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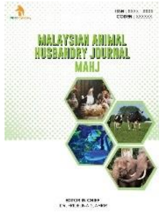

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RESEARCH ARTICLE

CAGE FISH CULTURE OF MIXED SEX NILE TILAPIA (*OREOCHROMIS NILOTICUS*) WITH DIFFERENT STOCKING DENSITY IN DANDA RIVER

Jeevan Rijal*, Prabesh Pandit, Deepa Bhatt, Shailesh Gurung and Ram Bhajan Mandal

Department of Aquaculture, Institute of Agriculture and Animal Sciences, Tribhuvan University, Kirtipur, Nepal
****Corresponding Author Email: rijaljeevan63@gmail.com***

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ABSTRACT

A field experiment was conducted to detect the growth performance of mixed sex Nile tilapia (*Oreochromis niloticus)* at different stocking density in Danda River, Rupandehi in 1m³ caged culture for 90 days. The experiment was conducted in Completely Randomized Design (CRD) with four treatments replicated thrice. The treatments were: Treatment-1, Treatment -2, Treatment-3 and Treatment-4 containing 10, 20, 30 and 40 fish/m³ respectively. The mean stocked weight of tilapia fingerling in each treatment was 11.31g, 10.93g, 10.23g and 10.10g, respectively. The feed containing 35% CP was supplied at the rate of 5% of body weight in initial month followed by 3% in the latter two months. Fish were fed twice daily at morning 9AM and next at evening 4PM. In this 90-day study, the study results indicated that Treatment T2 was significantly more effective than the other treatments in several key performance metrics ($p<0.05$). T2 exhibited the highest mean weight gain at 76.32g, significantly greater than T1 (69.83g), T3 (67.80g), and T4 (63.36g). Additionally, T2 recorded the highest daily weight gain at 0.84g, which was significantly greater than the gains in T1 (0.77g), T3 (0.75g), and T4 (0.70g). The survival rate in T2 was the highest at 90.00%, while T4 had the lowest survival rate at 70.67%, with these differences being statistically significant ($p<0.05$). In terms of total production, T4 achieved the highest production at 2078.34±22.75g, which was significantly higher than the production in T1 (480.48±24.57g) ($p<0.05$). Although T4 led in gross return at 235.42, the net return was highest in T2 at 61.70, with this being significantly different from the net returns in T1 (9.03) and T4 (2.59) ($p<0.05$). Additionally, the benefit-cost ratio (BCR) was also highest in T2, significantly outperforming T1, T3, and T4 ($p<0.05$). These findings suggest that 20 fish/m³ is the most effective treatment for enhancing growth performance, production, and economic returns in Tilapia fish farming.

KEYWORDS

Stocking Density, Growth Performance, Cage Culture, Mixed Sex Nile Tilapia.

1. INTRODUCTION

Nile tilapia has several characteristics that make it suitable for aquaculture, including fast growth rates and highquality fillets; omnivorous feeding habits; high disease resistance, an efficient feed conversion ratio; and consumer acceptance (Githukia et al., 2015; Thongprajukaew et al., 2017; Vasconcelos et al., 2018; El-Sayed 2002).

The Danda River, flowing through the mid-hills of Nepal, is characterized by its fast-moving waters and relatively stable temperature range, making it an ideal location for aquaculture practices such as cage culture. The river's steady flow ensures good oxygenation, which is crucial for the health and growth of aquatic species like tilapia. Additionally, the natural nutrient levels in the river support the growth of phytoplankton, providing a supplementary food source for fish. The Danda River's geographical location also offers accessibility to local farmers, making it a viable site for sustainable fish farming.

Nile tilapia, scientifically known as Oreochromis niloticus, is highly suitable for aquaculture due to its strong biological traits. This species is recognized for its rapid growth, ability to thrive in various environmental conditions, and toughness when it comes to handling stress (Vasconcelos, J.C., and de Oliveira, F.F., 2018). Tilapia are omnivores and consume a diverse range of food sources, such as plankton, algae, and commercial feed, which allows them to adapt well to different farming systems (Rai, S., and Shrestha, M.K., 2005). Moreover, they demonstrate efficient feed conversion ratios, allowing for significant biomass production with comparatively low feed inputs. These characteristics render tilapia an excellent choice for cage culture in river systems like the Danda.

