighed using a calibrated electronic balance.

2.8 Water quality parameters:

The water quality parameters monitored for all the experiment include dissolved oxygen concentration [Dissolved oxygen meter, Eutch instrument (Singapore), Cyber Scan DO 600)], water temperature (Glass thermometer), salinity (Refractometer, Horiba-S071 (LAQUAtwin, Japan), pH (pH meter, HANNA- HI98107, USA) daily basis while total ammonical nitrogen (TAN), nitrite-N and nitrate-N were measured at morning hrs on weekly basis. (American Public Health Association (APHA), 2005) over the 60 DOC of the experimental period.

2.8 Statistical Analysis

The data were analyzed using SPSS software version- 16 using one way and two ways ANOVA and Duncan's multiple range test ($p \leq 0.05$). The data analysis was done at Department of Agricultural Statistics, Navsari Agricultural University, Navsari.

3. Results:

3.1 Growth parameters at varying stocking densities in hapa

Table 5.1 shows that lower stocking density of fish fry had higher weight gain, average daily gain (ADG), length gain, net length gain, net weight gain and survival than other treatments. Significantly higher ($p<0.05$) net weight gain (3.994 ±0.034g), net length gain (6.744 ±0.020cm), ADG (0.067 ±0.001g) and survival (88.40 ±0.704%) were estimated in treatment T1. Significantly lower net length gain, net weight gain, ADG and survival of 5.440 ±0.018cm, 2.808 ±0.019g, 0.048 ±0.000g and 82.180 ±0.418%, respectively observed in treatment T4. From the above results it is revealed that treatment T1 is the most effective treatment for enhancing the growth of sillago fish fry.

3.2 Total length gain (cm)

The total means length attained by sillago fish fry was recorded weekly over the rearing period of 60 DOC and is given in Table 5.2 and illustrated in Fig. 3.2. Initially on DOC 1 mean total length range from 2.024 ±0.007 to 2.044 ±0.007cm in each experimental unit of various treatments was recorded. At the end of the experiment on DOC 60 total length ranged from 7.476 ±0.016 – 8.768 ±0.022cm. Higher growth of fish fry in terms of length was recorded 8.768 ±0.022 in the treated T1 (250 nos. of fish fry) than other treatments (Table 5.1).

All the treatments were significantly different with each other ($p<0.05$). Higher ($p<0.05$) mean length gain was recorded in T1 (0.584 ±0.033cm), While significantly lower mean length gain ($p<0.05$) was recorded in T4 (0.432 ±0.077cm) on 60 DOC (Table 5.2). However, the mean length gain of fish fry in T1 and T2 are statistically at par with each other during all the period except 14 DOC. Whereas, the mean length gain of fish fry in T3 and T4 are statistically at par with each other during all the period. Higher stoking density T4 (1000 nos fish fry) showed lower mean length gain than lower stoking density T1 (250 nos fish fry). All the treatments were statistically non-significant on 7 and 60 DOC. Treatment T1 showed significant ($p<0.05$) effect on mean length gain among all the treatments.

Radhakrishnan (1957) reported the mean length of sillago fish at one to four-year age groups as 14.8, 19.0, 22.4 and 24.0cm, respectively. Gowda (1988) has successfully used the combined method in the study of age and growth of S. sihama at Mangalore. He reported the presence of four-year age group in S. sihama, with mean length 15.5cm (0 year), 20.5cm (1 year), 24.5cm (2 years) and 27.5cm (3 years). Krishnamurthy and Kaliyamurthy (1978) found that the estimated mean length of sillago fish at ages one to five were 6.02, 13.1, 18.5, 22.7 and 26.57cm, respectively. Dhulkhed and Ramamurthy (1977) also observed fast growth of the species reach to marketable size (22.2 – 32.0cm) in about four months. In accordance to the present study significantly higher ($p<0.05$) length gain was recorded in treatment T1 (6.74g month-1).

Ramanthan et al. (1977) reported that the highest growth rate is that of standard length 0.091cm and 0.09cm for male and female, respectively, indicating that this character is the fastest growing part of the body. The mean length of fishes with three growth rings was 19.9cm. Hence, the average length of S. sihama at 0+, 1, 2, 3 years was fixed as 8.8, 13.0, 16.8 and 19.9cm, respectively. Daet (2019) was carried out to evaluate the potential of culturing sea bass in hapa-in-pond environment. The result showed better length gain increment of 13.81cm followed by 13.53cm and lowest was 11.39cm. This result indicated that stocking densities has significant effect in terms of length increment. Results only indicated that the group of sea bass stock at 10 pcs hapa-1 was significantly different to 25 pcs hapa-1 and 15 pcs hapa-1 also significantly different to 25 pcs hapa-1.

3.3 Total weight gain (g)

The total mean weight gain attained by sillago fish fry was recorded weekly over the rearing period of 60 DOC and is given in Table 5.3 and illustrated in Fig. 3.1. Initially on 1 DOC mean total weight ranged from 0.076 ±0.000 – 0.078 ±0.001g in each experimental unit of various treatments was recorded. At the end of the experiment (60 DOC) total weight ranged from 2.884 ±0.019 – 4.020 ±0.034g (Table 5.1). Periodic mean weight gain of fish increased significantly with decrease stoking density and the maximum weight gain (0.740 ±0.069g) was found at T1 (250 nos of fish fry) ($P<0.05$). Lower growth (0.512 ±0.043g) in terms of weight gain was recorded in the treatment T3 (1000 nos of fish fry). All the treatments were significantly different with each other (Table 5.3).

