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## Effect of millet-based Biofloc with Jeevamruth on water quality, growth, and crop productivity in an integrated fish-horticultural model

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### Abstract

This study evaluated the synergistic integration of Biofloc Technology (BFT) and natural farming input (Jeevamruth) under an integrated fish cum horticulture model using *Labeo rohita* and cluster bean (*Cyamopsis tetragonoloba*). Millet (*Pennisetum glaucum*) was used as a sustainable carbon source to maintain a 20:1 C:N ratio in biofloc systems. Treatments were tested under a completely randomized design: conventional culture (Control), BFT with millet (T<sub>1</sub>), and a combined treatment (T<sub>2</sub>: BFT + Jeevamruth 0.5%). Water quality parameters, fish growth indices, plant biomass were analyzed over 60 days. The combined treatment (T<sub>2</sub>) recorded the highest improvements in dissolved oxygen (6.4±0.3 mg/L), lowest ammonia (0.18±0.02 mg/L), and superior fish growth performance (SGR 1.38%, FCR 0.92). Cluster bean biomass increased by 31% over control, while system profitability improved by 28%. The results indicate a synergistic enhancement in nutrient cycling, microbial activity, and productivity, demonstrating the potential of millet-based biofloc and Jeevamruth integration as a sustainable circular aquaculture model.

**Keywords:** Biofloc technology, Jeevamruth, Integrated fish-horticulture system, *Labeo rohita*, *Cyamopsis tetragonoloba*

### Introduction

Aquaculture plays a crucial role in global food security and rural livelihoods, accounting for more than 50% of the fish consumed worldwide (FAO, 2024) [13]. Global aquaculture production reached 94.4 million tonnes in 2022, highlighting its rapid expansion as a sustainable source of animal protein (FAO, 2024) [13]. However, conventional aquaculture practices are challenged by water quality deterioration, feed inefficiency, and nutrient-rich effluent discharge, which can result in environmental degradation and increased production costs (Boyd *et al.*, 2022; Edwards, 2015) [32, 12]. To address these issues, researchers and practitioners have increasingly explored bio-integrated and circular farming systems that recycle nutrients between aquatic and terrestrial components to enhance sustainability and reduce waste (Ghaly *et al.*, 2005; Lal *et al.*, 2023) [16, 33]. Among innovative approaches, Biofloc Technology (BFT) has emerged as a promising low-input aquaculture system that maintains water quality through the microbial conversion of inorganic nitrogenous wastes into microbial biomass, which can be reutilized by cultured species (Avnimelech, 1999; Hargreaves, 2013) [5, 17]. The efficiency of BFT is primarily determined by the carbon-to-nitrogen (C: N) ratio, commonly maintained around 15:1-20:1 by supplementing external carbon sources such as molasses, wheat bran, tapioca, or rice flour (Crab *et al.*, 2012; Pérez-Fuentes *et al.*, 2016) [9, 29]. These carbon inputs stimulate heterotrophic bacterial growth, reducing ammonia and improving feed conversion efficiency. However, many commercial carbon sources are either imported or costly, limiting their large-scale use in rural aquaculture.

To address this, locally available millets (*Pennisetum glaucum*) rich in starch, carbohydrates, and micronutrients offer a potential sustainable carbon source alternative for BFT. Millets

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have a carbohydrate content of 60-70%, with a slower degradation rate that supports gradual microbial assimilation (Lukiwati *et al.*, 2018) [25]. Incorporating agricultural by-products such as millet in BFT can reduce costs, enhance circularity, and support rural farming integration. Although a few studies have examined alternative carbon sources like cassava or wheat bran, research on millet-based biofloc systems remains scarce.

Parallel to technological innovations like BFT, India has seen rapid adoption of Zero Budget Natural Farming (ZBNF) practices, which emphasize microbial enrichment and reduced chemical dependency. A key component of this system is Jeevamruth a traditional fermented microbial inoculant prepared from cow dung, cow urine, jaggery, pulse flour, and native soil. Studies have reported that Jeevamruth enhances soil microbial diversity, increases enzymatic activity, and improves plant nutrient uptake and yield (Sharma *et al.*, 2020) [30]. The formulation provides beneficial microorganisms such as *Azotobacter*, *Rhizobium*, *Bacillus*, and *Pseudomonas* spp., contributing to nitrogen fixation, phosphate solubilization, and overall nutrient cycling. However, the application of Jeevamruth in aquaculture systems particularly in combination with biofloc microbial processes remains underexplored.

Integrating biofloc systems and Jeevamruth-based natural inputs within an aquaculture horticulture framework may strengthen ecological efficiency by recycling organic nutrients across fish and crop components. In such models, nutrient-rich aquaculture effluents can be utilized for crop irrigation, while plants act as biofilters reducing nutrient accumulation in water (Hu *et al.*, 2022) [19]. This circular approach supports the "One Water, One Resource" concept, optimizing input use and reducing environmental footprints.

## Materials and Methods

The study was conducted at the College of Fisheries Science (CoFS), Kamdhenu University, Rajpur (Nava), Himmatnagar, Gujarat, India. All aquaculture experiments were performed in the wet-laboratory facility, while water quality analyses were carried out in the Soil and Water Chemistry Laboratory. The experiment lasted 60 days (March-May, 2025). A Completely Randomized Design (CRD) was used comprising one control and four treatments, each in triplicate. Each 1000-L FRP tank was hydraulically connected to three respective horticulture plots to enable nutrient transfer for the integrated fish-horticulture model.

Healthy *Labeo rohita* (rohu) fingerlings ( $8.8 \pm 0.2$  g) were procured from the Department of Aquaculture, CoFS, Kamdhenu University. Fish were disinfected in 0.05% KMnO<sub>4</sub> for 2 min and acclimatized for two months under laboratory conditions. Fish were stocked at 1 g L<sup>-1</sup> density (approximately 500 fish tank<sup>-1</sup>) and maintained under continuous aeration. Tanks were filled with bore-well water (previously quality tested), and water losses were compensated daily. The control received a 10% water exchange per day; all other treatments were operated as zero-water-exchange biofloc systems. Fish were fed a commercial floating feed containing 32% crude protein twice daily at 5% body weight day<sup>-1</sup> for the first 20 days.

Biofloc was prepared following Avnimelech (1999) [5] and Hargreaves (2013) [17]. Tanks were filled to 500 L, aerated for 5 days, and inoculated with a commercial probiotic mixture (5 g tank<sup>-1</sup>). Millet flour was used as a carbon

source containing approximately 64% C (Lukiwati *et al.*, 2018) [25]. The C:N ratio was adjusted to 20:1 by adding ~100 g millet tank<sup>-1</sup> day<sup>-1</sup>, calculated from the protein content (32%) of feed assuming 16% N in protein and 75% feed waste contribution. Floc maturity was confirmed when floc volume reached 10-15 mL L<sup>-1</sup> and total ammonia nitrogen < 0.5 mg L<sup>-1</sup>, measured with Imhoff cones and spectrophotometric tests (Avnimelech & Kochba, 2009) [6].

Jeevamruth was prepared per the NITI Aayog (2019) formulation: 2 kg cow dung, 1 L cow urine, 400 g jaggery, 400 g pulse flour, 200 g native soil, 10 g lime, and water up to 40 L. The mixture was fermented aerobically for 7 days with daily stirring and then filtered through cloth. The filtrate was applied to treatment tanks at 0.5% (T<sub>2</sub>) and 1% (T<sub>3</sub>) concentrations every 10 days; the combined treatment (T<sub>4</sub>) received 0.5% Jeevamruth along with millet-based biofloc.

A 200 m<sup>2</sup> field adjacent to the aquaculture setup was divided into 15 plots (3 replicates treatment<sup>-1</sup>). Cluster bean (*Cyamopsis tetragonoloba*) was grown as the test crop. Each plot was irrigated with corresponding aquaculture effluents through a mild-slope pipeline system ensuring gravitational flow.

Physico-chemical parameters were measured every 10 days using standard methods (APHA, 1998) [4]. Soil samples were collected pre- and post-experiment from 0-15 cm depth using a zig-zag pattern, composited, air-dried, and analyzed for pH, EC, and N-P-K status (Jackson, 1973) [20]. Every 20 days, 15 fish tanks<sup>-1</sup> were sampled to determine growth indices.

All data were subjected to One-way ANOVA using SPSS v26, and mean differences were evaluated by Tukey's HSD at  $p < 0.05$ . Results are presented as mean  $\pm$  standard error.

## Literature Review

### Millet-Based Biofloc Technology in Aquaculture Systems

Liu *et al.* (2019) [24] studied the application of biofloc technology (BFT) in freshwater pond aquaculture systems with the objectives of enhancing fish yield and improving water quality via microbial processes. Their research included three experimental treatments that used different carbon sources to stimulate floc formation and tracked ammonia, nitrite and fish growth over 60 days. Total ammonia nitrogen (TAN) levels in BFT ponds were consistently lower than 0.5 mg/L, compared to 1.3 mg/L in control ponds. Due to better waste stability and nutrient recycling, biofloc treatments increased fish production by 25-33%. Microbial analysis revealed significant enrichment of heterotrophic bacteria involved in nitrogen uptake and floc stability. The authors concluded that BFT facilitates ecological intensification by improving nutrient retention and lowering water exchange requirements.

Studied the impact of different C:N ratios on water quality, growth performance, digestive activity, and antioxidant markers in tilapia fingerlings within BFT systems. In comparison to the control group, three biofloc treatments (with the addition of molasses) featuring C:N ratios of 14, 17, and 20 (referred to as BFT<sub>14</sub>, BFT<sub>17</sub>, and BFT<sub>20</sub>, respectively) were tested against the control group (clear water). As the C:N ratio increased from 14 to 20, the dynamics of water quality revealed a transition from a primarily autotrophic biofloc to one that was more heterotrophic. Importantly, there were no significant differences in tilapia growth or feed conversion ratio

between the control, BFT<sub>14</sub> and BFT<sub>17</sub> groups. The results indicated that lowering the C:N ratio to 14 had no significant impact on biofloc formation, growth performance, or the physiological parameters of juvenile tilapia, showing the possibility for optimization within the aquaculture system.

