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Research Article

Effects of Nutrient Management on the Plankton Community: A Substantial Aquaculture Approach

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ABSTRACT

The comprehension of plankton communities is essential for the advancement of aquaculture, as they have a significant impact on environmental variables. In this regard, the study was conducted to investigate the ecological ramifications of nutrient management on the plankton community in pond. The experiment featured four treatments, each with three replications: T_0 was the control without feed and fertilizer, T_1 with only fertilizer, T_2 with fertilizer and feed, and T_3 with only feed. Tilapia (*Oreochromis niloticus*) fry were stocked and fed initially at 50% of body weight in T_3 and gradually reduced to 5%. Feeding in T_2 was half that of T_3, and fertilization was done weekly. In the study, four phytoplankton groups were identified: Chlorophyceae, Cyanophyceae, Bacillariophyceae, and Euglenophyceae, along with four zooplankton groups: Rotifera, Copepoda, Cladocera, and Crustacea. Chlorophyceae and Rotifera were discovered to be the most dominant phytoplankton and zooplankton groups, respectively. The treatments showed a significant difference ($P < 0.05$) in plankton, notably between T_2 and T_0. The mean plankton abundance was highest in treatment T_2. Findings indicated that the application of both fertilizers and feed was better for plankton population growth than other treatments. So, the study could recommend the combined application of fertilizers and supplemental feed as the best option for semi-intensive fish farming.

Introduction

Food is the most important and urgent need for optimal fish production and successful fish culture practices rely primarily on maintaining a healthy aquatic environment and producing adequate fish food organisms (Alam et al.*,* 2002; Hemal et al., 2017; Sunny et al.*,* 2019). To boost up aquaculture contribution to poverty alleviation, pond management should be focused on the paradigm of "feed the pond to grow fish". Nutrient availability is the prerequisite for satisfactory level production capability of a water body (Sunny et al., 2021a). Plankton growth is facilitated by the nutrients obtained through the breakdown of unused feed and organic wastes of living creatures, as well as nutrients obtained directly from supplied fertilizers in aquaculture ponds. When fish larvae migrate from their yolk sacs to external feeding, zooplankton is the first prey item they encounter.

Fish ponds are man-made habitats where fertilizer is constantly added to boost system productivity and profitability. The qualitative and quantitative features of plankton biomass and fish pond's carrying capacity are inextricably linked. The standing crop grows in proportion to the plankton biomass (Soni and Ujjania, 2021). Fertilizer application can significantly increase the natural productivity of a pond by providing vital nutrients for the development of aquatic biota. In the nursing of fingerling operation, feed is the major input and represents up to 60% of the total operational expenditure (Silva, 1992; Sunny et al., 2021b). So, effective technologies should be introduced to drive down the rearing cost.

Fertilization can pull down the operational cost effectively providing essential nutrients to aquatic biota consumed as fish food (Begum et al., 2007, Islam et al., 2018). The inorganic and organic fertilizers jointly do better than inorganic or organic alone (Rabanal, 1967).

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It impacts significantly on the plankton quality and quantity according to its types and doses, which ultimately improves healthy fish growth (Anetekhai et al., 2005; Bhakta et al., 2004). Chemical fertilizers drive phytoplankton growth and organic fertilizer drives zooplankton growth primarily and in pond they are considered higher quality nutrients because of their more readily dissolving qualities (Parameswarran et al., 1972). According to Saha (1978), chemical fertilizers increased phytoplankton growth while decreasing zooplankton growth, resulting in improved fish growth. Organic fertilizers and livestock waste products act as high-quality agent for increasing the abundance of fish food like larvae of insect and zooplankton, whereas chemical fertilizers predominantly produce phytoplankton. (Olah et al., 1986; Jhingran, 1983; Akand, 1986). Supplementary feeding of fish is also widespread in aquaculture, with agricultural byproducts being used (Wahab and Ahmed, 1992; Haq et al., 1994; Ahmed et al., 1997).

Therefore, it is important to update the present knowledge on the impact of nutrient management practices on the abundance and composition of phytoplankton and zooplankton communities in fish ponds and their relationship with nutrient management practices in order to identify the most effective nutrient management technique that can promote plankton growth and support sustainable aquaculture.

Materials and Methods

Study area

The research was conducted over a three-month period from September to November 2013 in twelve fish ponds at the Sylhet Agricultural University in Sylhet, Bangladesh. Every pond was 0.004 hectares with 1 meter of depth.

Experimental design

The experiment was divided into four treatments, each with three replications (R1, R2, and R3), in a fully randomized design. T_0 was control treatment without any feed and fertilizer, T_1 was treated with only fertilizer, T_3 was treated with only feed (twice daily) and T_2 was treated with fertilizer and half feed compared with T_3 (twice daily).