The stocking density significantly influenced the total weight gain ($P<0.05$). T1 (0.740 ±0.069g) showed the significantly higher mean weight gain among all the treatments whereas, it was at par with T2 and T3 on 60 DOC. Treatment T4 was also statistically at par with T2 and T3 on 60 DOC. Treatment T2 and T3 was at par with each other during 14, 21, 35, 56 and 60 DOC. Treatment T3 and T4 were also at par with each other during 7, 35, 56 and 60 DOC. The effect of T1 treatment (having 250 numbers of fish fry) was found superior among all the treatments (Table 5.3).

The sillago fish showed fast growth pace in different environments like salt water ponds, cages and net pens at Mandapam (India) with an average monthly growth of 1.9, 1.6 and 8.1g, respectively (Philipose et al., 2017). The fish readily accepts formulated pellet feed under culture conditions (James, 1984). Yousif et al. (2015) reported better growth results when brooders were provided with a diet of squid, sardines, shrimps, and pelleted feed (52% CP). In accordance to the present study significantly higher ($p<0.05$) final weight, weight gain and ADG were recorded in other species such as Daet, (2019) was carried out to evaluate the potential of culturing seabass in hapa-in-pond environment. He showed that treatment T1 (10 pcs m-3) obtained the highest weight gain increment of 148.80g followed by treatment T2 (15 pcs m-3) with (145.08g) and lowest in treatment T4 (10 pcs m-3) with (136.32g). Mojjada et al. (2013) reported that high stocking density of seabass fish (up to 2000 nos. m-3) with proper feeding rate, feeding frequency and water quality can help to obtain maximum growth.

Fortes, (1984) attempt to rear milk fish fingerlings in hapas using the stocking rates of 367, 500, 1000, and 2000 hapa-1. After 2 months of rearing, the fry grew from an initial weight of 0.2g to final weight of 3.3, 3.1, 4.1 and 2.4g, respectively. However, when European seabass was reared up to the age of 6 months, high densities enabled the highest growth rates from 6.6 to 27.6g (Papoutsoglou et al., 1998). Muyot et al. (2021) reported that the monthly growth of mangrove red snapper in the three stocking densities in hapa. The mean body weight was highest in 0.5 fish m-2 (SD) followed by 1 fish m-2 SD and the least at 3 fish m-2 SD. There was no significant difference ($p>0.05$) between snappers reared in 1 fish m-2 SD and 3 fish m-2 SD nor between 0.5 fish m-2 SD and 1 fish m-2 SD. Similar trend was also observed in the present study at different stocking density of sillago fry.

Similar results were recorded by the Philipose et al. (2010) in seabass nursery rearing. In their study ADWG at the end of the experimental period was 0.24g. ADWG in the present study was found to be high in low stocking density throughout the study period. Previous studies have also recorded that decreased weight gain with increasing stocking densities in largemouth bass fish (Petit et al., 2001) and silver perch (Rowland et al., 2004). The results of present study match with the findings of (Haque et al., 1984, Kawamoto et al., 1957) who achieved best growth at lower stocking densities of tilapia fish. The growth rate gradually increases as the stocking density of fish decreases and vice versa. This is for the reason that a relatively less number of fish of similar size in a pond could get more freedom, feed, minimum struggle and dissolved oxygen etc observed by various authors (Johnson, 1965; Wiener & Hameman 1982; Haque et al., 1984; Irwin et al., 1999; Ahmed, 1984; Benetti et al., 2002; Narejo et al., 2005 and 2010; Chavez et al., 2011). Daudpota et al. (2014), reported that a stocking density of T1 (250 fry hapa-1) might be suitable for the culture of red tilapia (hybrid) in hapa on artificial feed give optimal growth while, in T3 (300 fry hapa-1) lowest growth (29.09 ±0.0g) was recorded.

3.4 Average Daily Growth ADG (g)

Mean ADG (g) of sillago from various experimental units was observed weekly over the rearing period of 60 DOC are presented in Table 5.4 and illustrated in Fig. 3.4. At the end of the experiment on 60 DOC mean ADG ranged from 0.073 ±0.006 – 0.106 ±0.010g. Higher growth (0.106 ±0.010g) in terms of ADG was recorded in the treatment T1 (250 nos fish fry) than T2, T3 and T4. Whereas, lower ADG ($p<0.05$) was recorded in T4 (0.073 ±0.006g). All the treatments were significantly different during all the period except 42 and 49 DOC. However, treatments T1 and T2 are statistically at par with each other during 35, 56 and 60 DOC whereas; treatment T2 and T3 were at par during 7, 14, 21, 35, 56 and 60 DOC. Similarly, treatment T3 and T4 were also at par with each other during 7, 56 and 60 DOC, whereas, treatment T2 was at par with T3 and T4 on 56 and 60 DOC. The effect of treatment T1 (having 250 numbers of fish fry) was found superior among all the treatments (Table 5.4).

The results of the present study are also in agreement with the findings of Mehrim et al. (2018) reported that gray mullet (M. cephalus) gave significantly the best growth performance (average daily gain) at the lowest stocking density (40 fish m-3). Daet (2019) have reported that evaluated the potential of culturing seabass in hapa-in-pond environment. He observed that treatment 1 (10 pcs m-3) had highest weight gain increment of 148.80g followed by treatment 2 (15 pcs m-3) with (145.08g) and lowest in treatment 4 (10 pcs m-3) with (136.32g). Based from the result obtained, those group stocked at 10 pcs m-3 (T1) exhibited the highest mean daily increment of 1.65g followed by T2 with 1.61g and lowest in T4 with (1.51g).