Khanjani (2021) evaluated how different carbon sources affected water quality, biofloc composition and growth performance of Nile tilapia (*Oreochromis niloticus*). The experiment consisted of a control group (no carbon source added) and four biofloc treatments, each supplemented with different carbon sources: molasses (TM), starch (TS), barley flour (TB), and corn (TC), with three replications for each treatment. The TS treatment produced in the lowest dissolved oxygen (DO) levels (5.43 mg/l) and pH (7.28). The study found that diverse carbon sources significantly influence the biochemical properties of biofloc. Specifically, the TS treatment produced the largest biofloc size. The study concluded that different carbon sources in biofloc systems have distinct effects on water quality, the biochemical composition of biofloc, and biofloc size in culture tanks.

To achieve an optimal carbon to nitrogen ratio of 15:1 to 20:1 for the proliferation of heterotrophic bacteria within a biofloc system, it is critical to incorporate a source rich in organic carbon. Both carbon and nitrogen are required substrates for the bio-flocculation process; however, nitrogen can be acquired directly from the culture water, which is easily available for usage (Avnimelech, 1999) <sup>[5]</sup>. Organic carbon-rich sources include sugar, starch, cellulose, glucose, acetate, glycerol, and wheat flour. These carbon sources are characterized by their rapid degradation, which occurs within period of minutes to hours, and includes alcohols, sugars, starches, and fibres.

Carried out a 90-day study to explore the impact of biofloc generated from various carbon sources on the growth performance, survival rates, and body indices of *Pangasianodon hypophthalmus* fingerlings. The study utilized different carbon sources, such as tapioca, sorghum, pearl millet, and finger millet. The group that utilized finger millet as a carbon source demonstrated significantly enhanced weight gain, specific growth rate (SGR), feed efficiency ratio (FER), protein efficiency ratio (PER), and a reduced feed conversion ratio (FCR) in comparison to the control group (CW). The results of the research indicate that finger millet may serve as an excellent carbon source for biofloc systems.

**Jeevamruth and Its Role in Soil and Plant Health**

Sugumaran *et al.* (2024) <sup>[34]</sup> investigated the synergistic effects of Jeevamruth and Panchagavya in organic vegetable cultivation. The research focused on marigold (*Tagetes erecta*) and fenugreek (*Trigonella foenum-graecum*), comparing microbial activity, plant growth, and soil nutritional status between treatments. Jeevamruth application enhanced shoot biomass by 32% and root length by 18% over untreated controls. Carbon in soil microbial biomass increased by 41%, whereas nitrogen availability increased by 23%. Microbial isolates demonstrated considerable antagonistic activity against plant pathogens like *Fusarium* and *Rhizoctonia*. The study concluded that Jeevamruth serves not only as a nutrient source but also as a microbial inoculant that enhances rhizosphere resilience.

Amareswari and Sujathamma (2014) conducted a field study to determine the performance of Jeevamruth, a natural liquid fertilizer, as an substitute for chemical fertilizers in rice cultivation. The experiment was carried out at Kothavaripalli village, Andhra Pradesh, for three successive kharif and rabi seasons from 2007 to 2009. Two rice varieties Masura and Hamsa. Jeevamruth, which was made of native cow dung, urine, horse gram, jaggery, and water, was applied fortnightly with irrigation and used as a foliar spray. The results showed that, whereas chemical farming yielded somewhat more than Jeevamruth in Masura (3.0 vs. 2.775 tons/acre), Jeevamruth yielded better in Hamsa (2.625 vs. 2.5 tons/acre). Jeevamruth reduced the cost of cultivation by 18% for Masura and 19% for Hmasa. The benefit-cost ratio favored Jeevamruth: 3.39 for Masura and 1.09 for Hamsa, compared to 3.0 and 0.6 with chemical farming. In conclusion, Jeevamruth not only produced comparable or better yield, but it was also more cost-effective and environmentally sustain

**Sustainable Intensification and Resource Optimization**

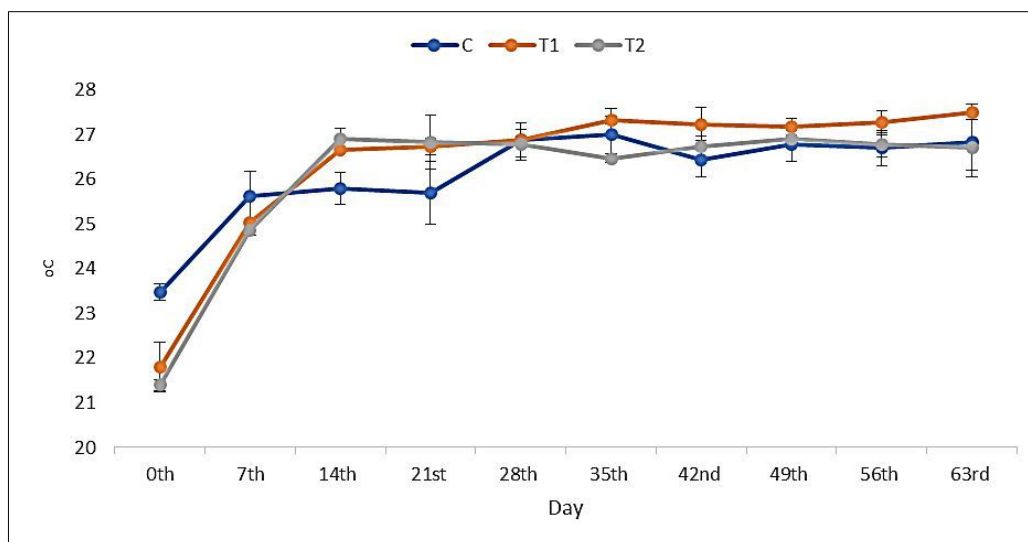
Al-Wabel *et al.* (2024) <sup>[39]</sup> evaluated the use of aquaculture wastewater to irrigate date palms and its effects on soil health, nutrient uptake, and fruit quality in arid ecosystems. Their field trial involved applying untreated aquaculture effluent to palm plantations over 90 days. Results showed a 28% increase in available nitrogen and a 34% rise in phosphorus in soil samples. Date palm fruit quality improved significantly, with increases in Brix value (17.6 to 20.4%) and potassium content. Importantly, microbial biomass carbon increased by 45%, indicating enhancement in soil microbial activity. The authors concluded that aquaculture effluent, when applied correctly, aquaculture effluent can replace synthetic fertilizers in fruit-based agroecosystems while improving long-term soil fertility.

Performed a systems-level analysis on a Hawaiian integrated aquaculture-agriculture system in which estuary fishponds fed taro plots. The researchers monitored nutrient flows and found that aquaculture effluent contributed over 60% of nitrogen and 40% of phosphorus needed for taro growth. Crop yield improved by 22% compared to freshwater irrigation controls. Additionally, runoff nitrogen was reduced by 35%, demonstrating effective nutrient uptake by the root system. The study concluded that integrating fish and agriculture systems not only boosts productivity but also reduces nutrient leakage into surrounding ecosystems.

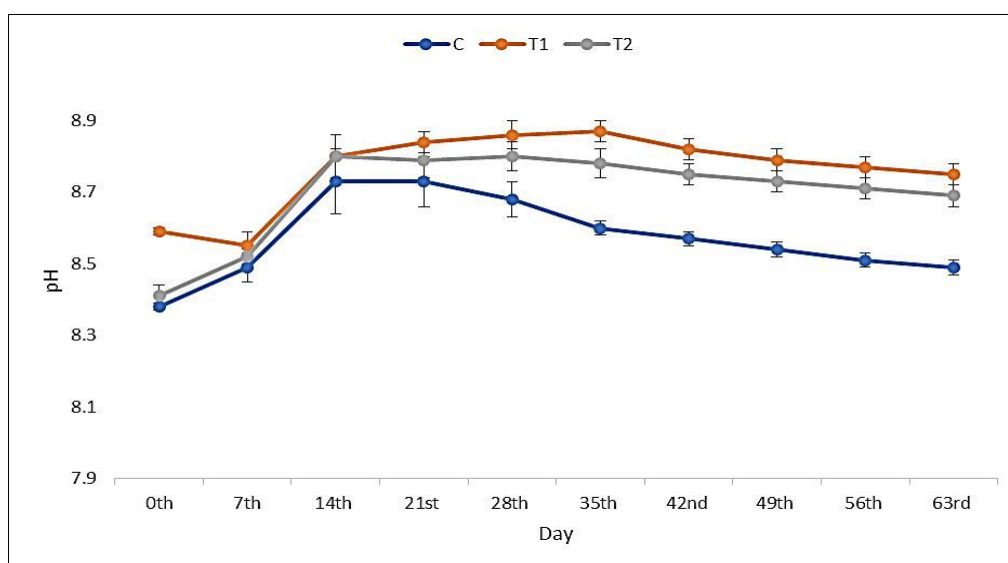
**Analysis**  
**Impacts on Water Quality Parameters**