Pond preparation

Dikes, holes were repaired and aquatic vegetation was cleared off mechanically (Islam et al., 2016). Chemical treatment was done for complete eradication of all undesirable organisms, lime was applied at 617.5 kg/hectare rate. TSP (triple super phosphate), cow dung and urea were applied at 1482 kg, 49.4 kg and 49.4 kg/hectare respectively to T_1 and T_2.

Nutrient management and feeding

Tilapia (*Oreochromis niloticus*) fry of 2.54 cm in size and 0.3 g by weight were fed initially at 50% to the end research at 5% of their body weight on T_3. Commercial feed application rate in treatment T_2 was half the amount of feed given in the treatment T_3. Fish were fed twice a day in case of T_2 and T_3. After stocking, fertilization in T_1 and T_2 was done weekly with decomposed cow dung (370.5 kg/ha), urea (9.88 kg/ha) and TSP (9.88 kg/ha). TSP was dissolved alone in water for 24 hours, then urea was mixed with it and sprayed over the pond water. Decomposed cow dung was applied in liquid form.

Water quality

Transparency, temperature (air and water), dissolved oxygen, and pH were recorded biweekly between 08:00 to 11:30 A.M. throughout the trial period. Temperature and transparency were recorded by a centigrade thermometer (div= 0.1°C) and secchi disc (25cm radius). The remaining parameters were determined by HACH Test Kit (Model: FF-2, HACH Company, USA).

Study of plankton

Every two weeks, 5 liters of water from each pond was collected and passed through a 55 µm meshed plankton net. Filtered water samples were filled to a volume of 50 ml in a measuring cylinder. For subsequent analysis, the concentrated water samples were preserved in a 50-ml plastic vial (Labtex, China) containing 10% formalin. A 1 ml sample of concentrated plankton was placed on the Sedgewick Rafter (S-R) cell. A cover slip was used to cover the counting chamber, after settling the plankton the chamber was taken under the microscope (Olympus CX41, Japan). Ten squares of the S-R cell were randomly chosen to count plankton and expressed number per liter water (APHA, 1992). It was identified to genus level with the help of Bellinger (1992) and Needham and Needham (1941). For the calculation of plankton abundance, the equation: $N = (P \times C \times 100) / L$ (Azim et al., 2001) was used; where N was the number of plankton cells per liter water, P was the number of planktons counted in 10 selected fields, C was the volume of final concentrated sample (ml), and L was the volume (l) of the pond water sample.

Data analysis

In SPSS version 16, data were analyzed using one-way ANOVA (analysis of variance), followed by Duncan's Multiple Range Test (DMRT). The data were analyzed at a 0.05% significance level and presented as a mean ±SD.

Results and Discussion

Physico-chemical parameters Temperature (°C)

Air temperatures ranged from 27.4°C to 31.2°C, while water temperatures ranged from 26.75° to 31°C. No significant difference (*p > 0.05*) was observed in temperature across the treatments. The water temperature was measured to be between 32.23°C and 32.61°C by Ara et al. (2018). According to Kunda et al. (2022), the average water temperature was 28.69±1.19°C which supports present study. In all treatments, the average air temperature was 30.03±1.67°C.

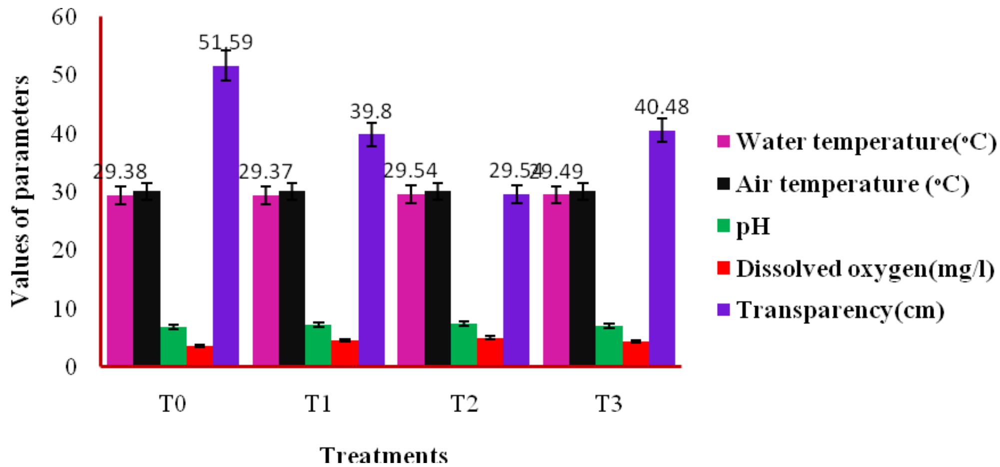

Figure 1. The mean of the physicochemical parameters

Water transparency (cm)