Results of the present study are also in accordance with the findings of Danaher et al. (2007) who reported that the average weight of tilapia stocked at low density was significantly higher than that stocked at high density. Results also are in agreement with the findings of Abd El-Salam, et al (2015) who studied the effect of stocking density of Nile tilapia (102 fish m-3 and 204 fish m-3) with an initial weight of 7g on growth performance for 14 weeks. He reported that body weight and daily weight gain of Nile tilapia were significantly decreased with increasing stocking density during most of the experimental periods studied.

3.5 Feed Conversion Ratio (FCR)

Table 5.1 shows the FCR ranged from 1.418 ±0.014 - 1.476 ±0.010. Treatment T2 showed lower ($p<0.05$) FCR than other treatment while T4 showed higher ($P<0.05$) FCR of 1.476 ±0.010. The present study revealed that FCR decreased with increasing stoking density. However, treatment T3 (1.458 ±0.012) and T4 (1.476 ±0.010) was statistically at par, whereas, T1 (1.424 ±0.012) and T2 (1.418 ±0.014) was also at par with each other. Better feed conversion ratio (FCR) was found in T2 (1.418 ±0.014).

Daudpota et al. (2013), reported that feed conversion ratio of 0.48, 0.48 and 0.49 in T1 (200 fry hapa-1), T2 (250 fry hapa-1) and T3 (300 fry hapa-1), respectively not significantly different ($p>0.05$). Philipose et al. (2010) reported FCR of 1.15 in 45-day nursery rearing of Asian seabass in indoor cement tanks. In this study, the FCR recorded at the three stocking rates were, 0.86, 0.85 and 0.90 for 1000 nos. m-3, 1500 nos. m-3 and 2000 nos. m-3, respectively during the 90 DOC. Significant differences ($p<0.05$) between 2000 nos. m-3 and the other two stocking rates were recorded, but on the other hand 1000 nos. m-3 and 1500 nos. m-3 did not differ significantly. The FCR values indicate that 2000 nos. m-3 stocking density group utilized the feed most efficiently and showed better feed conversion than the other two groups.

Huang (2019) studied the low feed conversion ratio was reported in diet containing 45% CP and 12% lipids in sillago fish. Kailasam et al. (2002) reported that in high stocking density of seabass, there was very less chances for social dominance and hierarchical territoriality and associated behavioral patterns, which lead to efficient utilization of the available space and feed in the culture environment. Daet (2019) was carried out to evaluate the potential of culturing seabass in hapa-in-pond environment showed that the FCR was significant in all treatments means and the value is significantly different ($p<0.05$). Data revealed that stocking density having 10 pcs m-3, 15 pcs m-3, 20 pcs m-3 and 25 pcs m-3 are all significantly different among treatments means. Consequently, the growth rate was decreased with decreasing food consumption (MacLeod, 1977).

In contrast to present study, Muyot et al. (2021) reported that the feed conversion ratio was not affected by the stocking density ($p>0.05$) of mangrove red snapper for three stocking densities in hapa. The highest FCR was obtained by snappers at 0.5 fish m-2 SD (5.9 ±0.1) and lowest at 3 fish m-2 SD (5.0 ±0.03). Snappers at 1 fish m-2 SD attained an FCR of 5.2 ±0.2.

Liti et al. (2005) opined that high density stocked fishes might have lower ability to convert given feed to flesh than fish stocked with low density in terms of growth. Philipose et al. (2010) reported FCR of 1.15 in 45-day nursery rearing of Asian seabass in indoor cement tanks. Mehrim et al. (2018) reported that gray mullet (M. cephalus) gave significantly the feed utilization (feed conversion ratio) at the lowest stocking density (40 fish m-3) which is agreed to the results of present study.

3.6 Survival Rate (%)

Survivals of sillago fish fry in the various treatments are detailed in Table 5.1 and illustrated in Fig. 3.3. The survival rate of sillago fish during the experiment varies from 82.18 ±0.418 - 88.40 ±0.704%. Not any definite trend of survival was observed with respect to stocking density. However significantly higher ($p<0.05$) survival rate of 88.40 ±0.704% was estimated in T1 followed by T2 (87.84 ±0.440%), T3 (83.92 ±0.703%) and T4 (82.18 ±0.418%). Treatment T1 and T2 are statistically at par with each other during 7, 21, 28, 42, 49, 56 and 60 DOC whereas T3 and T4 was at par with each other during all the period except 1, 7 and 14 DOC. The results showed that the survival rate of S. sihama fry at the higher stocking (1000 numbers) was significantly lower than lower stocking density levels ($p<0.05$) (Table 5.5).

Kailasam et al. (2001) observed a survival rate of seabass fish was 65% in higher stocking densities of 20 and 30 nos. L-1. Fortes (1984) was attempt to rearing milkfish fingerlings in hapas (each 1 × 1 × 1m) were installed in pond with stoking density of 500, 1000, 2000, 4000, and 6000 fry hapa-1. After one month culture period, survival was observed to range from 9% (6000 hapa-1) to 71% (500 hapa-1). He also performed the experiment based on different stocking densities like 367, 500, 1000 and 2000 hapa-1. After 2 months of rearing, survival rates were observed 93.2, 83.0, 86.0, and 52.5%, respectively. The same trend of sillago fish survival rate was observed in present study. Daet, (2019) was reported that the treatment T1 (10 pcs m-3) obtained a survival of 87% in seabass culture in hapa for 90 DOC which is significant different among the treatments. This was followed by 15 pcs m-3 with 64% survival rate, 20 pcs m-3 with 63% and lowest in 25 pcs m-3 with 47%.