**Table 1:** Average Temperature Value Recorded During the Experiment.

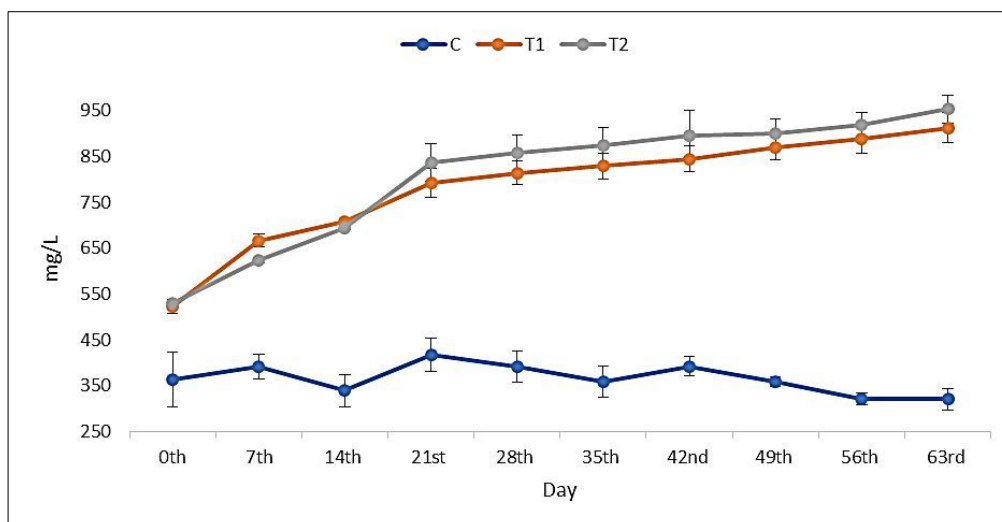
| Temperature          |                         |                         |                         |
|----------------------|-------------------------|-------------------------|-------------------------|
| Treatment            | C                       | T <sub>1</sub>          | T <sub>2</sub>          |
| 0 <sup>th</sup> day  | 23.47±0.19 <sup>a</sup> | 21.80±0.55 <sup>c</sup> | 21.40±0.12 <sup>c</sup> |
| 7 <sup>th</sup> day  | 25.63±0.55 <sup>A</sup> | 25.03±0.03 <sup>A</sup> | 24.87±0.12 <sup>A</sup> |
| 14 <sup>th</sup> day | 25.80±0.36 <sup>p</sup> | 26.67±0.03 <sup>p</sup> | 26.90±0.25 <sup>p</sup> |
| 21 <sup>st</sup> day | 25.70±0.70 <sup>S</sup> | 26.73±0.18 <sup>S</sup> | 26.83±0.60 <sup>S</sup> |
| 28 <sup>th</sup> day | 26.87±0.38 <sup>d</sup> | 26.87±0.09 <sup>d</sup> | 26.77±0.34 <sup>d</sup> |
| 35 <sup>th</sup> day | 27.00±0.58 <sup>R</sup> | 27.33±0.09 <sup>R</sup> | 26.47±0.09 <sup>R</sup> |
| 42 <sup>nd</sup> day | 26.43±0.37 <sup>k</sup> | 27.23±0.37 <sup>k</sup> | 26.73±0.24 <sup>k</sup> |
| 49 <sup>th</sup> day | 26.77±0.38 <sup>Y</sup> | 27.17±0.19 <sup>Y</sup> | 26.90±0.20 <sup>Y</sup> |
| 56 <sup>th</sup> day | 26.70±0.40 <sup>B</sup> | 27.27±0.27 <sup>B</sup> | 26.77±0.28 <sup>B</sup> |
| 63 <sup>rd</sup> day | 26.83±0.64 <sup>m</sup> | 27.50±0.17 <sup>m</sup> | 26.70±0.64 <sup>m</sup> |

**Table 2:** Average pH Value Recorded during Experiment Period.

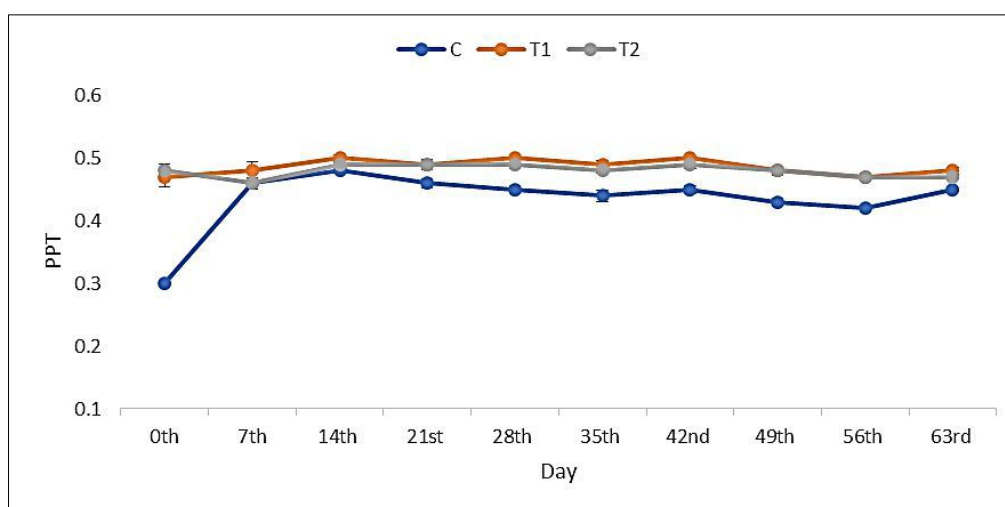
| pH                   |                         |                         |                         |
|----------------------|-------------------------|-------------------------|-------------------------|
| Treatment            | C                       | T <sub>1</sub>          | T <sub>2</sub>          |
| 0 <sup>th</sup> day  | 8.38±0.01 <sup>ab</sup> | 8.59±0.01 <sup>a</sup>  | 8.41±0.03 <sup>a</sup>  |
| 7 <sup>th</sup> day  | 8.49±0.04 <sup>A</sup>  | 8.55±0.04 <sup>A</sup>  | 8.52±0.02 <sup>A</sup>  |
| 14 <sup>th</sup> day | 8.73±0.09 <sup>q</sup>  | 8.80±0.06 <sup>pq</sup> | 8.80±0.06 <sup>pq</sup> |
| 21 <sup>st</sup> day | 8.73±0.07 <sup>P</sup>  | 8.84±0.03 <sup>P</sup>  | 8.79±0.05 <sup>P</sup>  |
| 28 <sup>th</sup> day | 8.68±0.05 <sup>e</sup>  | 8.86±0.04 <sup>d</sup>  | 8.80±0.04 <sup>de</sup> |
| 35 <sup>th</sup> day | 8.60±0.02 <sup>T</sup>  | 8.87±0.03 <sup>S</sup>  | 8.78±0.04 <sup>S</sup>  |
| 42 <sup>nd</sup> day | 8.57±0.02 <sup>n</sup>  | 8.82±0.03 <sup>m</sup>  | 8.75±0.03 <sup>m</sup>  |
| 49 <sup>th</sup> day | 8.54±0.02 <sup>V</sup>  | 8.79±0.03 <sup>U</sup>  | 8.73±0.03 <sup>U</sup>  |
| 56 <sup>th</sup> day | 8.51±0.02 <sup>z</sup>  | 8.77±0.03 <sup>y</sup>  | 8.71±0.03 <sup>y</sup>  |
| 63 <sup>rd</sup> day | 8.49±0.02 <sup>E</sup>  | 8.75±0.03 <sup>D</sup>  | 8.69±0.03 <sup>D</sup>  |

**Table 3:** Average TDS Value Recorded During Experiment Period.

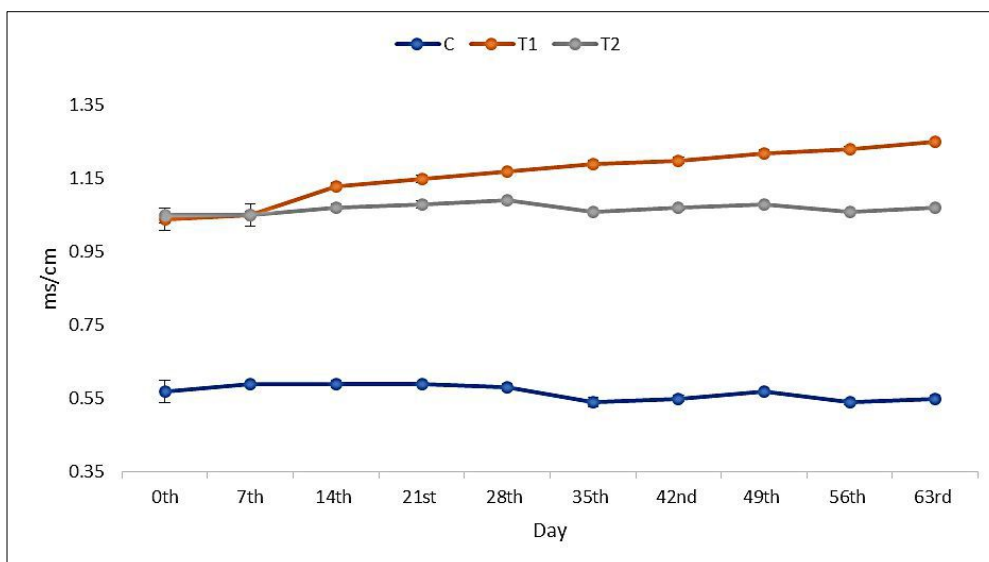
| TDS                  |                           |                                       |                           |
|----------------------|---------------------------|---------------------------------------|---------------------------|
| Treatment            | C                         | T <sub>1</sub>                        | T <sub>2</sub>            |
| 0 <sup>th</sup> day  | 363.08±59.67 <sup>b</sup> | 522.13±15.72 <sup>a</sup>             | 529.03±9.22 <sup>a</sup>  |
| 7 <sup>th</sup> day  | 392.18±27.11 <sup>B</sup> | 666.63±13.62 <sup>A</sup>             | 623.80±5.95 <sup>A</sup>  |
| 14 <sup>th</sup> day | 339.16±34.64 <sup>q</sup> | 709.00±6.03 <sup>p</sup>              | 694.33±4.33 <sup>p</sup>  |
| 21 <sup>st</sup> day | 416.86±36.38 <sup>U</sup> | 792.36±30.80 <sup>S<sup>T</sup></sup> | 837.36±41.44 <sup>S</sup> |
| 28 <sup>th</sup> day | 391.50±33.92 <sup>g</sup> | 814.73±25.21 <sup>d</sup>             | 858.76±38.98 <sup>d</sup> |
| 35 <sup>th</sup> day | 357.85±34.38 <sup>4</sup> | 829.13±27.36 <sup>2</sup>             | 874.66±38.56 <sup>l</sup> |
| 42 <sup>nd</sup> day | 392.32±20.57 <sup>n</sup> | 845.10±28.92 <sup>k</sup>             | 895.50±55.02 <sup>k</sup> |
| 49 <sup>th</sup> day | 358.68±9.58 <sup>O</sup>  | 869.03±26.94 <sup>M</sup>             | 900.63±30.45 <sup>M</sup> |
| 56 <sup>th</sup> day | 321.20±13.68 <sup>E</sup> | 888.76±31.19 <sup>C</sup>             | 920.23±26.54 <sup>C</sup> |
| 63 <sup>rd</sup> day | 320.42±22.89 <sup>l</sup> | 913.06±33.57 <sup>G</sup>             | 953.46±30.59 <sup>G</sup> |