The highest value of transparency was 56.00 cm in September and the lowest was 28.90 cm in November. The statistical analysis showed a significant difference ($P<0.05$) among T_0, T_1, and T_2 and also among T_0, T_2, and T_3. Tabaro et al. (2012) determined the transparency between 23 and 45 cm. The highest levels of transparency were documented by Saha and Sinha (1969) amid increased rain fall in August and September. Munni et al. (2013) measured the transparency of ponds in Tangail, Bangladesh, to be 32.5-57.5 cm. The average water transparency, as reported by Kunda et al. (2022), was 36.33±8.20 cm. The current study's findings are in close conformity with the above findings.

Water pH

Over the research period, pH levels ranged from 6.14 to 9.45, which is largely consistent with the results of Dewan et al. (1991), Munni et al. (2013), Makori et al. (2017) and Bhatnagar and Singh (2010). They recorded the pH value ranged from 6.6 to 8.8, 6.8 to 7.12, 6.1 to 8.3, and 7.65 to 9.22 respectively. The water pH was significantly different ($P<0.05$) between treatments T_0, T_1, and T_3 and T_0, T_2, and T_3, but not between treatments T_1 and T_2.

Dissolved oxygen (mg/l)

Dissolved oxygen fluctuated between 3.10 mg/l (due to grazing effect) and 5.20 mg/l (due to massive growth of plankton), which are largely consistent with the findings of Tabaro et al. (2012) from ranging 4.71±0.43- 5.0±0.38 mg/l in a tilapia culture pond; Wahid et al. (1997) ranging from 4.4-4.9 mg/l; Kohinoor et al. (1998), who recorded dissolved oxygen at 4.20 mg/l in the carp polyculture ponds. All the treatments were significantly different ($P<0.05$).

Plankton population

Plankton taxa were identified up to the genus level (Table 1 and 2). Almost 36 genera belonging to 8 planktonic groups were identified. Among them, twenty-four genera were of phytoplankton, *viz*. Bacillariophyceae (5), Chlorophyceae (11), Cyanophyceae (5), and Euglenophyceae (3), and 12 genera of zooplankton, *viz*. Rotifera (6), Crustacea (1), Cladocera (3), and Copepoda (2).

Table 1. Generic status of phytoplankton

Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae
Ankistrodesmus	*Navicula*	*Microsystis*	*Euglena*
Chlorella	*Nitzschia*	*Anabaena*	*Phacus*
Closterium	*Cyclotella*	*Gomphosphaeria*	*Trachelomonas*
Pediastrum	*Fragillaria*	*Oscillatoria*	-
Scenedesmus	*Syndra*	*Spirulina*	-
Tetraedon	-	-	-
Staurastrum	-	-	-
Volvox	-	-	-
Actinestrum	-	-	-
Crucigenia	-	-	-
Stichococcus	-	-	-

Table 2. Generic status of zooplankton

Rotifera	Copepoda	Cladocera	Crustacea
Brachionus	*Cyclops*	*Diaphanosoma*	Naupleus
Filinia	*Diaptomus*	*Sida*	-
Keratella	-	*Moina*	-
Trichocerca	-	-	-
Polyarthra	-	-	-
Asplanchna	-	-	-

Phytoplankton population

The mean (±SD) abundances (×10³ cells/l) of different groups of phytoplankton over the study period ranged from 12.45±1.93, 35.45±8.03, 52.81±16.84 and 26.00±4.55 in T_0, T_1, T_2 and T_3 treatments respectively. Hoque et al. (2014) identified 38 genera of phytoplankton in mola carplet monoculture fish pond in Bangladesh. Alam et al. (2002) found 35 genera of plankton (28 were phytoplankton and 7 genera were zooplankton) in a newly excavated limed and fertilized pond in the Bangladesh Agricultural University campus, Bangladesh.

Fortnightly abundance of phytoplankton

Chlorophyceae

The mean (±SD) abundances (×10³ cells/l) of Chlorophyceae were found to be 4.62±0.97 in T_0, 14.29±3.58 in T_1, 24.76±12.06 in T_2 and 10.86±1.91 in T_3 (Figure 2). In November, the highest number of Chlorophyceae was found in T_2, and the lowest in T_0. Throughout the trial, the Chlorophyceae were the most abundant phytoplankton group. The T_0, T_1, T_2 and T_0, T_2, T_3 were significantly different (P<0.05) but the T_1 and T_3 were not.