Muyot et al. (2021) reported that the mangrove red snapper in the three stocking densities in hapa there was no significant difference ($p>0.05$) in the survival rate of snappers in the different SD. The lowest stocking density (0.5 fish m-2 SD) attained the highest survival rate of 92 ±4.6% while snappers at 1 fish m-2 SD and 5 fish m-2 SD had 86 ±2.3% and 78 ±7.1%, respectively which is similar result to present study of sillago fish fry. Daudpota, et al., (2013), reported that highest survival (100%) was attained in T1 (200 fry hapa-1) with lower stocking density, followed by T2 (250 fry hapa-1) (98%) and T3 (300 fry hapa-1) (95%) in red tilapia fish.

3.7 Economics

Total operational expenditure for sillago fish fingerling production ranged from ₹ 273 – 1030/-m-3 (Table 5.6). It includes the expenditures on fish seeds, feeds and labors. The higher biomass (0.22kg m-3), total operational cost (₹ 1030 m-3), Gross income (₹ 2,065/-m-3), net income (₹ 1,035/-) and cost of production (₹ 2.49/-) were recorded in treatment T4 (1000 nos of fish fry) than other treatment. This higher income directly associated with higher fish yield, stocking density as well as survival rate of fish fry received from treatment T4 (1000 nos fish fry). Inclusion of costly seed contributes to hike the operational cost for all the treatments. As far as unit fish production cost is concerned it ranged from Rs. 2.42 – 2.49/-m-3.

Net profit m-3 is ranged from ₹ 282 – 1,035/- (Table 5.6). The higher net profit of ₹ 1,035/-m-3 was received from T4, whereas, lower net profit ₹ 282/-m-3 was received from T1. These data revealed that higher profit can be earned using higher stocking density in hapa for sillago fish fingerlng production. Benefit cost ratio (B:C ratio) ranged from 1.00 – 1.07 and it is presented in Table 5.6. The higher (B:C ratio of 1.07 was recorded in T2 and lower of 1.00 was in T4.

Mojjada et al. (2013) reported that total biomass production of 1.11 kg day-1 was obtained at high stocking density (2000 nos. m-3) of sebass fish rearing. Analysis of B:C ratio is often used to assess economic feasibility of new approach or technologies (Baranchuluun et al., 2014). In agreement to the findings of the present study, Muyot et al. (2021) observed the mangrove red snapper in the three stocking densities in hapa condition. The cost analysis showed that the 0.5 fish m-2 SD had a low net profit of PHP 51,200/- while the 1 fish m-2 SD and 3 fish m-2 SD had a higher net profit of PHP 1,43,478/- to PHP 4,81,177/- hectare-1, respectively. Net profit kg-1 of harvested snapper fish was also two times bigger at higher stocking densities. The analysis of cost-benefit ration showed that all three-stocking density are economically feasible, with a BC ratio of 0.31, 0.61, and 0.91 for the 0.5, 1.0, and 3.0 fish m-2 SD, respectively.

In present study, there was an increasing trend of biomass with increasing stocking density. The production is more in high stocking density in terms of yield as well a number of seed m-3 for sillago fish. The study shows a strong trend that final yield increased with increasing stocking density of sillago fish. These results are in conformity with those recorded by Cruz and Ridha (1989) and Watanabe et al. (1990) for tilapia fish trail.

3.8 Physico-chemical parameters of water

Experimental units (Hapa) were kept in pond at Aqua Farm Danti, COFS, KU, Navsari and water parameters were recorded daily (pH, salinity, DO, temperature) and weekly (Total Ammonical Nitrogen (TAN) Nitrite and Nitrate) basis during experimental period of 60 DOC. The physico-chemical parameters such as pH, salinity, DO, temperature, Total Ammonical Nitrogen (TAN) Nitrite and Nitrate were at normal ranges in pond water (Table 5.7).

3.8.1 Temperature

The temperature data are given in Table 5.7. Pond water temperatures ranged from 18.00 ºC to 27.30 ºC during experiment period. There was no significant difference during rearing period of 60 DOC. In the present experiment, the temperature was found 18.00 °C to 27.30 °C, this lower range was due to the winter season started during end of the experiment. Water temperature had a negative relationship with DO indicating DO increased with decrease temperature. The decreased DO level in fish culture pond reduced feeding, starvation, slow growth as well as more fish mortality, either directly or indirectly (Bhatnagar and Garg, 2000).

3.8.2 Salinity:

The salinity of pond water was recorded on daily basis. The data are given in Table 5.7. It ranged from 6.90 to 16.80 ppt. The wide variations in salinity might be due to the rainy season throughout the experiment period of 60 days. The recorded salinity in the study (6.90 to 16.80 ppt) was within the recommended range for fish rearing (Boyd, 1982).