Cage culture refers to an aquaculture technique where fish are enclosed in floating net structures within natural or artificial bodies of water. Tilapia can be successfully raised in cages in the Danda River, thanks to the conducive conditions of the river. This method allows for higher stocking densities than traditional pond culture, resulting in greater production per unit area (El-Sayed, A.-F. M., 2006). The unrestricted flow of water through the cages helps to maintain optimal water quality, lowering the risk of diseases and poor growth typically associated with stagnant water. Additionally, cage culture makes management and harvesting easier, which can result in more reliable and profitable production outcomes for local farmers. First, it allows researchers to assess the viability of cage culture in a real-world setting, where variables such as water flow, temperature fluctuations, and natural food availability can significantly impact fish growth and health (Bhandari, B.,1995). Additionally, natural water studies can provide insights into the environmental impacts of aquaculture, helping to develop strategies that minimize negative effects such as water pollution and habitat degradation.

Finally, by studying tilapia production in natural waters, researchers can generate data that supports the development of aquaculture in regions where access to artificial ponds or recirculating systems is limited, thus promoting food security and economic development in rural communities.

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2. MATERIALS AND METHOD

The experiment was conducted at Danda River on the territory of IAAS Paklihawa Agriculture campus located at Siddharthanagar municipality of Rupandehi district. The experiment was carried out during the winter season from 23rd October, 2023 to 24th December, 2023 up to 90 days. The experimental area is situated in South-Western Terai region of Nepal. Geographically, the experimental site located in the Terai region of Nepal. The district had Tropical to Sub-tropical climate with hot summer and cold winter. It is located in south-west of Nepal.

The experiment was carried out in 12 fish cages measuring 1 cubic meter, with mesh sizes of 0.8 mm. Four bamboo poles were used to support each gage in its upper four corners. To keep the cage's construction intact, the lower corners was tied with ropes and secured to the stone. On the top face, a small feeding hole was made available. Viable-sized fry from the Mandal Hatchery in Patthardanda, Rupandehi were placed in bags containing oxygen and water and allowed to acclimatize for 7 days before starting the experiment. During acclimation, extruded commercial diet was feed containing 32% crude protein before using the test diet. The fry was then transferred to individual cages at a stocking density of 10,20,30 and 40 fish per cage and fed once daily with appropriate food according to treatment.

For the experiment, Completely Design (CRD) was used having the four experimental diets.

Table 1: Experimental Diets

Treatment ID	Treatment details (Stocking density i.e., no. of fish per m^3)
T_1	10 (No feeding)
T_2	20 (With feeding)
T_3	30 (With feeding)
T_4	40 (With feeding)

Altogether there were four treatments replicated 3 times. The lottery method was used to randomize the treatments.

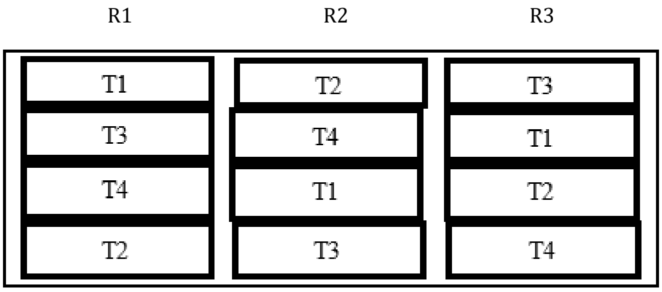

Figure 1: Layout of the research

A commercial floating pellet was used in the experimental period. The pellet size was 1.8-2mm and the feed contained 28-30% crude protein, 5.6% crude lipid 14.23% crude ash and 9.5% moisture. The fingerlings were initially fed at 5% of their body weight, once a day at morning 9AM up to 1st two months and then reduce by 3% of its body weight at the last month. The major water quality parameter such as temperature, dissolved oxygen and pH were measured and recorded on weekly interval throughout the experimental period at 10AM by using Hanna Mixed Field Water test kit while the turbidity was recorded weekly using the Secchi Disk Measurement method. Fingerling of Mixed sex Nile Tilapia fish were brought from Mandal fish hatchery, Patthardada, Tilottama municipality, Rupandehi which is near to the research site. Fingerling containing poly bag was kept in pond for a week for Thawing, it helps to reduce mortality of fish from temperature fluctuation. During stocking of fry in cage it was about 12-17gm in average. In T1=10, T2=20, T3=30 and T4=40 fishes were stocked.