**Table 4:** Average Salinity Value Recorded During Experiment Period.

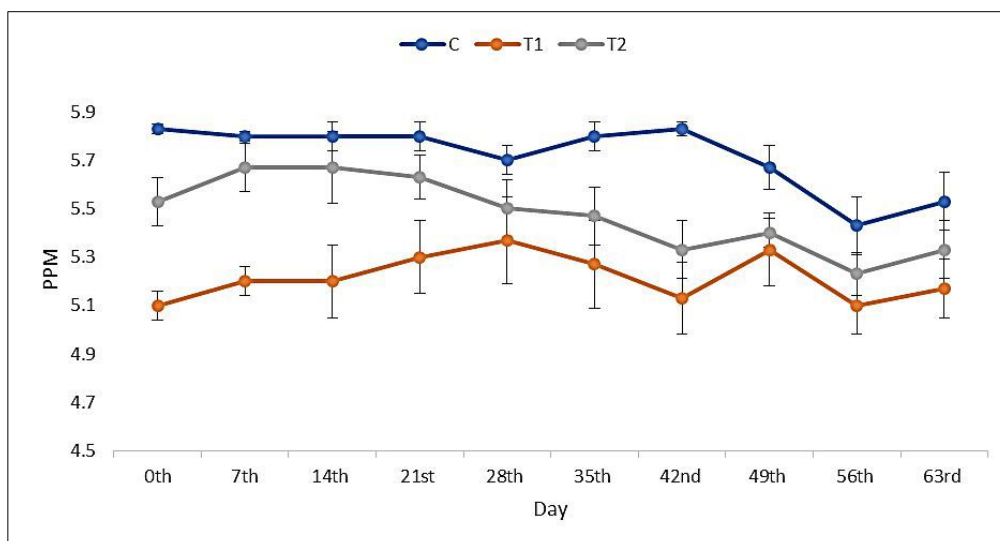
| Treatment            | Salinity                |                         |                          |
|----------------------|-------------------------|-------------------------|--------------------------|
|                      | C                       | T <sub>1</sub>          | T <sub>2</sub>           |
| 0 <sup>th</sup> day  | 0.30±0.004 <sup>b</sup> | 0.47±0.015 <sup>a</sup> | 0.48±0.010 <sup>a</sup>  |
| 7 <sup>th</sup> day  | 0.46±0.003 <sup>A</sup> | 0.48±0.015 <sup>A</sup> | 0.46±0.009 <sup>A</sup>  |
| 14 <sup>th</sup> day | 0.48±0.003 <sup>P</sup> | 0.50±0.006 <sup>P</sup> | 0.49±0.003 <sup>P</sup>  |
| 21 <sup>st</sup> day | 0.46±0.007 <sup>Q</sup> | 0.49±0.007 <sup>P</sup> | 0.49±0.009 <sup>PQ</sup> |
| 28 <sup>th</sup> day | 0.45±0.006 <sup>T</sup> | 0.50±0.006 <sup>S</sup> | 0.49±0.006 <sup>S</sup>  |
| 35 <sup>th</sup> day | 0.44±0.009 <sup>I</sup> | 0.49±0.006 <sup>S</sup> | 0.48±0.003 <sup>s</sup>  |
| 42 <sup>nd</sup> day | 0.45±0.006 <sup>V</sup> | 0.50±0.003 <sup>U</sup> | 0.49±0.006 <sup>U</sup>  |
| 49 <sup>th</sup> day | 0.43±0.006 <sup>Z</sup> | 0.48±0.006 <sup>y</sup> | 0.48±0.007 <sup>y</sup>  |
| 56 <sup>th</sup> day | 0.42±0.006 <sup>N</sup> | 0.47±0.006 <sup>M</sup> | 0.47±0.006 <sup>M</sup>  |
| 63 <sup>rd</sup> day | 0.45±0.003 <sup>I</sup> | 0.48±0.006 <sup>K</sup> | 0.47±0.003 <sup>K</sup>  |

**Table 5:** Average Conductivity Value Recorded During Experiment Period.

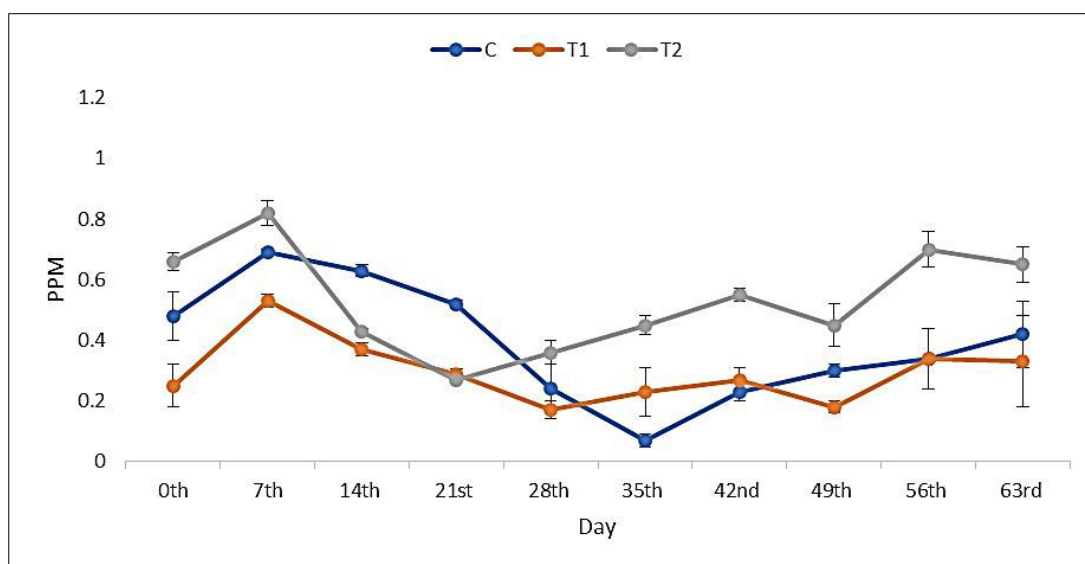
| Treatment            | Conductivity            |                         |                         |
|----------------------|-------------------------|-------------------------|-------------------------|
|                      | C                       | T <sub>1</sub>          | T <sub>2</sub>          |
| 0 <sup>th</sup> day  | 0.57±0.03 <sup>b</sup>  | 1.04±0.03 <sup>a</sup>  | 1.05±0.02 <sup>a</sup>  |
| 7 <sup>th</sup> day  | 0.59±0.004 <sup>B</sup> | 1.05±0.03 <sup>A</sup>  | 1.03±0.01 <sup>A</sup>  |
| 14 <sup>th</sup> day | 0.59±0.01 <sup>r</sup>  | 1.13±0.01 <sup>P</sup>  | 1.08±0.01 <sup>q</sup>  |
| 21 <sup>st</sup> day | 0.59±0.004 <sup>V</sup> | 1.15±0.01 <sup>S</sup>  | 1.10±0.01 <sup>T</sup>  |
| 28 <sup>th</sup> day | 0.58±0.01 <sup>g</sup>  | 1.17±0.007 <sup>d</sup> | 1.11±0.009 <sup>e</sup> |
| 35 <sup>th</sup> day | 0.54±0.01 <sup>4</sup>  | 1.19±0.01 <sup>1</sup>  | 1.08±0.004 <sup>2</sup> |
| 42 <sup>nd</sup> day | 0.55±0.008 <sup>n</sup> | 1.20±0.008 <sup>k</sup> | 1.09±0.006 <sup>l</sup> |
| 49 <sup>th</sup> day | 0.57±0.006 <sup>P</sup> | 1.22±0.008 <sup>M</sup> | 1.11±0.007 <sup>N</sup> |
| 56 <sup>th</sup> day | 0.54±0.007 <sup>F</sup> | 1.23±0.008 <sup>C</sup> | 1.07±0.005 <sup>D</sup> |
| 63 <sup>rd</sup> day | 0.55±0.008 <sup>J</sup> | 1.25±0.007 <sup>G</sup> | 1.08±0.004 <sup>H</sup> |

**Table 6:** Average Dissolve Oxygen Value Recorded During Experiment Period.

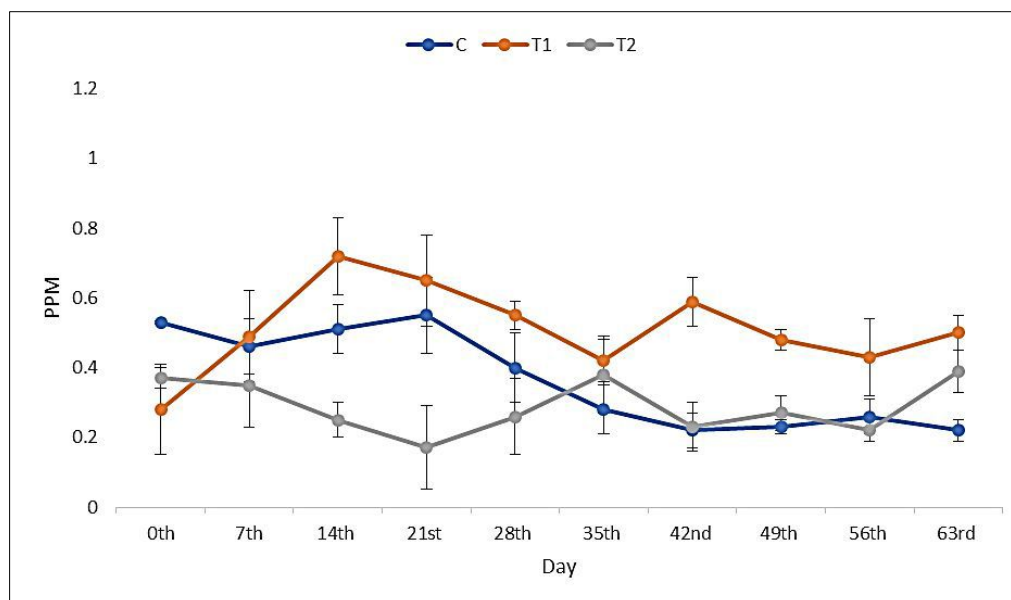
| D.O.                 |                         |                         |                         |
|----------------------|-------------------------|-------------------------|-------------------------|
| Treatment            | C                       | T <sub>1</sub>          | T <sub>2</sub>          |
| 0 <sup>th</sup> day  | 5.83±0.02 <sup>ab</sup> | 5.10±0.06 <sup>ab</sup> | 5.90±0.10 <sup>a</sup>  |
| 7 <sup>th</sup> day  | 5.80±0.02 <sup>A</sup>  | 5.20±0.06 <sup>A</sup>  | 5.90±0.10 <sup>A</sup>  |
| 14 <sup>th</sup> day | 5.80±0.06 <sup>M</sup>  | 5.20±0.15 <sup>M</sup>  | 5.40±0.15 <sup>M</sup>  |
| 21 <sup>st</sup> day | 5.80±0.06 <sup>p</sup>  | 5.30±0.15 <sup>p</sup>  | 5.43±0.09 <sup>p</sup>  |
| 28 <sup>th</sup> day | 5.70±0.06 <sup>P</sup>  | 5.37±0.18 <sup>P</sup>  | 5.43±0.12 <sup>P</sup>  |
| 35 <sup>th</sup> day | 5.80±0.06 <sup>d</sup>  | 5.27±0.18 <sup>e</sup>  | 5.33±0.12 <sup>e</sup>  |
| 42 <sup>nd</sup> day | 5.83±0.03 <sup>D</sup>  | 5.13±0.15 <sup>D</sup>  | 5.17±0.12 <sup>D</sup>  |
| 49 <sup>th</sup> day | 5.67±0.09 <sup>m</sup>  | 5.33±0.15 <sup>mn</sup> | 5.30±0.06 <sup>mn</sup> |
| 56 <sup>th</sup> day | 5.43±0.12 <sup>j</sup>  | 5.10±0.12 <sup>fj</sup> | 5.17±0.09 <sup>fj</sup> |
| 63 <sup>rd</sup> day | 5.53±0.12 <sup>l</sup>  | 5.17±0.12 <sup>kl</sup> | 5.30±0.12 <sup>kl</sup> |