Table 5.1: Growth parameters of S. sihama fry in different treatments during rearing period of 60 DOC (Mean ±SE)

Parameters	T1	T2	T3	T4	SEm±	CD (=0.05)	CV%
Initial length(mm)	2.024 ±0.007	2.028 ±0.010	2.044 ±0.007	2.036 ±0.015	0.000	NS	1.143

Initial weight (g)	0.076 ±0.000	0.078 ±0.000	0.078 ±0.001	0.076 ±0.000	0.000	NS	1.481
Final length (cm)	8.768 ±0.022^{a}	8.160 ±0.017^{b}	7.644 ±0.016^{c}	7.476 ±0.016^{d}	1.694	0.074	0.502
Final weight (g)	4.020 ±0.034^{a}	3.672 ±0.022^{b}	3.316 ±0.021^{c}	2.884 ±0.019^{d}	1.184	0.102	1.595
Net gain length (cm)	6.744 ±0.020^{a}	6.132 ±0.016^{b}	5.600 ±0.018^{c}	5.440 ±0.018^{d}	1.738	0.087	0.754
Net gain weight (g)	3.994 ±0.034^{a}	3.599 ±0.021^{b}	3.238 ±0.022^{c}	2.808 ±0.019^{d}	1.184	0.103	1.636
ADG-weight (g)	0.067 ±0.001^{a}	0.061 ±0.000^{b}	0.055 ±0.000^{c}	0.048 ±0.000^{d}	0.000	0.002	1.832
FCR	1.424 ±0.012^{bc}	1.418 ±0.014^{c}	1.458 ±0.012^{ab}	1.476 ±0.010^{a}	0.004	0.036	1.881
Yield (kg)	0.888 ±0.016^{d}	1.613 ±0.016^{c}	2.087 ±0.017^{b}	2.370 ±0.013^{a}	2.097	0.062	1.915
Survival (%)	#70.120 (88.40 ±0.704^{a})	#69.604 (87.84 ±0.440^{a})	#66.379 (83.920 ±0.703^{b})	#66.379 (82.180 ±0.418^{b})	0.675	2.002	1.599

ADG- Average daily growth; WG- weight gain; FCR- Feed conversion ratio; NS – Non-significant. CD – Critical Difference, Means with different superscript in a column differ significantly (Two way ANOVA). Data are expressed as mean ± SE of five replicates. # Arcsine transformed value; figures in parenthesis indicate arcsine retransformed value.

Table 5.2: Mean length gain (cm) of S. sihama fry in different treatments during culture period of 60 days (Mean ±SE)

Treatment	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**60**
T1	0.164 ±0.012	0.324 ±0.010^{a}	0.504 ±0.031^{a}	0.692 ±0.034^{a}	0.892 ±0.040^{a}	1.096±0 .029^{a}	1.312 ±0.049^{a}	1.536 ±0.036^{a}	0.584 ±0.033
T2	0.152 ±0.016	0.276 ±0.012^{b}	0.444 ±0.017^{ab}	0.616 ±0.015^{ab}	0.808 ±0.020^{ab}	1.008 ±0.036^{a}	1.220 ±0.068^{ab}	1.440 ±0.046^{ab}	0.508 ±0.029
T3	0.144 ±0.012	0.260 ±0.013^{b}	0.396 ±0.030^{b}	0.544 ±0.047^{b}	0.728 ±0.051^{bc}	0.912 ±0.033^{b}	1.112 ±0.022^{bc}	1.324 ±0.034^{bc}	0.464 ±0.039
T4	0.140 ±0.019	0.252 ±0.016^{b}	0.380 ±0.021^{b}	0.524 ±0.025^{b}	0.700 ±0.011^{c}	0.872 ±0.027^{b}	1.064 ±0.037^{c}	1.268 ±0.088^{c}	0.432 ±0.077
SEm±	0.001	0.005	0.016	0.029	0.037	0.050	0.062	0.072	0.022
CD (P=0.05)	NS	0.053	0.076	0.134	0.142	0.131	0.191	0.165	NS
CV%	22.31	10.301	13.145	12.245	9.856	7.282	8.801	8.863	21.764

*Significant (P<0.05)

Table 5.3: Mean weight gain (g) of S. sihama fry in different treatments during culture period of 60 days (Mean ±SE)

Treatment	7	14	21	28	35	42	49	56	60
T1	0.139 ±0.002[a]	0.197 ±0.003[a]	0.274 ±0.008[a]	0.359 ±0.006[a]	0.431 ±0.034[a]	0.516 ±0.023	0.600 ±0.034	0.692 ±0.045[a]	0.740 ±0.069[a]
T2	0.111 ±0.003[b]	0.174 ±0.005[b]	0.245 ±0.006[b]	0.325 ±0.008[b]	0.407 ±0.011[ab]	0.480 ±0.037	0.552 ±0.063	0.632 ±0.032[a]	0.668 ±0.037[ab]
T3	0.105 ±0.006[c]	0.163 ±0.007[b]	0.226 ±0.010[b]	0.298 ±0.004[c]	0.362 ±0.023[bc]	0.436 ±0.042	0.492 ±0.029	0.564 ±0.050[ab]	0.592 ±0.060[ab]
T4	0.093 ±0.004[c]	0.139 ±0.007[c]	0.196 ±0.003[c]	0.256 ±0.009[d]	0.317 ±0.006[c]	0.371 ±0.039	0.432 ±0.029	0.492 ±0.045[b]	0.512 ±0.043[b]
SEm±	0.001	0.003	0.005	0.009	0.013	0.020	0.026	0.037	0.048
CD (P=0.05)	0.017	0.023	0.030	0.030	0.088	NS	NS	0.131	0.161
CV%	8.100	7.487	6.815	5.224	12.513	17.933	17.816	16.417	19.102

*Significant (p<0.05)

Table 5.4: Mean Average daily growth (g) of S. sihama fry in different treatments during culture period of 60 days (Mean ±SE)