Fish were hand-fed with prepared pellet according to the total weight of the fish in each cage. Fish were fed once daily between 8:00-9:00 a.m. The first month fish were fed 5% of the body weight, the next two month with 3%. Each month, 30% of the total fish were seine netted from each cage to assess its growth performance. The weight was measured monthly by taking five sample fish from each cage randomly to measure weight with electric weighing machine (Kerro-series P3 BL5002 Max-500g, D=0.1g) at 30, 60 and 90 days after stocking. Monthly from each cage sample fish were collected by seine netting and its growth performance was assessed. Data were collected on length (cm) using measuring scale of 30cm size and weight (g) basis using electronic compact scale (Kerro-series P3 BL5002 Max-2000g, D=0.01g).

The growth parameters were calculated using following formula (Usandi *et al*., 2019).

- Specific Growth Rate (%):

$$\frac{[\log(\text{final weight})(\text{g})] - [\log(\text{initial weight})(\text{g})]}{\text{Time interval in days}} \times 100$$

- Survival Rate (%):

$$\frac{\text{Total number of fish havested}}{\text{Total number of fish stocked}} \times 100$$

- Daily weight gain(g/day) = (Mean Final weight – Mean Initial Weight) ×100 / Experimental Period
- Net Fish Yield (ha^{-1} yr^{-1}) = Harvest Weight (Kg)-Stocked Weight (Kg) ×10×365/culture area × Culture Period

Economic analysis of the experiment which was carried out for 90 days was carried out and the Total fixed cost, Total variable cost, Total cost Total return, Net return and Benefit cost ratio was calculated.

Mathematically,

Total Cost = Total fixed cost + Total Variable Cost

Gross Return = Total return obtained from the selling of Nile tilapia

Net Return = Gross Return – Total Cost

Benefit Cost Ratio = Total Benefit / Total cost

Data were managed and tabulated in Microsoft Excel 2013. The data analysis and graphical representation was done by using Microsoft Excel and R – Studio Software, Version: 2024.04.2+764.

3. RESULT AND DISCUSSION

The Initial mean weight (g), Final mean weight (g), Daily weight Gain (g), Specific Growth Rate (%) and Survivability of four different treatments are presented in Table 3.

Table 2: Growth performance of mixed sex Nile tilapia during experimental period of 90 days

Stocking density (No. of fish per m3)		Mean growth weight (g)		
	Initial mean weight 0 days	30 days	60 days	90 days
T1	11.31±0.45[a]	27.54±0.12[c]	55.60±0.82[a]	80.06±0.23[b]
T2	10.93±0.32[ab]	36.98±0.33[a]	60.46±0.13[a]	87.63±0.87[a]

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Table 2 (cont): Growth performance of mixed sex Nile tilapia during experimental period of 90 days				
T3	10.23±0.43^{ab}	33.02±0.47^{b}	52.61±0.62^{c}	77.93±0.53^{c}
T4	10.10±0.54^{b}	31.28±0.21^{b}	50.44±0.54^{d}	74.23±0.78^{d}
SEm (±)	0.286	1.95	2.16	2.82
LSD (=0.05)	0.694	2.07	1.49	1.42
CV (%)	3.465	3.42	1.44	0.95
Grand mean	10.64	32.20	54.78	79.96
F-test	0.114*	***	***	***

Note: Different lowercase letters on same column indicate statistically significant difference between treatments (p< 0.05), as performed by the least significant difference.

Table 3: Mean value of growth parameters and survivability of Nile Tilapia during experimental period of **90** days.