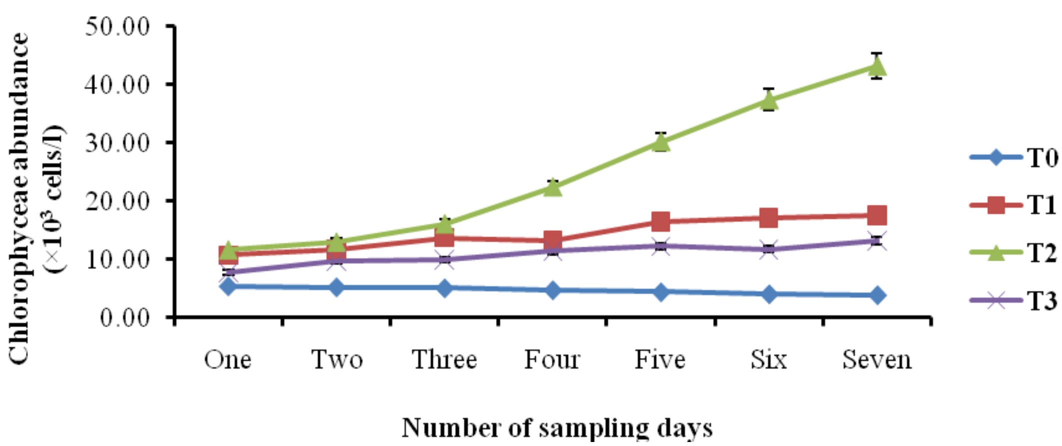

Figure 2. Fortnightly variation of Chlorophyceae.

Cyanophyceae

The mean (±SD) abundances (×10³ cells/l) of Cyanophyceae were 4.64±0.73 in T_0, 11.05±2.44 in T_1, 14.90±3.56 in T_2 and 8.55±1.94 in T_3. The highest number of Cyanophyceae was found in T_2, while the lowest was found in T_0. Cyanophyceae were the second dominant group of phytoplankton from September to November. The treatments were significantly different (P<0.05).

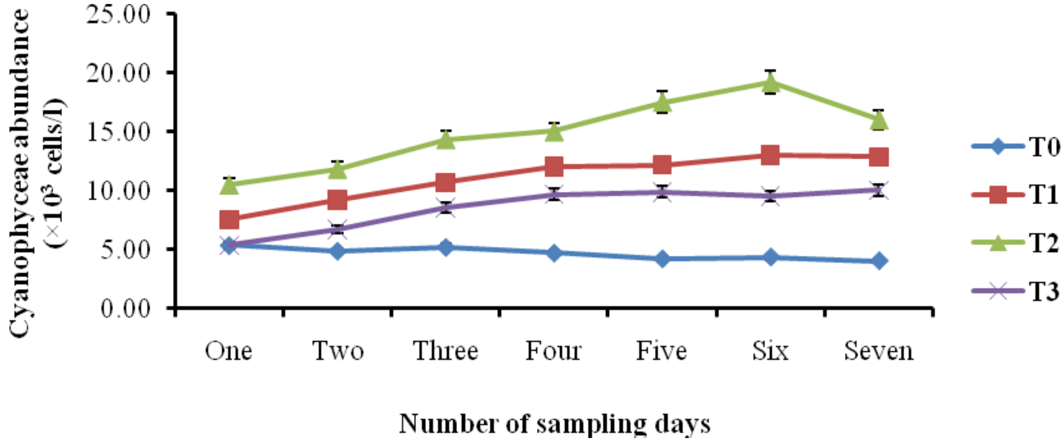

Figure 3. Fortnightly variation of Cyanophyceae.

Bacillariophyceae

The mean (±SD) abundances (×10^3 cells/l) of Bacillariophyceae were found 2.88±0.71 in T_0, 8.12±2.39 in T_1, 10.02±2.42 in T_2, and 5.31±0.78 in T_3. Bacillariophyceae were substantially higher (P<0.05) in number in T_2 than other three treatments. During the experiment, Bacillariophyceae were identified to as the third most dominant phytoplankton group out of four.