Treatment	7	14	21	28	35	42	49	56	60
T1	0.019 ±0.000[a]	0.028 ±0.000[a]	0.039 ±0.000[a]	0.051 ±0.001[a]	0.062 ±0.005[a]	0.074 ±0.003	0.086 ±0.005	0.099 ±0.006[a]	0.106 ±0.010[a]
T2	0.016 ±0.000[b]	0.025 ±0.001[b]	0.035 ±0.001[b]	0.046 ±0.001[b]	0.058 ±0.002[ab]	0.069 ±0.005	0.079 ±0.009	0.090 ±0.005[a]	0.096 ±0.005[ab]
T3	0.015 ±0.000[bc]	0.023 ±0.001[b]	0.032 ±0.001[b]	0.042 ±0.001[c]	0.052 ±0.003[bc]	0.062 ±0.006	0.070 ±0.004	0.081 ±0.007[ab]	0.085 ±0.009[ab]
T4	0.013 ±0.001[c]	0.020 ±0.001[c]	0.028 ±0.000[c]	0.036 ±0.001[d]	0.045 ±0.001[c]	0.053 ±0.006	0.062 ±0.004	0.070 ±0.006[b]	0.073 ±0.006[b]
SEm±	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
CD (P=0.05)	0.002	0.004	0.004	0.004	0.012	NS	NS	0.019	0.023
CV%	7.442	8.122	6.846	4.962	12.281	18.004	17.808	16.370	19.199

*Significant (p<0.05)

Table 5.5: Mean survival rate (%) of S. sihama fry in different treatments during culture period of 60 days (Mean ±SE)

Treatment	1	7	14	21	28	35	42	49	56	60
T1	#89.359 100.0 ±0.000	#89.359 100.0 ±0.000[a]	#85.805 99.04 ±0.676	#81.849 97.92 ±0.408[b]	#80.317 97.12 ±0.408[a]	#78.626 96.08 ±0344[a]	#75.573 93.76 ±0.438[a]	#73.376 91.76 ±0.722[a]	#71.769 90.16 ±0.755[a]	#70.120 88.40 ±0.704[a]
T2	#89.359 100.0 ±0.000	#89.359 100.0 ±0.000[a]	#86.842 99.40 ±0.400	#84.081 98.84 ±0.349[a]	#79.010 96.32 ±0418[ab]	#76.076 94.20 ±0.245[b]	#74.453 92.82 ±0.346[a]	#72.661 91.08 ±0.609[a]	#71.224 89.60 ±0.684[a]	#69.604 87.84 ±0.440[a]
T3	#89.359 100.0 ±0.000	#88.892 99.94 ±0.053[a]	#85.048 99.20 ±0.202	#81.210 97.64 ±0.172[b]	#77.143 96.96 ±0.582[b]	#74.749 93.08 ±0.313[c]	#71.562 89.98 ±0.508[b]	#70.038 88.32 ±0.574[b]	#67.982 85.92 ±0.643[b]	#66.379 83.92 ±0.703[b]
T4	#89.359 100.0 ±0.000	#86.777 99.62 ±0.124[b]	#84.916 99.20 ±0.105	#81.393 97.74 ±0.216[b]	#77.277 95.12 ±0.393[b]	#73.861 92.26 ±0.330[c]	#70.359 88.68 ±0.538[b]	#69.357 87.56 ±0.420[b]	#66.871 84.56 ±0.459[b]	#65.036 82.18 ±0.418[b]
SEm±	0.000	0.438	1.294	0.651	0.652	0.390	0.480	0.574	0.585	0.485
CD (P=0.05)	NS	1.809	NS	1.952	2.692	1.610	1.984	2.369	2.417	2.002
CV%	0.000	1.105	3.378	1.773	1.858	1.149	1.471	1.797	1..884	1.599

Arcsine transformed value; figures in parenthesis indicate arcsine retransformed value.

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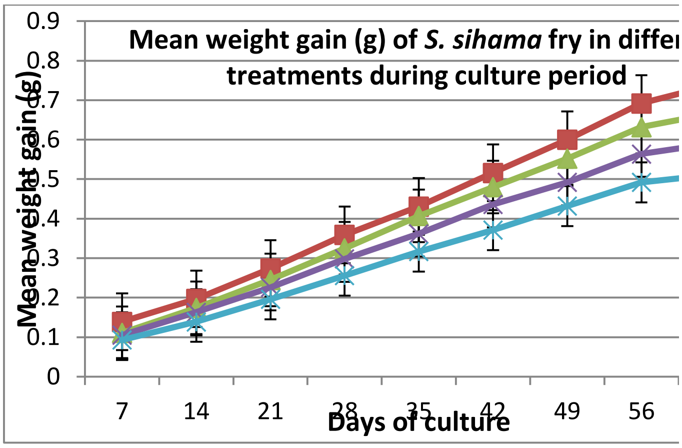
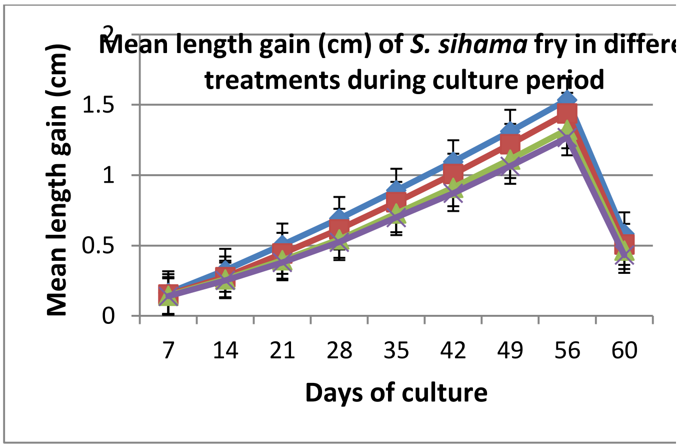
Table 5.6: Economics of S. sihama fry in different treatments during culture period of 60 days (Per cubic meter basis)