Treatment	Daily weight gain(g)	Final weight(g)	Total Production (kg/m3/yr)	Specific Growth Rate (SGR)	Survivability (%)
T1	0.77±0.02^{b}	80.06±0.23^{b}	1.92±0.43^{c}	0.80±0.02^{ab}	80.66±0.67^{b}
T2	0.84±0.06^{a}	87.63±0.87^{a}	6.30±0.81^{bc}	0.82±0.03^{a}	90.00±0.00^{a}
T3	0.75±0.01^{c}	77.93±0.53^{c}	6.85±0.93^{b}	0.79±0.05^{ab}	76.80±0.67^{ab}
T4	0.69±0.05^{d}	74.23±0.78^{d}	8.31±0.75^{a}	0.74±0.04^{b}	70.66±0.33b^{c}
SEm (+_)	0.03	2.82	0.935	0.013	6.29
LSD (0.05)	0.0134	1.42	3.05	0.023	14.46
Mean	0.77±0.04	79.96	5.345±0.35	0.78±0.03	74.16±0.33
CV (%)	0.92	7.08	30.31	1.55	10.35
F- Value	**	***	**	0.00184**	0.0084

Note: Different lowercase letters on same column indicate statistically significant difference between treatments (p< 0.05), as performed by the least significant difference.

Highest SGR was observed in T2 (0.93) which was significantly different with T1 (0.87), T3 (0.83) and T4 0.75) (p>0.05) and also T4 was significantly different with T1, T2, and T3 (p>0.05).

Gross return, Net return, benefit cost ratio and total variable cost involved in the production of fingerlings are shown in the table 5.

Table 4: Comparative economic analysis for each treatment on m^3 basic per harvest (values are given as NRs).

Variable Cost	T1	T2	T3	T4
Mixed sex Nile Tilapia	36.71±0.11^{c}	74.56±0.5^{b}	111.61±0^{ab}	151.43±0.5^{a}
Feed	22.56±1.69^{b}	40.14±1.57^{ab}	50.41±1.32^{ab}	69.40±1.23^{a}
Sub Total Variable Cost	59.27±1.34^{d}	114.70±1.03^{c}	162.02±1.32^{b}	220.83±0.6^{a}
Fixed Cost				
Cage Depreciation (20%)	12±0^{a}	12±0^{a}	12±0^{a}	12±0^{a}
Sub Total Fixed Cost	12±0^{a}	12±0^{a}	12±0^{a}	12±0^{a}
Total Cost	71.27±0.67^{c}	126.70±0.51^{ab}	174.02±0.66^{ab}	232.83±0.3^{a}
Gross Return				
Mixed sex Nile Tilapia	80.24±3.0^{d}	188.40±2.67^{c}	201.41±2.30^{b}	235.42±0.64^{a}
Total	80.24±3.0^{d}	188.40±2.67^{c}	201.41±2.30^{b}	235.42±0.64^{a}
Net Return	9.03±2.23^{bc}	61.70±2.61^{a}	27.35±1.64^{b}	2.59±0.34^{c}
BC	1.12±0.717^{a}	1.48±0.013^{a}	1.15±0.002^{a}	1.01 ±0.018^{a}

Mean and range of Temperature, dissolved oxygen and pH level of experimental site were measured daily and the mean and range are tabulated below.

Table 5: Mean and Range of water quality parameters measured daily during experimental period of 90 days.

Treatment	Parameters		
	pH	Dissolved Oxygen (mg/L)	Temperature (°C)
T1	7.15±0.17^{b}	6.23±0.22^{b}	29.76±0.95^{a}
T2	7.08±0.19^{b}	6.30±0.17^{b}	29.80±0.89^{a}
T3	7.32±0.23^{a}	6.17±0.27^{b}	29.78±0.87^{a}
T4	7.21±0.11^{ab}	6.49±0.16^{a}	29.70±0.85^{a}
LSD (0.05)	0.30	0.030	1.22
Mean	7.18	6.33	29.71
F-Value	2.01	2.14	2.02
CV (%)	5.28	0.43	5.21

3.1 Temperature

The obtained result is presented in the figure 2 below.