**Table 7:** Average Ammonia Value Recorded During Experiment Period

| Ammonia              |                         |                          |                         |
|----------------------|-------------------------|--------------------------|-------------------------|
| Treatment            | C                       | T <sub>1</sub>           | T <sub>2</sub>          |
| 0 <sup>th</sup> day  | 0.48±0.08 <sup>a</sup>  | 0.25±0.17 <sup>a</sup>   | 0.24±0.03 <sup>a</sup>  |
| 7 <sup>th</sup> day  | 0.69±0.01 <sup>AB</sup> | 0.53±0.02 <sup>ABC</sup> | 0.44±0.04 <sup>BC</sup> |
| 14 <sup>th</sup> day | 0.63±0.02 <sup>P</sup>  | 0.37±0.02 <sup>PQ</sup>  | 0.26±0.008 <sup>Q</sup> |
| 21 <sup>st</sup> day | 0.52±0.014 <sup>m</sup> | 0.29±0.014 <sup>n</sup>  | 0.18±0.008 <sup>n</sup> |
| 28 <sup>th</sup> day | 0.24±0.08 <sup>Y</sup>  | 0.17±0.03 <sup>Y</sup>   | 0.37±0.04 <sup>Y</sup>  |
| 35 <sup>th</sup> day | 0.07±0.02 <sup>r</sup>  | 0.23±0.08 <sup>rs</sup>  | 0.28±0.03 <sup>rs</sup> |
| 42 <sup>nd</sup> day | 0.23±0.03 <sup>MN</sup> | 0.27±0.04 <sup>MNO</sup> | 0.16±0.02 <sup>O</sup>  |
| 49 <sup>th</sup> day | 0.30±0.02 <sup>yz</sup> | 0.18±0.02 <sup>z</sup>   | 0.22±0.07 <sup>z</sup>  |
| 56 <sup>th</sup> day | 0.34±0.10 <sup>CD</sup> | 0.34±0.10 <sup>CD</sup>  | 0.24±0.06 <sup>D</sup>  |
| 63 <sup>rd</sup> day | 0.42±0.11 <sup>s</sup>  | 0.33±0.15 <sup>s</sup>   | 0.20±0.06 <sup>s</sup>  |

**Table 8:** Average Nitrite Value Recorded During Experiment Period.

| Nitrite   |                                   |                        |                        |
|-----------|-----------------------------------|------------------------|------------------------|
| Treatment | C                                 | T <sub>1</sub>         | T <sub>2</sub>         |
| 0th day   | 0.53±0.005 <sup>a</sup>           | 0.28±0.13 <sup>a</sup> | 0.46±0.03 <sup>a</sup> |
| 7th day   | 0.46±0.080 <sup>A</sup>           | 0.49±0.13 <sup>A</sup> | 0.48±0.22 <sup>A</sup> |
| 14th day  | 0.51±0.07 <sup>P</sup>            | 0.72±0.18 <sup>P</sup> | 0.65±0.05 <sup>P</sup> |
| 21st day  | 0.55±0.14 <sup>m</sup>            | 0.65±0.13 <sup>m</sup> | 0.66±0.14 <sup>m</sup> |
| 28th day  | 0.4±0.10 <sup>Y<sup>Z</sup></sup> | 0.55±0.04 <sup>Y</sup> | 0.55±0.14 <sup>Y</sup> |
| 35th day  | 0.28±0.07 <sup>r</sup>            | 0.42±0.06 <sup>r</sup> | 0.48±0.11 <sup>r</sup> |
| 42nd day  | 0.22±0.05 <sup>M</sup>            | 0.59±0.07 <sup>M</sup> | 0.33±0.07 <sup>M</sup> |
| 49th day  | 0.23±0.02 <sup>z</sup>            | 0.48±0.03 <sup>y</sup> | 0.23±0.05 <sup>z</sup> |
| 56th day  | 0.26±0.05 <sup>C</sup>            | 0.43±0.11 <sup>C</sup> | 0.17±0.03 <sup>C</sup> |
| 63rd day  | 0.22±0.03 <sup>s</sup>            | 0.5±0.05 <sup>s</sup>  | 0.23±0.06 <sup>s</sup> |



### Influence on Fish Growth and Health

**Table 9:** Average Initial and Final Weight Recorded During Experimental Period

| Treatment      | Average initial weight | Average final weight    |
|----------------|------------------------|-------------------------|
| Control        | 8.73±0.03 <sup>a</sup> | 13.34±0.20 <sup>B</sup> |
| T <sub>1</sub> | 8.83±0.03 <sup>a</sup> | 13.04±0.82 <sup>B</sup> |
| T <sub>2</sub> | 8.79±0.03 <sup>a</sup> | 15.43±0.44 <sup>A</sup> |

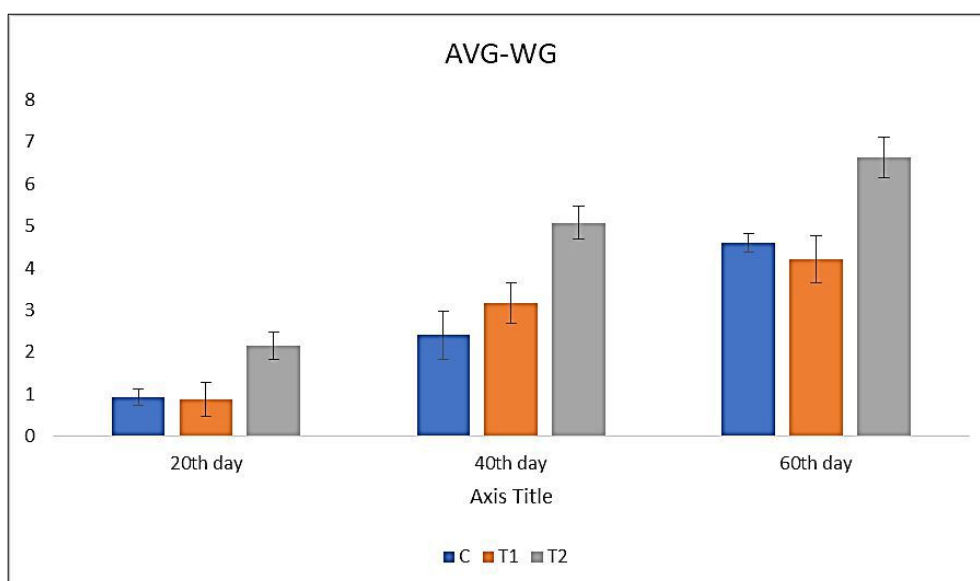
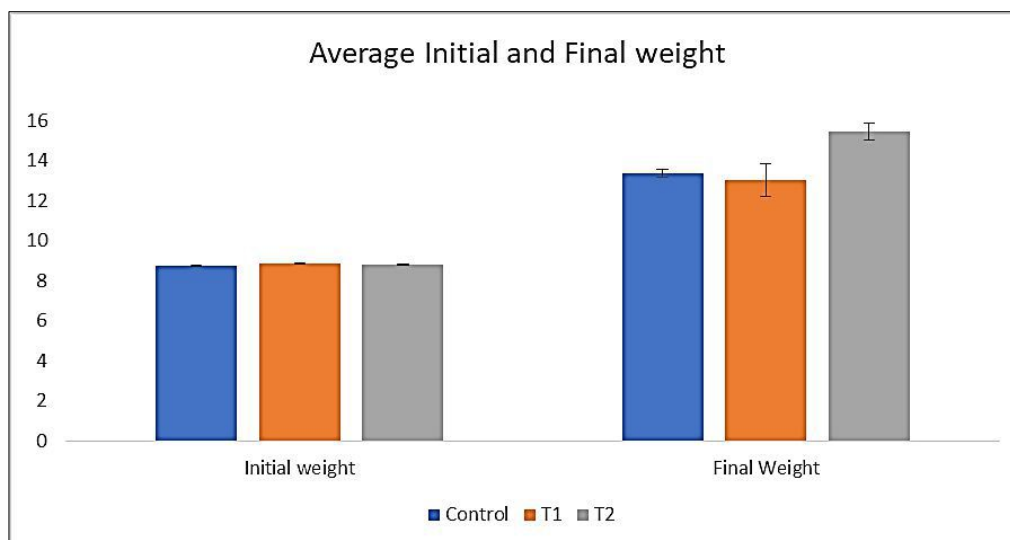