Treatment	Survival (%)	No. of survivors	ABW (g)	Biomass (kg)	Total feed (kg)	Total cost of seed (₹)	Total cost of feed (₹)	FCR	Labor (₹)	Total operational cost (₹)	Gross income (₹)	Net income (₹)	BC ratio	Cost of prod. (₹)
T1	88.67	111	0.82	0.08	0.11	250	3.44	1.42	20	273.00	555	282	1.03	2.46
T2	87.20	218	0.84	0.16	0.23	500	6.76	1.42	20	527.00	1090	563	1.07	2.42
T3	83.87	315	0.71	0.19	0.27	750	8.18	1.46	20	778.00	1575	797	1.02	2.47
T4	82.57	413	0.66	0.22	0.33	1000	9.95	1.48	20	1030.00	2065	1035	1.00	2.49

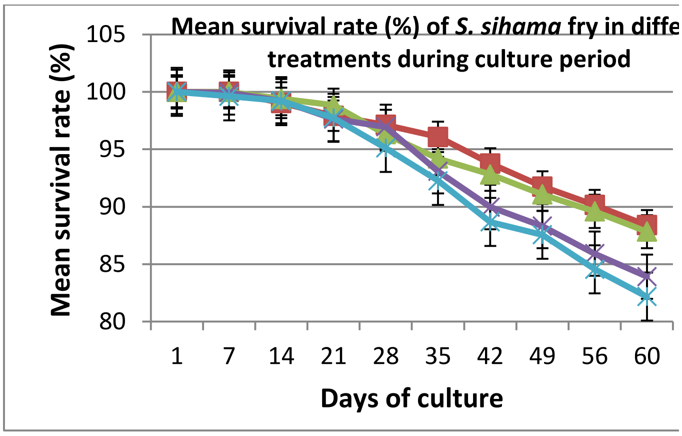
Assumptions:
1. Feed cost - ₹ 30kg^{-1}
2. Labour cost calculated as 0.30 hr day^{-1}
3. Seed cost- ₹ 2 seed^{-1}
4. Market rate- ₹ 5 fingerling^{-1}
5. Rearing period - 2 months



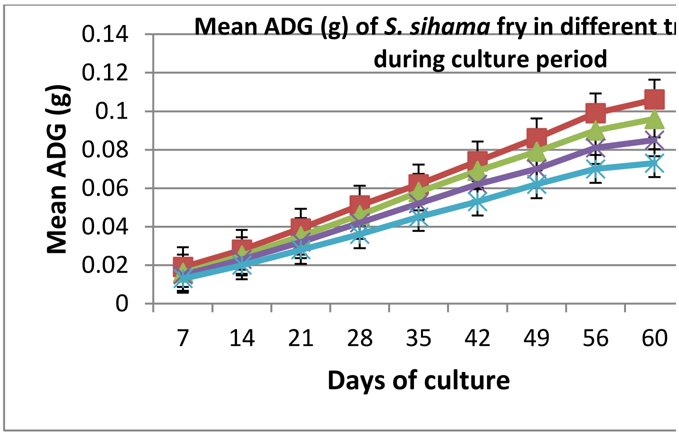
Mean weight gain (g) of S. sihama fry in different treatments during experiment period of 60 days



Mean length gain (g) of S. sihama fry in different treatments during experiment period of 60 days



Mean Survival rate (%) of S. sihama fry in different treatments during experiment period of 60 days



Mean Average Daily Growth (ADG) of S. sihama fry in different treatments during experiment period of 60 days

3.8.3 Dissolved oxygen (DO)

The data of dissolved oxygen during rearing period of 60 DOC are shown in Table 5.7. It ranged from 4.30 to 7.20 ppm. The dissolved oxygen content was within the optimum range that showed their suitability for sillago fish rearing. The DO content should be more than 5.0 ppm was suggested for fisheries, recreation and irrigation (EQS, 1997). However, DO investigated in the present study is comparable with the suitable range of 4.32 - 7.20 ppm for fish rearing (Waycott, 2015; Volstorf, 2021).

3.8.4 pH

The pH of pond water was recorded on daily basis. The data are given in Table 5.7. During the study, pH ranged between 8.00 - 8.50. The lowest value of pH (8.00) and the highest value (8.50) were recorded during experiment period of 60 DOC. In present study there was no remarkable difference of pH value throughout the experiment period. The pH recorded in the present study falls between the optimum required pH 6.5 to 8.5 for aquatic life (Hepher & Pruginin, 1981; Svobodova et al., 1993; Devi et al., 2017). Extremely alkaline water (More than pH 9) is unsafe as ammonia toxicity increases speedily. At higher temperatures fish are more susceptible to pH changes.

3.8.5 Total Ammonical Nitrogen (TAN) (NH3-N)

Total ammonical nitrogen (TAN) was measured at morning hours on weekly basis. During the present study Total Ammonical Nitrogen ranged between 0.06 to 0.16 ppm (Table 5.7). There was no remarkable variation of ammonia throughout the experiment. Usually the value of ammonia is high at higher temperature. The ammonia concentration is inversely related to fish growth and yields and high values of ammonia do cause toxicity (Beleau, 1988; Abdulla, 1990; Buttner et al., 1993; Champman et al., 1992; Hargreaves and Semra, 2001). Bhatnagar and Singh (2010) recommended the level of ammonia (<0.2 ppm) suitable for fish rearing in pond.