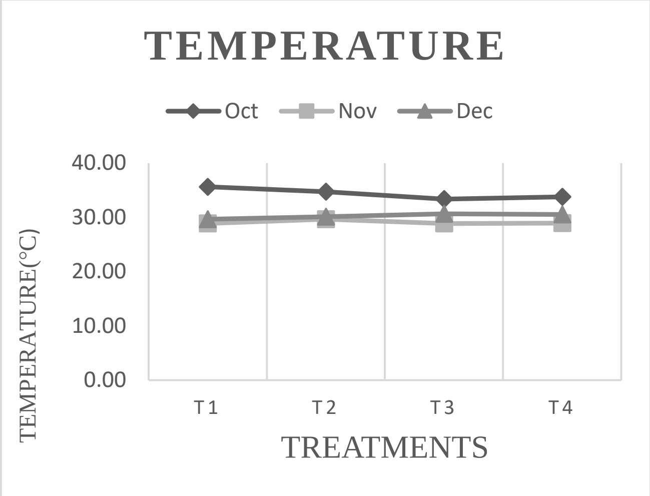

Figure 2: Monthly temperature variation during the experimental period of 90 days.

3.2 Dissolved oxygen (DO)

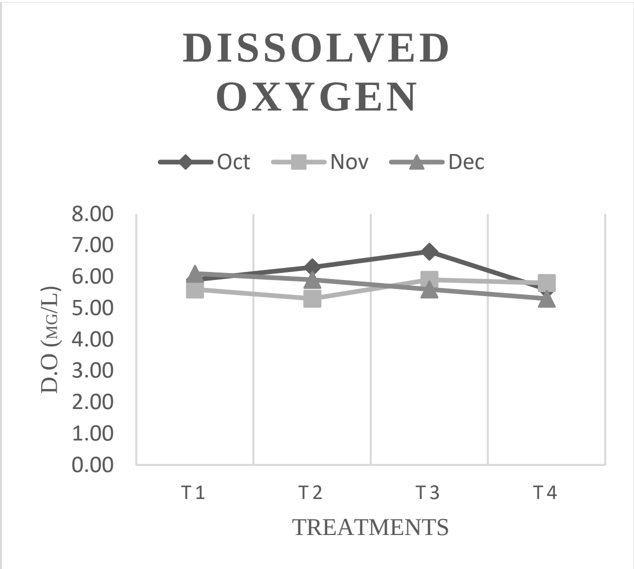

Figure 3: Monthly Dissolved Oxygen variation during the experimental period of 90 days.

Potential of Hydrogen (pH)

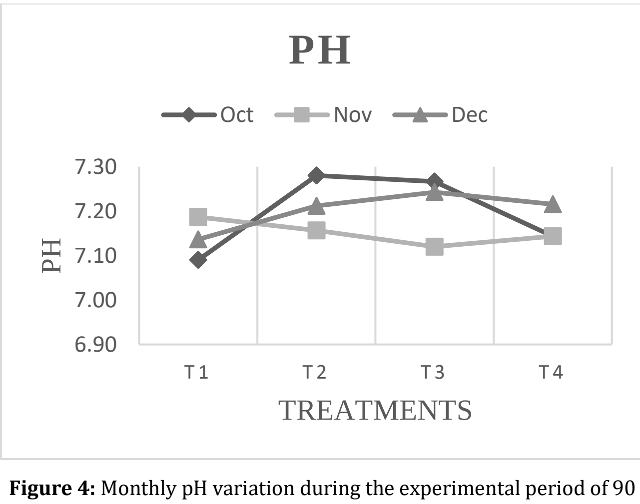

Figure 4: Monthly pH variation during the experimental period of 90 days.

4. Discussion

The mean of initial stocked weight of mixed sex Nile tilapia fingerlings in different treatment was 11.31g, 10.93g, 10.53g, 10.22g in T1, T2, T3, and T4 respectively which were not significantly different with each other ($p>0.05$). Total number of stock fingerlings were 10,20,30,40 in each cage of volume $1m^3$. At the 90 days after stocking mean weight of fish was highest in T2 (86.44g) which was significantly higher than T1 (79.64g), T3 (75.53g), T4 (70.11g) at ($p<0.05$). Likewise, Highest mean weight gain was recorded in T2 (76.32g) ($p<0.05$) which was significantly different with T1 (69.83g), T3 (67.80g) and T4 (59.36g) ($p>0.05$) and also T4 was significantly different with T1, T2, and T3. Similarly, Highest percentage weight gain was recorded in T1 (38.30g) ($p<0.05$) which was significantly different with T2 (33.76g), T3 (22.40g) and T4 (14.47g) ($p>0.05$) and also T4 was significantly different with T1, T2, and T3 but T2 and T3 were not significantly different with each other ($p>0.05$). Highest daily weight gain was recorded in T2 (0.84g) ($p<0.05$) which was significantly different with T1 (0.77g), T3 (0.75g) and T4 (0.70g) ($p>0.05$) and also T4 was significantly different with T1, T2, and T3($p>0.05$).