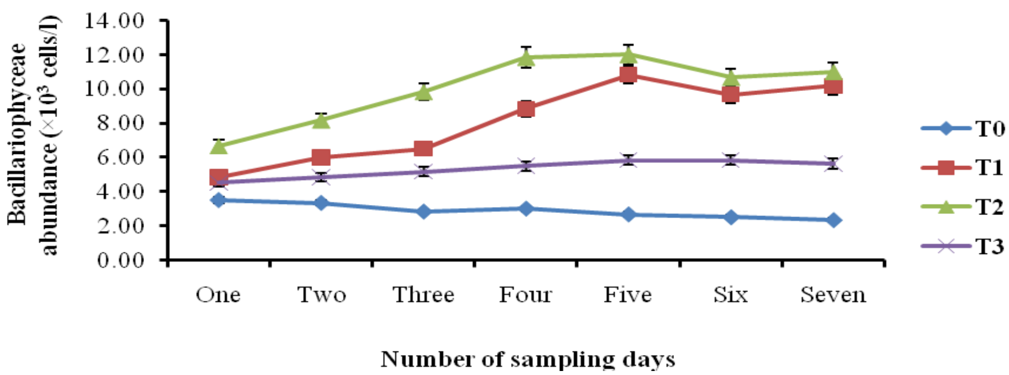

Figure 4. Fortnightly variation of Bacillariophyceae.

Euglenophyceae

Throughout the trial, the Euglenophyceae were determined to be the least dominant phytoplankton group. The mean (±SD) abundances (×10^3 cells/l) of Euglenophyceae were observed to range from 0.31±0.33, 2±1, 3.12±1.14 and 1.29±0.64 in T_0, T_1, T_2 and T_3 treatments respectively. All the treatments were significantly different (P<0.05) in terms of Euglenophyceae.

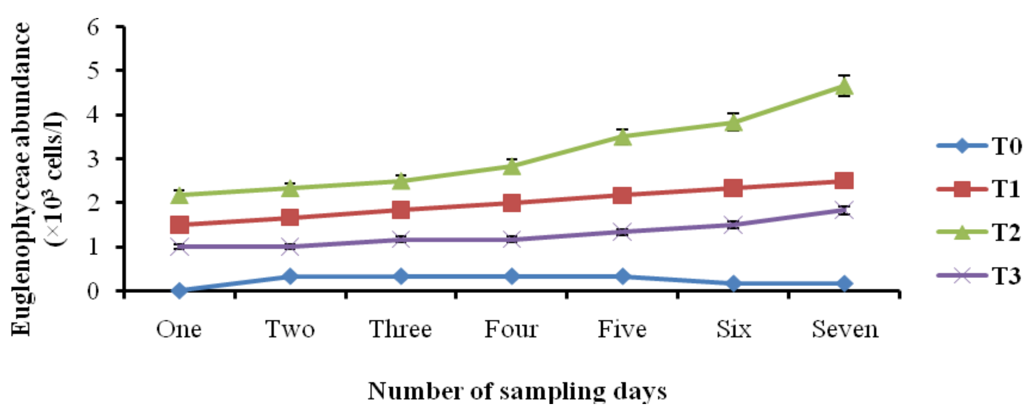

Figure 5. Fortnightly variation of Euglenophyceae.

Mean abundance of total phytoplankton

The phytoplankton abundance was 12.45±1.93 (×10³ cells/l) in T_0, 35.45 ±8.03 (×10³ cells/l) in T_1, 52.81±16.84 (×10³ cells/l) in T_2 and 26.00±4.55 (×10³ cells/l) in treatment T_3. Mean abundance of phytoplankton among the treatments are shown in Figure 6.

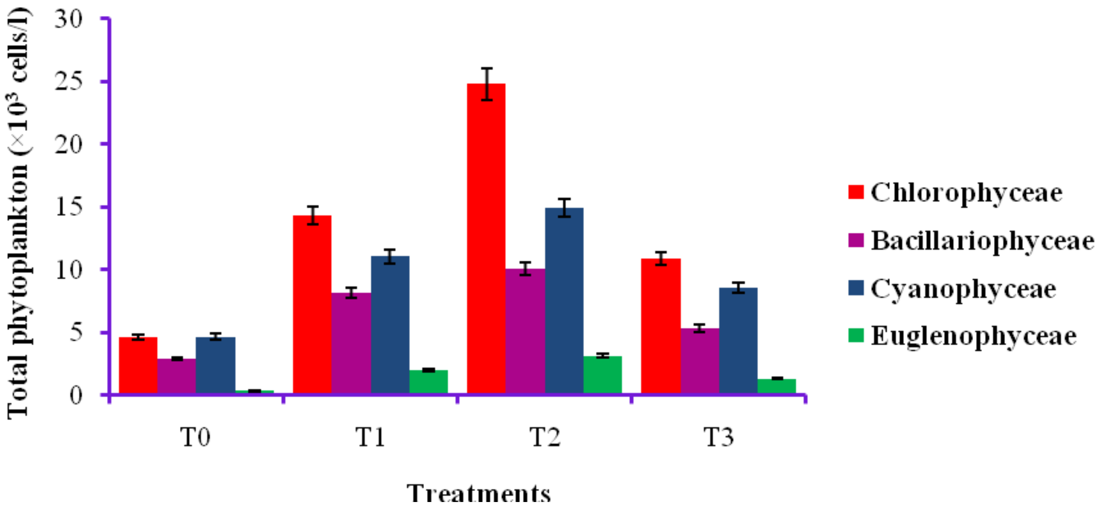

Figure 6. Mean abundance of total phytoplankton.

