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Original Article

Study of blue-green algae in rural fish ponds, Mymensingh, Bangladesh

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ABSTRACT

As blue-green algal blooms are very frequent in rural fish ponds in Bangladesh throughout the year, a study was carried out in 12 rural fish ponds under four treatments at Sutiakhali, Mymensingh, Bangladesh to see the relationship between environmental parameters and noxious *Cyanobacteria*. In ponds of treatment 1 (T_1), one-third of the water surface was covered by duckweed (*Lemna minor*); in treatment 2 (T_2), 0.5 kg lime/decimal/month was applied; in treatment 3 (T_3), both duckweed (as in T_1) and lime (as in T_2) were applied; and in treatment 4 (T_4), ponds were considered as control where none of duckweed or lime was applied. Around 51 genera of phytoplankton belonging to *Euglenophyceae* (3), *Cyanophyceae* (22), *Cholorophyceae* (16), and *Bacillariophyceae* (10) were recorded. Among *Cyanobacteria*, *Microcystis* spp., *Anabaena* spp., and *Aphanizomenon* spp. abundantly occurred throughout the study period. The highest cell density of *Cyanobacteria* was found in the ponds of T_1 followed by T_4, T_2, and T_3. Acidic pH (>6 and <7) was found to be most conducive for the bloom of cyanophytes. During the early bloom of cyanophytes, both nitrate-nitrogen and phosphate-phosphorus of the pond water were found high and there was a decreasing trend of nutrient concentration from the peak bloom period. In the ponds of T_3, bloom of *Cyanobacteria* did not occur possibly due to alkaline pH and shade, and also nutrient absorption by duckweed. From the research findings, it can be concluded that the combined use of duckweed and lime can be effective in water quality maintenance as well as in controlling cyanobacteria blooms for sustainable fish production.

Keywords: Algal pollution, *Cyanobacteria*, nitrate-nitrogen, pH, phosphate-phosphorus

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INTRODUCTION

The microscopic planktonic algae play an important role in the environment as critical food for fish and crustaceans, but in some situations algal blooms can have a negative effect, causing severe economic losses to aquaculture and fisheries and having major environmental and human health impacts.[1] Harmful algal bloom (HAB) is a threat throughout the world as there are reports of more toxic algal species, more fisheries resources affected, more disease due to algal toxins, and more economic losses from HABs than ever before.[2] Cyanobacteria (blue-green algae) blooms have become increasingly common and causing water quality problems in ponds and lakes in many countries of the world.[3] Toxicity problems with massive fish kills from cyanobacterial blooms have been documented in waters throughout the world.[2,4]

Toxic *Cyanobacteria* are also recognized as a hazard to human and animal welfare. There are many reports that people and animals are becoming acutely ill from contact with water contaminated with blue-green algal toxins. Chorus and Bartram[5] have studied the possible relationship between the consumption of surface drinking water contaminated with toxic blue-green algae (pond, ditch, and river vs. well water or deep well water) and an increased risk for primary hepatic cancer (as well as chronic gastrointestinal diseases) in China. From the evidence in hand, it is clear that HABs are becoming one of the major threats to fisheries and human health as well as to animal welfare.

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In Bangladesh, freshwater ponds and lakes especially in rural areas are used for multipurposes – fish culture, bathing, washing kitchen utensils, cooking, drinking cattle, and in some cases as drinking water of human beings.[6] It is therefore important that the resource base should be used in a sustainable way and that the resource base should not be damaged or destroyed. However, unfortunately, water quality deterioration, especially harmful algal pollution by cyanophytes and euglenophytes, in ponds and lakes are becoming more common and producing increasingly adverse impact on aquaculture as fish farmers apply high doses of fertilizers and feeds in their ponds for getting higher fish production.[7-9] Reduced growth and in adverse situation mortality of fishes, off-flavor from decayed algae and bad odors from fish muscle are often reported.[10] Incidence of hepatitis, dysentery, diarrhea, etc., is also very common in this country which might have direct or indirect link with the cyanotoxins as it is reported elsewhere in the world.

In any year or season, the individual water body has its own populations of harmful and beneficial algae, the dominance of which is dependent not only on the weather but on the specific geochemical conditions of the water body too. The timing and duration of the bloom season of harmful algae depend largely on the climatic conditions of the region. In temperate zones, mass occurrences of *Cyanobacteria* are most prominent during the late summer and early autumn and may past for 2–4 months. In regions with more differences on subtropical climates, the bloom season may start earlier and persist longer.[5] Several factors influence the abundance and toxicity of harmful algae. Growth and toxicity of harmful algae vary from species to species even within the same species when different strains are tested.[11] Seasonal dynamics of *Cyanobacteria* in water resources are the principal component of cyanotoxin monitoring programs and can provide an effective early warning system for the development of potentially toxic blooms. The present paper deals with the influence of environmental factors on the dynamics of *Cyanobacteria* in rural fish ponds with an aim to keep sustainable fish production through controlling noxious algae.