3.8.6 Nitrite (NO2-N)

Nitrite was measured at morning hours on weekly basis. The data of Nitrite during rearing period are shown in Table 5.7. In all sampling days, the Nitrite content was within the optimum range. The lowest

(0.012 ppm) NO2-N value and highest (0.11 ppm) was found during experiment period of 60 DOC. According to (Bagarinao, 1994) 0.02-1.0 ppm is lethal to many fish species, >1.0 ppm is lethal for many warm water fishes and <0.02 ppm is acceptable. So as per the above citations, present results are within the tolerable limits for the rearing of sillago fish in pond.

3.8.7 Nitrate (NO3-N)

Nitrate was measured at morning hours on weekly basis. The data of Nitrate during rearing period are shown in Table 5.7. In all sampling days, the Nitrite content was within the optimum range. The lowest NO3-N value 0.04 ppm and the highest 0.18 ppm was found during experiment period of 60 DOC (Table 5.7). According to (Moniruzzaman, 2015) nitrate is relatively nontoxic to fish and not cause any health hazard except at exceedingly high levels (above 90 ppm). Meck (1996) described the favorable range of 0.1 to 4.0 ppm in fish culture. The results of present study correlate with results recorded by Moniruzzaman (2015).

Thus, all above mentioned parameters during the experiment were in the required range for sillago fish rearing.

Table 5.7: Physico-chemical parameters (Daily and weekly) of pond water during culture period of 60 days (Mean ±SE)

Parameters	**Pond-1**
Daily basis	
Temperature (ºC)	22.24 ±3.11 (18.00 – 27.30)
pH	8.26 ±0.13 (8.00 – 8.50)
DO (ppm)	5.77 ±0.77 (4.30 – 7.20)
Salinity (ppt)	12.24 ±2.59 (6.90 – 16.80)
Weekly basis	
Ammonia NH_3-N (ppm)	0.094 ±0.03 (0.060 – 0.160)
Nitrate NO_3-N (ppm)	0.10 ±0.005 (0.04 – 0.18)
Nitrite (NO_2-N) (ppm)	0.02 ±0.110 (0.02 – 0.11)

The values in parenthesis indicate range value of water quality parameters of pond.

4. Discussion:

The study was conducted using 2.0 x 1.0 x 1.0m 'hapa' as experimental units fixed in a 1400m2 pond. A total of 12,500 fry of sillago were randomly allocated to 20 experimental hapas. Fish fry were acclimated with the pond environment by rearing them in hapa net for a week. Fish fry with an average initial weight of 0.076 ±0.00g were randomly stocked in the hapa at 250 fish hapa-1, 500 fish hapa-1, 750 fish hapa-1 and 1000 fish hapa-1designated as T1, T2, T3 and T4 treatment, respectively each with five replicates (Kongkumnerd, 1999). Each hapa was covered at the top with a piece of small mesh size net to prevent escape of fish by jumping and predation of birds. The sillago fish fry nursery rearing period lasted for 60 days. Growth, survival, FCR and cost analysis were determined at the end of the experiment.

Results of different stocking density of sillago fish fry in hapa nursery rearing are summarized below.

Significantly (p<0.05) higher growth was achieved in treatment T1 followed by T2, T3 and T4 whereas, treatment T1 showed significant (p<0.05) effect on total length gain of fish fry. Survival ranged from 82.18 – 88.40% at the conclusion stage of the experiment with significant (p<0.05) differences among all the treatments. The yields were recorded 0.888kg, 1.613kg, 2.087kg and 2.370kg in treatment T1, T2, T3 and T4, respectively. Treatment T4 showed superior and significant (p<0.05) effect on yield than T1, T2 and T3. Stocking density of sillago fish fry was not significantly affecting FCR. No significant difference (p>0.05) in FCR was observed in different stocking densities. The significantly (p<0.05) higher ADG (0.067 ±0.001g) was achieved in treatment T1 followed by T2, T3 and T4 (p<0.05). The stocking density significantly (p<0.05) influenced the total weight gain. Treatment T1 (0.740 ±0.069g) showed the highest mean weight gain during 60 DOC. Higher stocking density significantly (p<0.05) decreased the total weight gain of fish fry. Significantly lowered (p<0.05) weight gain of treatment T4 in fish fry was observed at higher stocking densities (0.512 ±0.043g). The effect of treatment T1 (250 numbers of fish fry hapa-1) was found superior among all the treatments. The highest final ADG was observed in treatments T1 (0.106 ±0.010g) and lowest in T4 (0.073 ±0.006g). The effect of treatment T1 (250 numbers of fish fry) was found superior among all the treatments. There was no significant difference in food conversation ratio among all the treatments and it was found lower in treatment T2 (1.418 ±0.014). Also observed that the FCR was directly proportional to the stocking density and survival rate of fish fry. The results showed that the survival rate of S. sihama fry at the higher stocking density (1000 numbers of fish hapa-1) was significantly lower compared to lower stocking density (p<0.05). The treatments T4 (1000 numbers of fry hapa-1) gave higher net income of ₹ 1,035/- and higher cost of production (₹ 2.49m-3) with benefit cost ratio (BCR) of 1.00. Whereas, cost of production was found lower in treatment T2 (₹ 2.42m-3) and T1 (₹ 2.46m-3).

5. Conclusion:

Based on overall findings and discussion aided by available literature, the following conclusions could be drawn from the present study:

The present study has established that for nursery raising of sillago fry, lower stocking density (250 number of fish fry hapa-1) in hapa yields higher growth and survival without affecting FCR. It also fetches higher net income with higher benefit cost ratio (BCR) and lower cost of production. However, final weight, final length, weight gain, length gain, average daily gain and survival were higher in lower stocking densities, but more yields was observed in higher stocking density.

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