**Table 10:** Average Weight Gain Recorded During Experimental Period.

| Parameter | Treatment      | 20 <sup>th</sup> DAY    | 40 <sup>th</sup> DAY   | 60 <sup>th</sup> DAY    |
|-----------|----------------|-------------------------|------------------------|-------------------------|
| AVG-WG    | C              | 0.94±0.19 <sup>ab</sup> | 2.41±0.57 <sup>A</sup> | 4.60±0.21 <sup>q</sup>  |
|           | T <sub>1</sub> | 0.88±0.41 <sup>a</sup>  | 3.17±0.49 <sup>A</sup> | 4.21±0.56 <sup>pq</sup> |
|           | T <sub>2</sub> | 2.15±0.32 <sup>a</sup>  | 5.08±0.39 <sup>A</sup> | 6.63±0.49 <sup>p</sup>  |

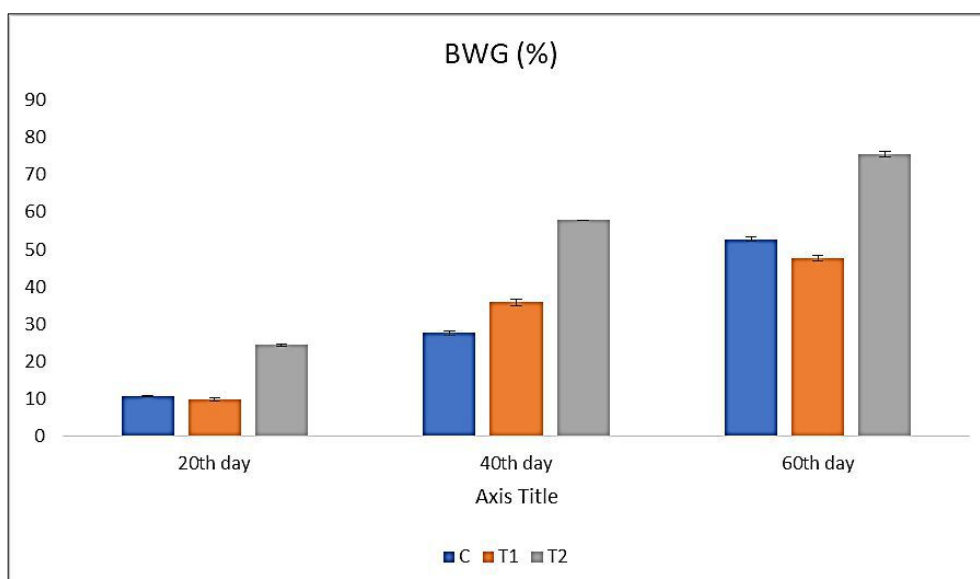
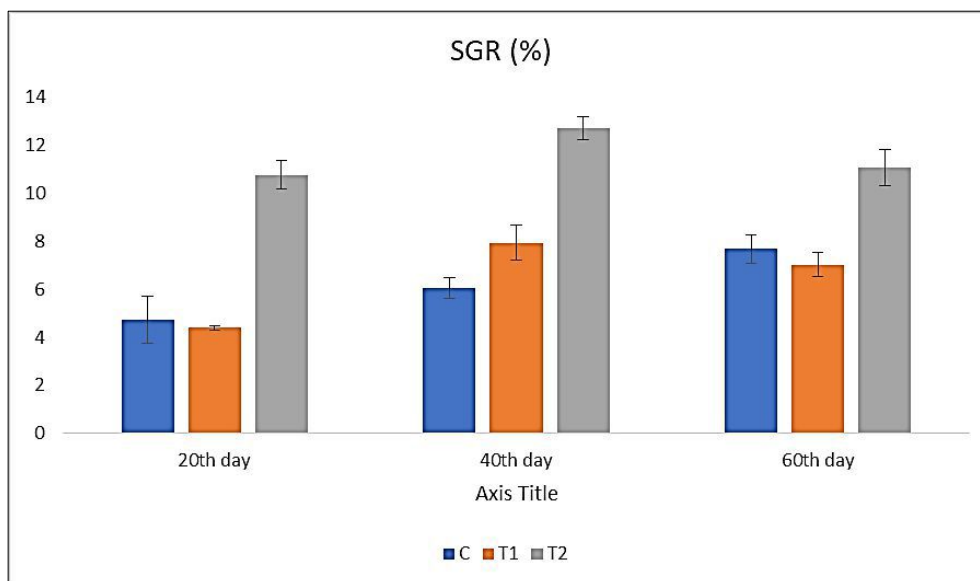
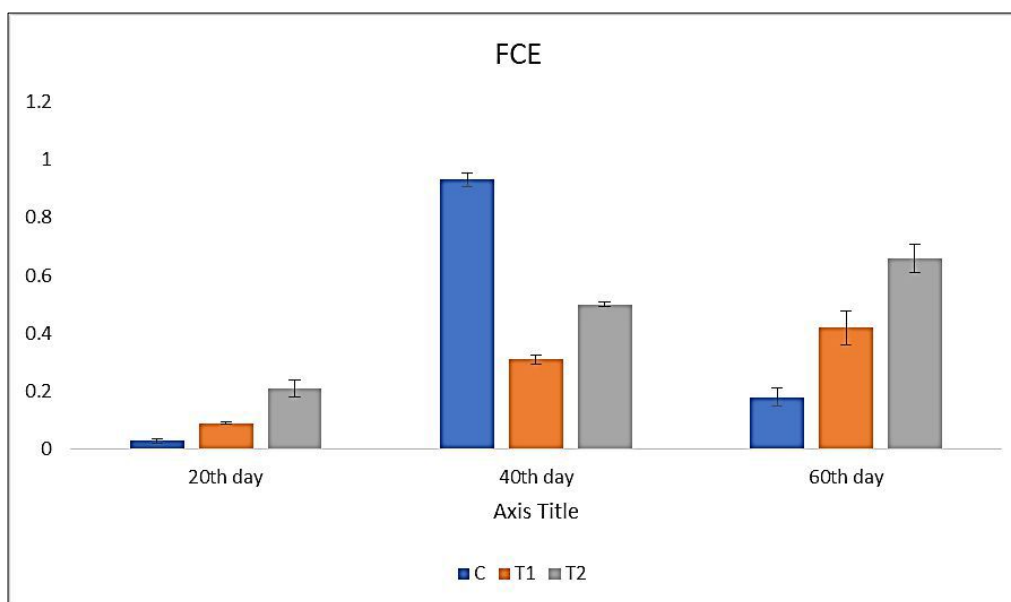


**Table 11:** Body Weight Gain Recorded During Experimental Period.

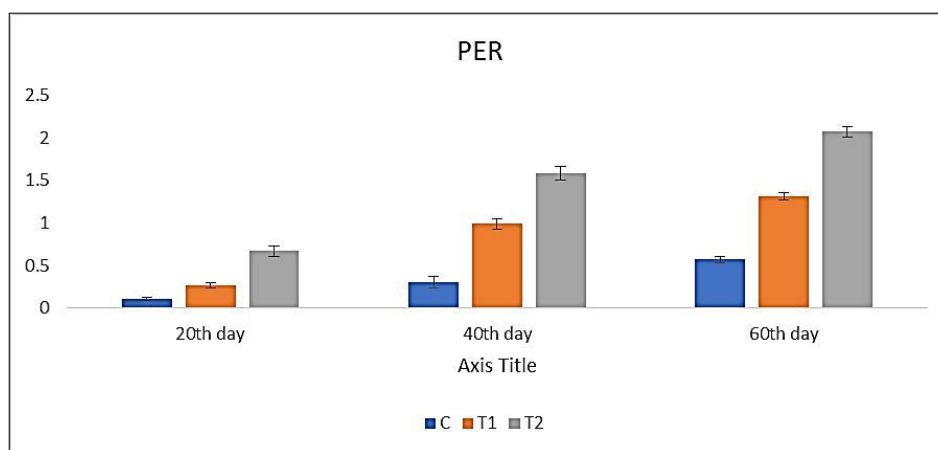
| Parameter | Treatment      | 20 <sup>th</sup> DAY     | 40 <sup>th</sup> DAY    | 60 <sup>th</sup> DAY     |
|-----------|----------------|--------------------------|-------------------------|--------------------------|
| BWG (%)   | C              | 10.79±0.19 <sup>ab</sup> | 27.63±0.62 <sup>A</sup> | 52.69±0.57 <sup>Pq</sup> |
|           | T <sub>1</sub> | 9.93±0.41 <sup>a</sup>   | 35.83±0.86 <sup>A</sup> | 47.66±0.75 <sup>Pq</sup> |
|           | T <sub>2</sub> | 24.46±0.32 <sup>a</sup>  | 57.82±0.01 <sup>A</sup> | 75.47±0.74 <sup>P</sup>  |

**Table 12:** Specific growth rate recorded during experimental period.

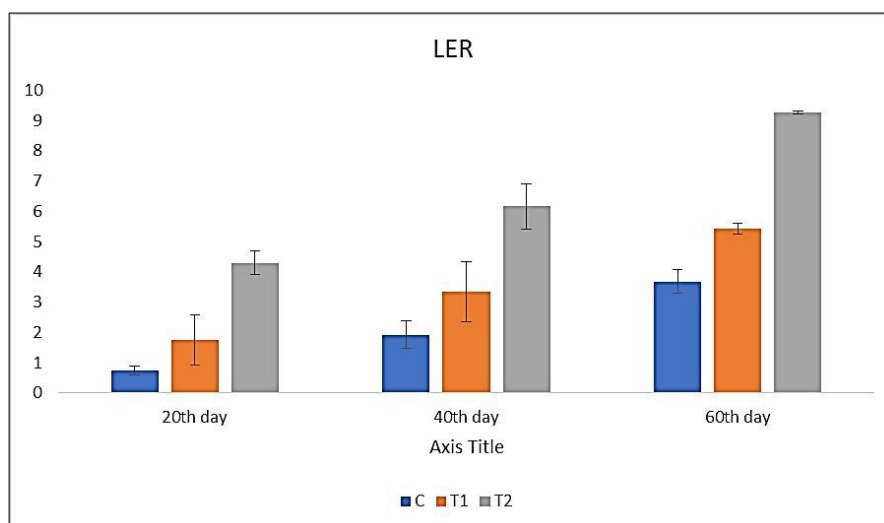
| Parameter | Treatment      | 20 <sup>th</sup> DAY    | 40 <sup>th</sup> DAY    | 60 <sup>th</sup> DAY    |
|-----------|----------------|-------------------------|-------------------------|-------------------------|
| SGR (%)   | C              | 4.71±0.98 <sup>ab</sup> | 6.03±0.43 <sup>A</sup>  | 7.67±0.35 <sup>Pq</sup> |
|           | T <sub>1</sub> | 4.39±0.09 <sup>a</sup>  | 7.93±0.73 <sup>A</sup>  | 7.02±0.44 <sup>Pq</sup> |
|           | T <sub>2</sub> | 10.75±0.60 <sup>a</sup> | 12.70±0.49 <sup>A</sup> | 11.05±0.54 <sup>P</sup> |