MATERIALS AND METHODS

Location and Pond Facilities

The experiment was carried out for a period of 5 months from mid-June to mid-November in 12 rain-fed ponds in Sutiakhali, Mymensingh, Bangladesh. The ponds were not interconnected and had no inlet or outlet.

Experimental Design

The experiment was conducted under four treatments, namely, T_1, T_2, T_3, and T_4 each with three replications. T_1 and T_2 were assigned to the ponds treated with duckweed and lime, respectively. T_3 was assigned to the ponds treated with both duckweed and lime and T_4 as control ponds.

Pond Preparation

The experimental ponds were dried, renovated, and exposed to sunlight for several days. The pond bottoms were treated with lime at the rate of 1 kg/decimal. Both organic and inorganic fertilizers were applied after 7 days of liming. One-third of the water surface of the ponds of T_1 and T_3 was covered with duckweed.

Collection and Analysis of Water Samples

Water quality parameters (temperature, pH, phosphate-phosphorus, and nitrate-nitrogen) were analyzed fortnightly in the Water Quality and Pond Dynamics Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, Bangladesh. The temperature was measured with a Celsius thermometer. pH was measured with an electric pH meter (Jenway, Model 3020 UK). The concentration of phosphate-phosphorus and nitrate-nitrogen was recorded directly from the reading of spectrophotometer (HACH Kit, DR 2010) with Phosver 3 and Nitriver 5 powder pillows for 25 ml filtered water samples.

For plankton enumeration, water samples were collected from a different depth of each pond. A known volume (10–15 L) of water sample was collected in a plastic bucket and passed through a plankton net of 25 μm mesh size. The concentrated plankton samples were preserved in plastic vials with 5% buffered formalin for subsequent studies.

The number of cells was counted using a Sedgewick-Rafter (S-R cell) counting cell under a microscope. Population size was calculated from an average of the cell number per milliliter. The qualitative study of phytoplankton was done up to generic level following APHA[12] and Bellinger.[13]

All the data collected throughout the study period were analyzed statistically following analysis of variance (ANOVA) and correlation for interpretation of the results.

RESULTS

The temperature was found to vary from 28.9 to 31.9°C, and pH fluctuated between 6.56 and 8.09 throughout the study period [Figure 1a and b]. The highest value of p_H (8.09) was observed in the lime treated ponds (T_2) at the end of July and the lowest (6.56) in the control ponds in mid-August.

A significant variation of nitrate-nitrogen (0.60–1.51 mg/l) was found in the control ponds. In the control ponds, a sharp increase of nitrate-nitrogen was recorded on July 30 and then started to decrease [Figure 2a]. Lower concentration of nitrate-nitrogen was observed in the duckweed treated ponds (T_1 and T_3) with a minimum value (0.40 mg/l) in T_3 on September 15. A significantly higher concentration of phosphate-phosphorus was observed in the control ponds with a maximum value

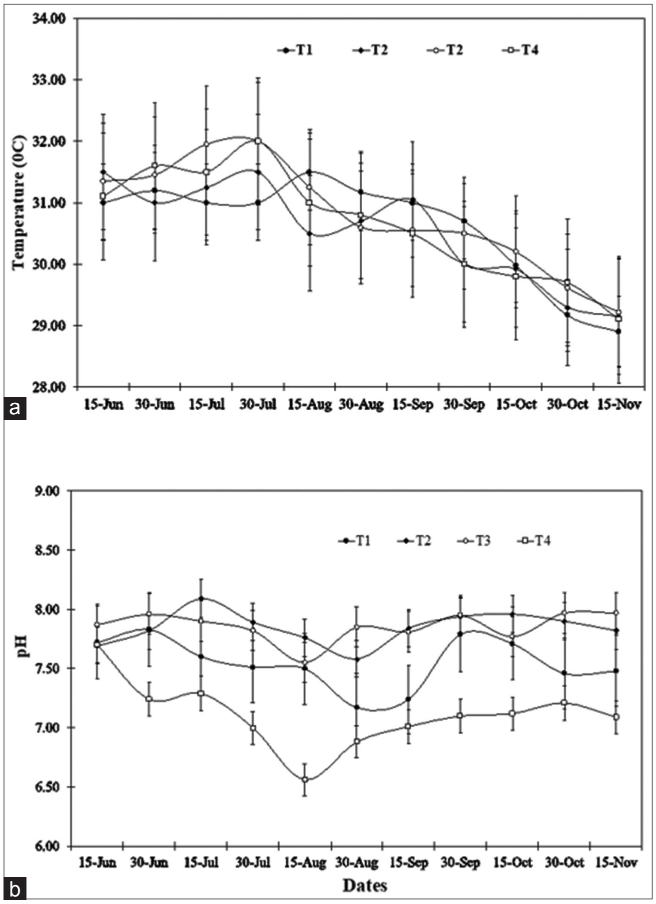

Figure 1: Fortnightly variations of temperature (a) and pH (b) in the ponds of T_1, T_2, T_3, and T_4 in Sutiakhali, Mymensingh, Bangladesh