The maximum number of Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae were identified in T_2 and the minimum number in T_0 in November. Chlorophyceae was the most prominent phytoplankton group, while Euglenophyceae was the least dominant. All the treatments were significantly different (P<0.05) from each other. Hossen et al. (2018) found Chlorophyceae dominancy among phytoplankton groups in the ponds of Khulna University campus treated with inorganic fertilizer.

Zooplankton population

The mean (±SD) abundances (×10³ cells/l) of different categories of zooplankton over the whole experimental period were 4.43±1.69, 20.26 ±3.76, 24.21±5.45 and 15.76±15.76 in T_0, T_1, T_2 and T_3 treatments respectively. Haque (1996), found 12 and Hoque et al. (2014) found 13 genera of zooplankton which is similar with the present investigation. The maximum zooplankton concentration was found in T_2 with feed and fertilizer and the lowest in T_0 without fertilizer and feed. Knisely and Geller (1986) found phytoplankton selectivity of zooplankton in natural specifically, copepods and rotifers dislike Chlorophyceae and Cyanophyceae and the primary zooplankton groups in freshwater (copepods, rotifers and cladocerans) rely on Bacillariophyceae more than Chlorophyceae and Cyanophyceae for algal food. As a result, the abundance of Chlorophyceae and Cyanophyceae was higher than that of Bacillariophyceae throughout the experiment.

Fortnightly abundance of zooplankton

Rotifera

The mean (±SD) abundance (×10³ cells/l) of Rotifera were reported to vary from 2.74±0.86, 12.12±2.93, 13.60±3.67 and 2.29±2.17 in T_0, T_1, T_2 and T_3 treatments respectively. Treatment T_0 showed poor growth of Rotifera, with the lowest number found in November, whereas the highest growth was recorded in treatment T_2 in November. T_0, T_1, T_3 and T_0, T_2, T_3 were significantly different (P<0.05) in terms of Rotifera. However, no significant differences in Rotifera were recorded between T_1 and T_2.

Copepoda

Copepoda were the second-most abundant and dominant zooplankton group, with the highest T_2 growth and the lowest T_0 growth. The mean (±SD) abundance (×10³ cells/l) of Copepoda were recorded to vary from 0.79±0.41 (T_0), 4.4±0.94 (T_1), 5.43±1.02 (T_2), and 3.86±0.85 (T_3). All the treatments were significantly different (P<0.05).

Cladocera

The mean (±SD) abundances (×10³ cells/l) of Cladocera were found to vary like 0.62±0.44 (T_0), 2.62±0.63 (T_1), 3.21±0.80 (T_2) and 1.81±1.05 (T_3). It showed third dominant groups of zooplankton and were detected in the highest numbers in T_2 and the lowest numbers in T_0. The treatments were significantly different (P<0.05) in terms of Cladocera.

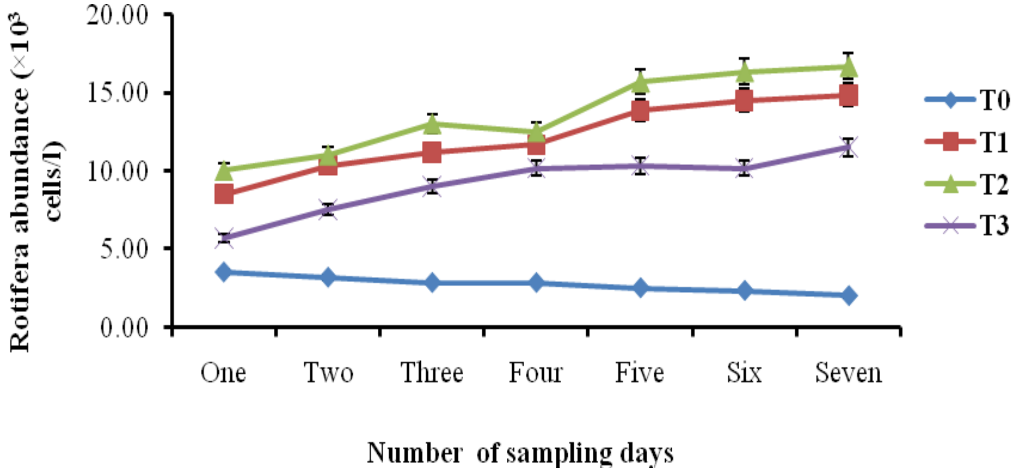

Figure 7. Fortnightly variation of Rotifera.