**Table 13:** Feed conversion Efficiency recorded during experimental period.

| Parameter | Treatment      | 20 <sup>th</sup> DAY     | 40 <sup>th</sup> DAY     | 60 <sup>th</sup> DAY     |
|-----------|----------------|--------------------------|--------------------------|--------------------------|
| FCE       | C              | 0.03±0.008 <sup>b</sup>  | 0.93±0.023 <sup>B</sup>  | 0.18±0.008 <sup>r</sup>  |
|           | T <sub>1</sub> | 0.09±0.0041 <sup>b</sup> | 0.31±0.0148 <sup>B</sup> | 0.42±0.0086 <sup>q</sup> |
|           | T <sub>2</sub> | 0.21±0.031 <sup>a</sup>  | 0.50±0.059 <sup>A</sup>  | 0.66±0.049 <sup>p</sup>  |

**Table 14:** Protein efficiency ratio recorded during experimental period.

| Parameter | Treatment      | 20 <sup>th</sup> DAY   | 40 <sup>th</sup> DAY    | 60 <sup>th</sup> DAY   |
|-----------|----------------|------------------------|-------------------------|------------------------|
| PER       | C              | 0.11±0.02 <sup>b</sup> | 0.30±0.07 <sup>B</sup>  | 0.57±0.04 <sup>r</sup> |
|           | T <sub>1</sub> | 0.27±0.03 <sup>b</sup> | 0.99±0.04 <sup>AB</sup> | 1.31±0.07 <sup>q</sup> |
|           | T <sub>2</sub> | 0.67±0.06 <sup>a</sup> | 1.58±0.08 <sup>A</sup>  | 2.07±0.06 <sup>p</sup> |

**Table 15:** Lipid efficiency ratio recorded during experimental period.

| Parameter | Treatment      | 20 <sup>th</sup> DAY   | 40 <sup>th</sup> DAY    | 60 <sup>th</sup> DAY   |
|-----------|----------------|------------------------|-------------------------|------------------------|
| LER       | C              | 0.75±0.15 <sup>b</sup> | 1.92±0.45 <sup>B</sup>  | 3.68±0.17 <sup>r</sup> |
|           | T <sub>1</sub> | 1.75±0.83 <sup>b</sup> | 3.34±0.98 <sup>AB</sup> | 5.42±0.74 <sup>q</sup> |
|           | T <sub>2</sub> | 4.30±0.40 <sup>a</sup> | 6.16±0.19 <sup>A</sup>  | 9.26±0.58 <sup>p</sup> |

### Effects on Crop Productivity

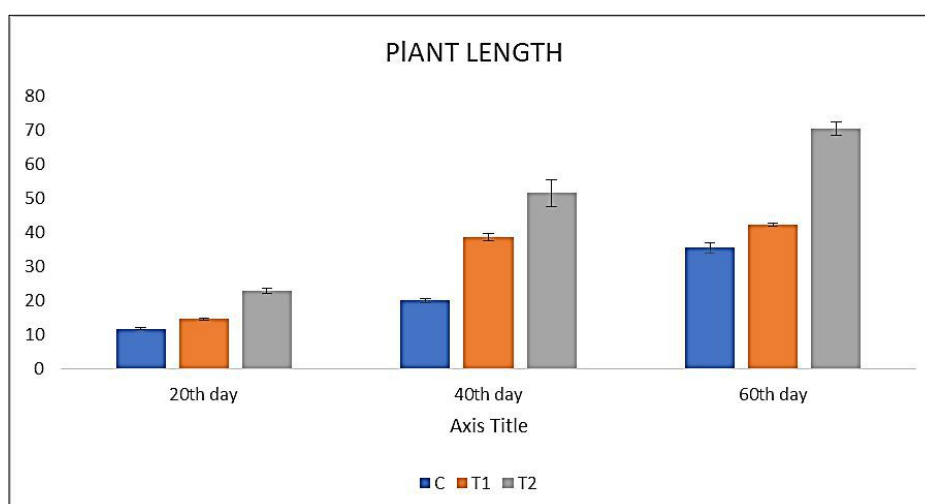


Table 16: Average Plant Length Recorded During Experimental Period.

| Parameter    | Treatment      | 20 <sup>th</sup> DAY     | 40 <sup>th</sup> DAY    | 60 <sup>th</sup> DAY     |
|--------------|----------------|--------------------------|-------------------------|--------------------------|
| Plant length | C              | 11.90±0.37 <sup>c</sup>  | 20.10±0.58 <sup>C</sup> | 35.50±1.44 <sup>r</sup>  |
|              | T <sub>1</sub> | 14.76±0.31 <sup>bc</sup> | 38.66±1.15 <sup>B</sup> | 42.40±0.41 <sup>qr</sup> |
|              | T <sub>2</sub> | 23.06±0.75 <sup>a</sup>  | 51.53±3.84 <sup>A</sup> | 70.36±2.00 <sup>p</sup>  |

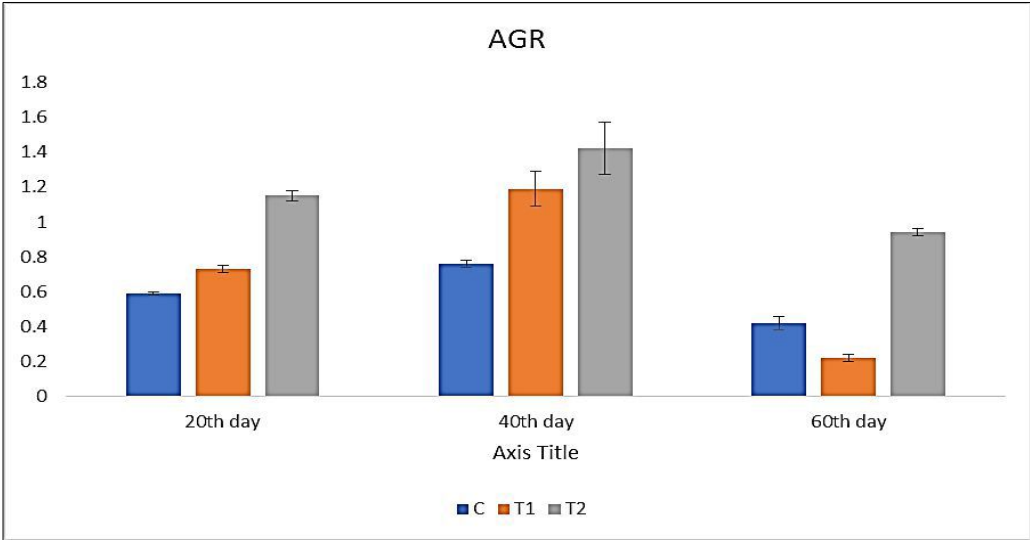
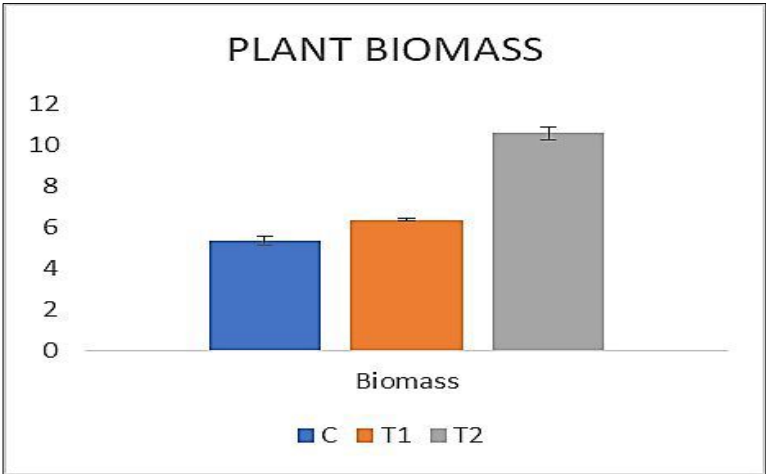


Table 17: Average growth rate recorded during experimental period.

| Parameter    | Treatment      | 20 <sup>th</sup> DAY    | 40 <sup>th</sup> DAY    | 60 <sup>th</sup> DAY    |
|--------------|----------------|-------------------------|-------------------------|-------------------------|
| AGR (cm/day) | C              | 0.59±0.01 <sup>c</sup>  | 0.76±0.02 <sup>C</sup>  | 0.42±0.04 <sup>Pq</sup> |
|              | T <sub>1</sub> | 0.73±0.01 <sup>bc</sup> | 1.19±0.10 <sup>AB</sup> | 0.22±0.02 <sup>q</sup>  |
|              | T <sub>2</sub> | 1.15±0.03 <sup>a</sup>  | 1.42±0.15 <sup>A</sup>  | 0.94±0.08 <sup>p</sup>  |

Table 18: Average Plant Biomass Recorded During Experimental Period.

| Parameter     | Treatment      | Biomass                 |
|---------------|----------------|-------------------------|
| Plant Biomass | C              | 5.33±0.22 <sup>r</sup>  |
|               | T <sub>1</sub> | 6.36±0.06 <sup>qr</sup> |
|               | T <sub>2</sub> | 10.55±0.3 <sup>p</sup>  |



Discussion

In the present 60-day experimental trial, a Completely Randomized Design (CRD) was employed to assess the influence of millet-based biofloc (T<sub>1</sub>), biofloc integrated with 0.5% Jeevamruth (T<sub>2</sub>), and a control group (C) without carbon supplementation on the physicochemical parameters of the water, growth performance of *Labeo rohita*, and the growth response of *Cyamopsis tetragonoloba*. Millet was used as a unique exogenous carbon source, representing a

novel and sustainable alternative to conventional carbon inputs like molasses or wheat bran, which are commonly employed in biofloc systems Sengupta *et al.*, 2024 [36]. Throughout the study, notable improvements were recorded in biofloc-based treatments, particularly in T<sub>2</sub>, demonstrating the synergistic role of millet-derived carbon and microbial enrichment from Jeevamruth in enhancing microbial activity, nutrient recycling, and overall system stability.