The highest total production was recorded in T4 (8.31±0.75g) ($p<0.05$) which was significantly different with T3 (6.85±0.93g), T2 (6.30. ±0.81) and T1(1.92±0.43) ($p>0.05$). Also, T1 was significantly different with T2 ($p>0.05$). The production data shows that T4 has the largest output (8.31±0.75g), exceeding the other treatments. This is a significant improvement from T1, which had the lowest production at 1.92±0.43g. The considerable difference between T4 and the other treatments, as well as T1 and T2, implies that higher stocking densities may result in enhanced production. However, the outcome may differ based on local factors such as water quality, feed availability, and management approaches (Rai and Shrestha, 2005).

Highest Specific Growth Rate (SGR) was observed in T2 (0.93) which was significantly different with T1 (0.87), T3 (0.83) and T4 0.75) ($p>0.05$) and also T4 was significantly different with T1, T2, and T3 ($p>0.05$). The specific growth rate (SGR) in this study was found to be highest in T2, followed by T1, which is consistent with the findings of Islam (2007), Alam (2009), and Masum (2012), who showed that higher SGR was observed in the Nile Tilapia diet with the lowest stocking density. There was a significant difference ($p < 0.05$) between the treatments. The variation in SGR values of mixed sex Nile tilapia in the current study could be attributed to regional temperature differences and the river's natural production. The third cause could be the initial size difference of the mixed-sex Nile tilapia employed in the tests, which is also supported by Sapkota et al. (2022).

Highest survival rate was recorded in T2 (90.00±2.36) ($p<0.05$) which was not significantly different with T1 (80.66 ±1.5), but significantly different with T3 (76.80±1.18) and T4 (70.67±0.94) ($p>0.05$) and also T3 was significantly different with T4 ($p>0.05$). Treatment T2 had the best survival rate (90.03%), whereas T4 had the lowest survival rate (70.66%). There was a significant difference ($P\geq0.05$) across the different treatments, which was within the ideal range determined by Wagle et al (2016). The survival rate of fish among diet groups ranged from 81.3% to 94.3%. Hassan (2007) and Masum (2012) found similar survival rates in Nile tilapia, ranging from 79.44% to 89.83% and 84 to 92%, respectively. Various stocking densities were found to have a deleterious effect on survival rate. Low stocking densities result in the maximum survivability. This is due to less competition for food and space among fish, as well as lower ammonia output.

During the experimental period of 90 days, the mean temperature was found to be 29.73 ºC. Similarly, mean dissolved oxygen was found to be 6.33 mg/l and the mean pH range was 7.18 during the experimental period. According to the research conducted by (Syafi'i, 2017) condition of water quality parameters were similar to the result obtained from this result, namely the temperature 29.73-29.78 ºC. The dissolved oxygen was 6.33-6.86mg/l and the pH were 6.38 to 6.72.

Water quality during the experimental period was found at desired level. Parameters like temperature, pH, dissolved oxygen, were not significantly different ($p>0.05$) among various treatments. The results of the water quality parameters were found within acceptable range of fish culture and all of them were more or less similar without any abrupt changes in any parameters of the river. No significant difference in mean temperature (°C), water dissolve oxygen (mg/L), pH, ammonia (mg/L), and nitrate (mg/L) was observed at different feed level in different treatments which signifies there is no role of diet level on water quality parameters of the system. According to Ghanbari et al. (2010), Mallya (2007), Wuchter et al. (2006), Koltia et al. (2002), Islam et al. (2022), Schram et al. (2018), and Sachar and Raina (2014), all water quality parameters were within the ideal range. Water quality affects the overall health and growth of farmed fish. Temperature, suspended particles, dissolved oxygen, nitrite, ammonia, alkalinity, and CO2 are all important parameters (Timmonsand and Ebeling, 2010). The trend of the dissolved oxygen level is in increasing order which is due to the decrease in the temperature of the water as the research progress as the dissolved oxygen of the water is inversely proportional to the water temperature. The increasing pH range as the research progress is due to the decrease in the temperature as the water temperature and pH are inversely proportional to each other. There were no sudden changes in any of the ponds' parameters, and the results of the water quality metrics were all within an acceptable range for fish culture.