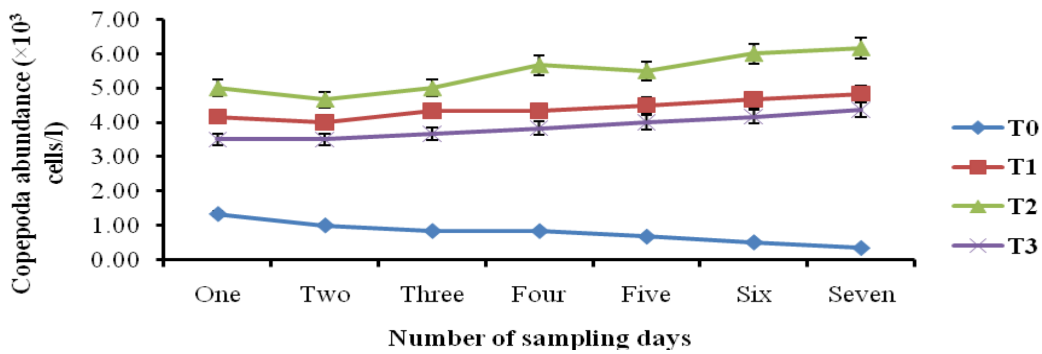

Figure 8. Fortnightly variation of Copepoda.

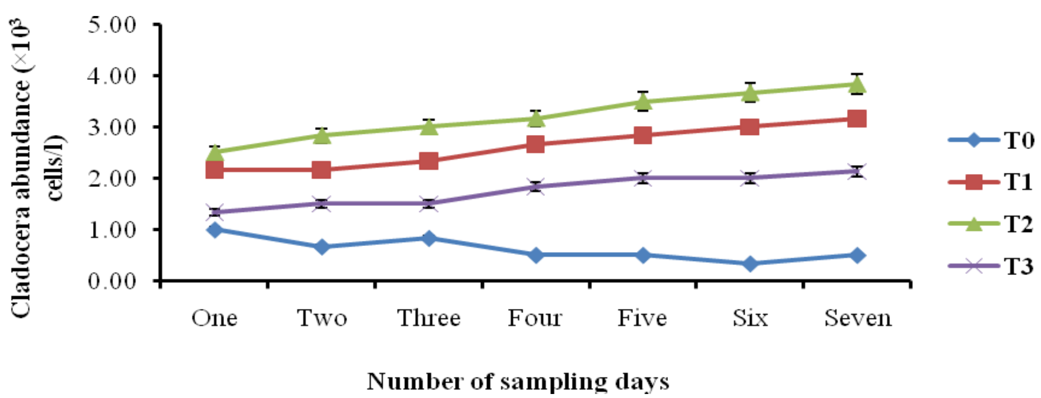

Figure 9. Fortnightly variation of Cladocera.

Crustacea

The mean (±SD) values of Crustacea were 1.74±0.42 in T_0, 1.49±0.38 in T_1, 1.23±0.31 in T_2 and 1.45±0.31 in T_3 treatment showing the least dominant group throughout the experimental period. The treatments T_0, T_1, T_2 and T_0, T_2, T_3 were significantly different (P<0.05) of Crustacea found among T_0, T_1, T_2 and T_0, T_2, T_3. However, for Crustacea, treatments T1 and T3 showed no significant difference.