### Physicochemical Parameters

Temperature exhibited a gradual increase in all treatments during the 60-day trial, with biofloc-based groups showing slightly higher and more stable thermal profiles than the control. The enhanced stability in T<sub>2</sub> indicates microbial-driven heat production and system equilibrium, which aligns with findings by (Joshna *et al.*, 2024)<sup>[21]</sup> who demonstrated that microbial activity contributes to thermal homeostasis and promotes biochemical stability in integrated aquaculture systems. Such stable thermal regimes are considered essential for maintaining microbial synergy and physiological balance in cultured species (Chudasama *et al.*, 2024)<sup>[8]</sup>.

pH fluctuations followed a dynamic but stabilizing pattern across treatments. Both T<sub>1</sub> and T<sub>2</sub> maintained higher pH values throughout the experiment compared to the control, implying effective microbial buffering and organic matter degradation. The higher pH in these systems supports the findings of (Sengupta *et al.*, 2024)<sup>[36]</sup>, who reported that biofloc systems sustain stable pH through active nitrification driven by ammonia-oxidizing and nitrite-oxidizing bacteria. The presence of Jeevamruth in T<sub>2</sub> likely further intensified microbial proliferation, enhancing the decomposition of organic compounds and supporting the results of (Lal *et al.*, 2024)<sup>[35]</sup>, who emphasized the necessity of a balanced microbial environment for maintaining optimal pH and nutrient cycling efficiency.

TDS and electrical conductivity (EC) increased steadily over the trial period, especially in T<sub>2</sub>, suggesting enhanced microbial biomass accumulation and mineralization processes. The rising trend of TDS and EC can be attributed to ionic accumulation due to microbial metabolism and nutrient recycling, consistent with the observations of Deng *et al.* (2020)<sup>[11]</sup>, and Liu *et al.* (2019)<sup>[24]</sup>. The gradual rise in EC in the millet- and Jeevamruth-supplemented systems further demonstrates the link between microbial density and ionic load, highlighting the importance of microbial-driven nutrient conversion in maintaining water quality stability. Salinity remained relatively stable throughout the culture period, with only minor elevation in the biofloc treatments. The slightly higher salinity in T<sub>2</sub> compared to the control suggests ionic enrichment from organic and microbial activity, corroborating the findings of (Al-Sayegh *et al.*, 2024)<sup>[2]</sup> and (Khanjani *et al.*, 2024)<sup>[22]</sup>, who noted that biofloc systems effectively buffer ionic changes through microbial assimilation, ensuring a stable freshwater environment conducive to fish welfare.

Dissolved Oxygen (DO) levels displayed a gradual decline in biofloc treatments, attributed to heightened microbial respiration and organic decomposition. While microbial intensification improves nutrient cycling, it also increases biological oxygen demand (BOD), as reported by (Sengupta *et al.*, 2024)<sup>[36]</sup>. The moderate reduction in DO in T<sub>2</sub> suggests active heterotrophic bacterial metabolism, a characteristic of healthy biofloc systems, provided sufficient aeration is maintained to prevent oxygen limitation.

Ammonia (TAN) concentrations decreased steadily in T<sub>1</sub> and markedly in T<sub>2</sub>, where the lowest final TAN levels were recorded. The improved ammonia removal efficiency in T<sub>2</sub> reflects the combined action of millet-based carbon supplementation, which supports heterotrophic microbial assimilation, and Jeevamruth-derived microbial inoculants that enhance nitrification and ammonia oxidation. These findings agree with (Robles-Porchas *et al.*, 2020)<sup>[38]</sup> and

(Chen *et al.*, 2023)<sup>[7]</sup>, who highlighted that carbon-driven microbial enrichment facilitates nitrogen immobilization and detoxification in biofloc environments. The stable reduction of ammonia in T<sub>2</sub> underscores the efficient nitrogen cycling characteristic of optimized biofloc systems (Liu *et al.*, 2019; Luo *et al.*, 2019)<sup>[24, 26]</sup>.

Nitrite concentrations exhibited treatment-dependent variations, with the control maintaining higher levels over time compared to biofloc treatments. In T<sub>2</sub>, transient increases were followed by efficient reduction, indicating effective nitrification and microbial stabilization. The observed nitrite dynamics correspond with (Ferreira *et al.*, 2019)<sup>[14]</sup> and (Abakari *et al.*, 2020)<sup>[11]</sup>, who emphasized the necessity of balanced microbial communities for complete nitrification and nitrite oxidation in aquaculture systems. Such efficient nitrogen management within biofloc environments minimizes toxicity risks and promotes healthier aquatic conditions.

### Fish Growth Performance

Growth performance of *Labeo rohita* showed remarkable improvement in T<sub>2</sub>, where the final weight (15.43±0.44 g) significantly surpassed both the control (13.34±0.20 g) and T<sub>1</sub> (13.04±0.82 g). The enhanced growth in T<sub>2</sub> highlights the synergistic contribution of millet and Jeevamruth in improving nutrient availability and microbial biomass production. Biofloc technology provides a natural source of microbial protein that supports improved feed efficiency and fish growth, as reported by (Sengupta *et al.*, 2024)<sup>[36]</sup> and (Lal *et al.*, 2024)<sup>[35]</sup>. The superior microbial activity in T<sub>2</sub> likely maintained a stable microbial ecosystem, generating nutritionally rich flocs that served as supplementary feed.

Average Weight Gain (AVG-WG) and Body Weight Gain Percentage (BWG%) followed a similar trend, with T<sub>2</sub> recording the highest improvements, indicating effective microbial assimilation and nutrient conversion. These findings align with (Panigrahi *et al.*, 2020)<sup>[28]</sup> and (Hersi *et al.*, 2023)<sup>[18]</sup>, who demonstrated that microbial augmentation improves protein assimilation and intestinal health, enhancing growth performance in cultured fish. Moreover, the elevated BWG% in T<sub>2</sub> mirrors the results of and (Abakari *et al.*, 2020)<sup>[11]</sup>, who found that optimized C:N ratios and microbial bioenhancers increase weight gain and feed efficiency in biofloc systems.

Specific Growth Rate (SGR%) also peaked in T<sub>2</sub> (11.05±0.54%), demonstrating the beneficial impact of enhanced microbial recycling on fish metabolism. (Wu *et al.*, 2024) reported that organic carbon supplementation stimulates microbial communities, leading to improved nutrient retention and accelerated growth rates. Similarly, the elevated Feed Conversion Efficiency (FCE), Protein Efficiency Ratio (PER), and Lipid Efficiency Ratio (LER) observed in T<sub>2</sub> indicate superior feed utilization and nutrient assimilation efficiency. Such improvements have been documented by (Zablon *et al.*, 2022)<sup>[37]</sup> and (Cuzon *et al.*, 2004)<sup>[10]</sup>, who noted that biofloc-supplemented feeds enhance digestive enzyme activity and promote efficient nutrient uptake. The combined use of millet and Jeevamruth in T<sub>2</sub> thus provided a biologically rich medium that optimized protein and lipid metabolism while reducing feed waste and environmental load.

### Crop Growth Performance

The performance of *Cyamopsis tetragonoloba* exhibited a consistent pattern with the aquatic results, with T<sub>2</sub> producing the highest plant height (70.36±2.00 cm), average growth rate (0.94±0.23 cm/day), and biomass (10.55±0.3 g). These improvements can be attributed to the nutrient-rich irrigation effluent derived from the millet-Jeevamruth biofloc system, which enhanced microbial activity and nutrient bioavailability in the rhizosphere. Similar observations were made by (Fimbres-Acedo *et al.*, 2020) [15] and (Zimmermann *et al.*, 2023) [31], who reported that biofloc effluents enriched with microbial biomass significantly improve crop growth and nutrient uptake efficiency. The synergistic influence of Jeevamruth further enhanced enzymatic nutrient transformation, as described by (Kumar *et al.*, 2018) [23], ensuring sustained nutrient release and promoting vigorous plant growth. These findings collectively validate that the integration of biofloc effluents with microbial amendments can simultaneously enhance aquaculture and agriculture productivity within an eco-efficient framework.

### Conclusion

The combined effects of the millet-derived carbon source and microbial enrichment through Jeevamruth resulted in superior physicochemical water stability, efficient nitrogen transformation, and robust microbial community development. These synergistic interactions led to optimized water quality parameters stable pH, elevated TDS and EC due to microbial activity, controlled ammonia and nitrite levels, and consistent thermal and salinity profiles a well-balanced, self-regulating biofloc environment.

The positive impact of the T<sub>2</sub> system extended to biological performance, where *Labeo rohita* exhibited the highest growth indicators, including final weight, average weight gain, specific growth rate, and feed utilization efficiencies (FCE, PER, LER). These improvements can be attributed to the enhanced microbial biomass, nutrient recycling, and continuous availability of microbial protein and lipids within the biofloc matrix. The inclusion of Jeevamruth played a pivotal role in stimulating beneficial microbial populations, accelerating organic matter decomposition, and improving feed assimilation efficiency. *Cyamopsis tetragonoloba* cultivated using effluent from the T<sub>2</sub> treatment exhibited significant increases in height, growth rate, and biomass, confirming the potential of biofloc effluent as a nutrient-rich organic input for integrated aquaponic and agro-aquaculture systems. The combined use of Jeevamruth and millet not only supported microbial proliferation and nutrient mineralization but also provided a sustainable and eco-friendly approach for recycling aquaculture waste into plant-available nutrients.

the integrated biofloc-Jeevamruth system (T<sub>2</sub>) proved to be an efficient, sustainable, and biologically enriched model that improved water quality, enhanced fish growth performance, and promoted crop productivity. By reducing dependence on synthetic inputs and optimizing microbial-driven nutrient cycling, this approach offers a viable pathway toward circular and low-impact aquaculture-agriculture integration. The results strongly advocate for the broader adoption of natural carbon sources like millet in combination with indigenous microbial stimulants such as Jeevamruth to advance sustainable biofloc technology and resource-efficient food production systems.

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