5. Summary and Conclusion

When Nile tilapia is raised in natural river circumstances, a variety of factors might affect their growth and performance. Studies on mixed-sex Nile tilapia grown in natural river environments have found that stocking density is crucial in determining growth performance and overall fish health. In these natural settings, a variety of treatments with varying stocking densities—from low to high—are used to see how tilapia respond in terms of growth rates, survival, and overall productivity. The natural changes in water quality parameters like as temperature, dissolved oxygen, and pH have a substantial impact on these results. Natural rivers typically provide a dynamic environment with greater dissolved oxygen levels due to constant water movement, resulting in generally favorable circumstances for fish growth. In terms of growth performance, research have repeatedly shown that lower stocking densities lead to higher individual weight gain and specific growth rates (Alam, M.N., 2009). Fish in these settings have less competition for food and room, so they can develop more efficiently. Higher stocking densities, on the other hand, tend to diminish individual weight gain and SGR due to greater competition for limited resources such as food and space, which can lead to increased stress and potentially higher death rates (Kunda, M. and Pandit, D.,2021).

Survival rates in these natural river studies are generally high across all treatments, with decreased mortality shown at low and medium stocking volumes. This is due to decreased competition and stress among the fish. However, high stocking densities, despite increasing total production due to the increased quantity of fish, frequently result in poorer individual development rates (Akongyuure, D.N., 2015). The recommended stocking density for mixed-sex Nile tilapia in natural river habitats ranges from low to medium. These densities strike the optimal compromise between individual growth performance and overall production, ensuring that fish are healthy and growing effectively. High stocking densities should be used with caution due to the potential negative effects on individual fish growth and health (Hassan, S.J., 2007).

Similarly, a study comparing the growth performance of mixed-sex and mono-sex Nile tilapia in cage culture discovered that lower stocking densities resulted in higher individual growth rates and specific growth rates (SGR) due to reduced competition for resources (Chakraborty, S. B., and Banerjee, S., 2010). In contrast, higher stocking densities resulted in decreased individual growth but improved total production due to the larger number of fish stocked (Githuikia, C.M., 2015).

Another study on the effect of stocking density on the growth performance of Nile tilapia in a cage culture system in Lake Kuriftu, Ethiopia, discovered a negative relationship between stocking density and growth rate (El-shaidy, 2015). Higher densities resulted in poorer growth performance and survival rates, demonstrating the stress and competition that fish face in crowded environments (Chakraborty, B.K., 2009). Furthermore, study comparing the performance of mixed-sex and hormonally-reversed Nile tilapia found that optimizing stocking densities could reduce uncontrolled breeding and precocious maturity in mixed-sex tilapia. This strategy strikes a balance between high output and maintaining individual fish health and growth rates (Kembenya, E.M., and Ondiba, R.N., 2021).

Feed conversion ratio and benefit cost ratio is an important parameter in fish culture as it has direct effect on production and economic return of fish. In the above research, it was found that the feed conversion ratio was recorded lowest in T2 which was significantly different with T1, T2 and T4 ($p<0.05$). The gross return was found highest in T4 (235.42 ± 0.64^{c}) which was significantly different to T1, T2 and T3 ($p< 0.05$). The net return was found highest in T2 (61.70) which was significantly different to T1 and T4(2.59 ± 0.34) ($p<0.05$). T4 was also found significantly different to T1, T3 (27.35 ± 2.61) and T3 ($p< 0.05$). Highest BCR was recorded in T2 (1.48 ± 0.013) which was significantly different with T1, T3 and T4 ($p<0.05$). Thongprajukaew (2017) claimed that Nile tilapia has several features that make it suitable for aquaculture, including fast growth rates and high-quality fillets, tolerance to environmental conditions, and the ability to endure stress caused by handling.

Overall, these data highlight the need of controlling stocking numbers in mixed-sex Nile tilapia culture to maximize both individual growth performance and total production. Lower to medium densities are generally advised for optimal growth results while maintaining good survival rates and overall fish health.

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