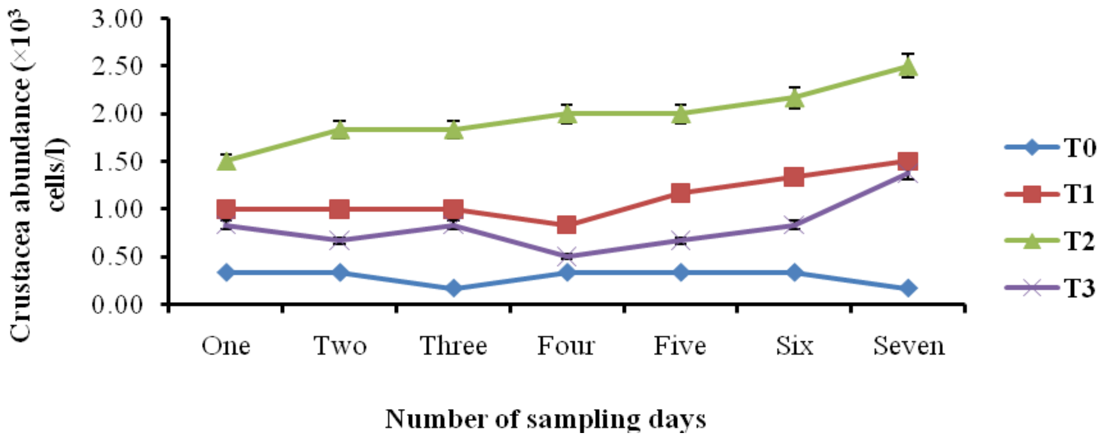

Figure 10. Fortnightly variation of Crustacea

Mean abundance of zooplankton

The mean abundance (×10³ cells/l) of total zooplankton was 4.43±1.69 in T_0, 20.26 ±3.76 in T_1, 24.21±5.45 in T_2 and 15.76±15.76 in T_3 (Figure 11). In November, the abundance was highest in T_2 and lowest in T_0 indicating the positive impact of both fertilizer and unutilized feed. Throughout the study period, Rotifera was the most prevalent zooplankton group, whereas Crustacea was the least prominent. All the treatments were significantly different (*P*<0.05) from each other. Hossen et al. (2018) recorded Copepoda dominancy among zooplankton groups in earthen ponds of Khulna University campus treated with inorganic fertilizers.

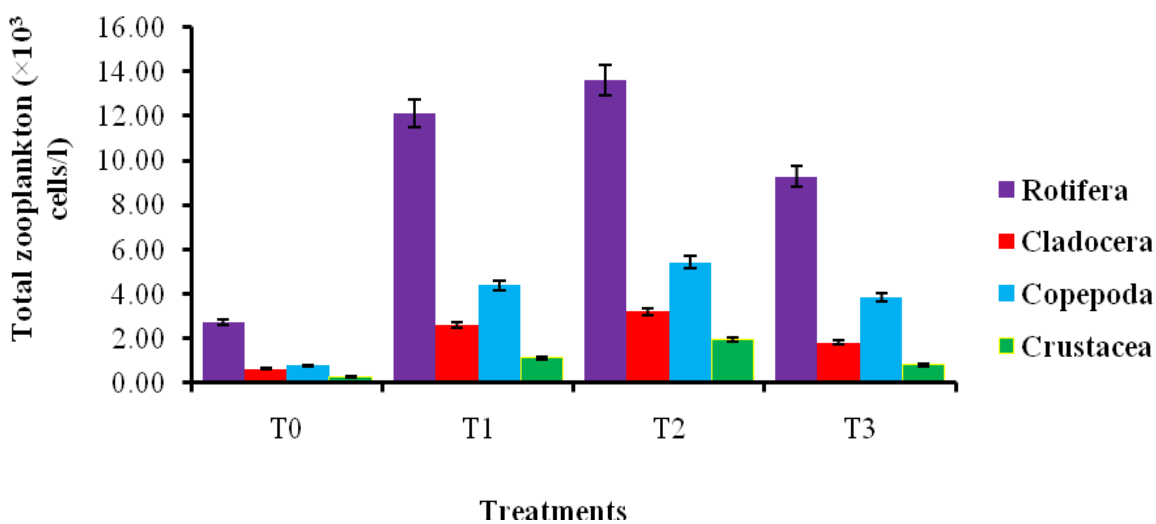

Figure. 11 Mean abundance of total zooplankton

Total plankton

The mean values (×10³ cells/l) of total plankton production was found 16.88±3.12, 55.71±11.68, 77±21.12 and 41.76±7.67 in T_0, T_1, T_2 and T_3 treatment respectively. There were significant differences (*P*< 0.05) present for total plankton among the four treatments. Treatment T_2 was better for total plankton production than treatments T_1, T_3, and T_0, respectively. Soni and Ujjania (2020) recorded a mean value of total plankton 3230 no/l from Vallabhsagar reservoir of Gujrat. Bhatnagar and Singh (2010) recommended optimum plankton population of 3000-4500 no/l as suitable for aqua culture. So the present studied ponds are more productive probably due to fertilization.

Conclusion

Twelve ponds stocked with tilapia were used to test the impact of nutrient management on the plankton population. Throughout the experiment, temperatures, pH, transparency, and dissolved oxygen were all found to be within the acceptable range. For maximum plankton production, proper nutrient management is essential. During the study period, the maximum growth of plankton was found in treatment T_2. Phytoplankton and zooplankton were dominated by

Chlorophyceae and Rotifera, respectively, during the research period. According to the above findings, the combined effect of fertilizer and feed is better for plankton growth in pond environments, which is beneficial to aquaculture.

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