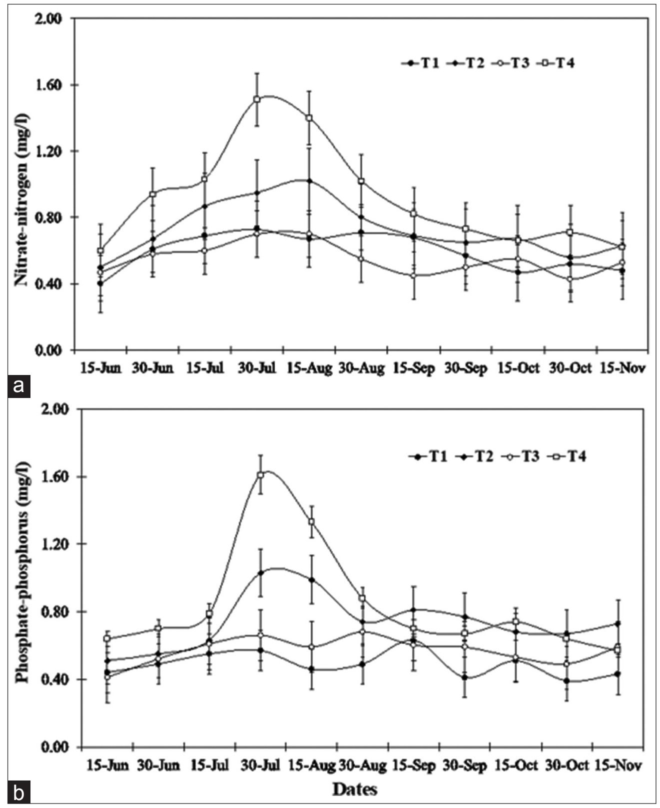

Figure 2: Fortnightly variations of nitrate-nitrogen (a) and phosphate-phosphorus (b) in the ponds of T_1, T_2, T_3, and T_4 in Sutiakhali, Mymensingh, Bangladesh

(1.61 mg/l) on July 30 [Figure 2b]. Comparatively lower concentration of phosphate-phosphorus was recorded in the duckweed treated ponds (T_1 and T_3).

About 51 genera of phytoplankton belonging to *Euglenophyceae* (3), *Cyanophyceae* (22), *Cholorophyceae* (16), and *Bacillariophyceae* (10) were recorded from the studied ponds. Euglenophytes and cyanophytes were the dominant or codominant phytoplankton over the study period. The abundance of chlorophytes occupied third place, and bacillariophytes were the least abundant group of phytoplankton throughout the study period.

The highest number of total phytoplankton (45.79×10^4 cells/l) was exhibited in T_4 (control ponds) in mid-August, and the minimum (6.11×10^4 cells/l) was exhibited in T_3 (both duckweed and lime treated ponds) in mid-June [Figure 3]. On the basis of mean value, the highest cell density was enumerated in control ponds (T_4). Duckweed treated ponds (T_1) occupied the second position and then the lime treated ponds (T_2). The lowest abundance was recorded in T_3 where both lime and duckweed were applied.

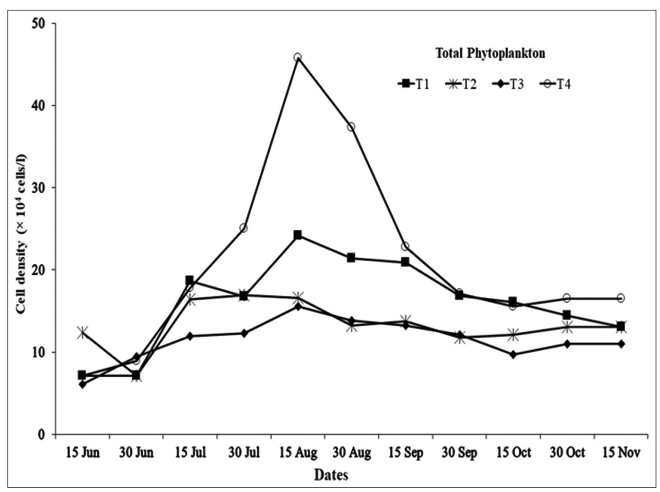

Figure 3: Fortnightly variations in the abundance of total phytoplankton in farmers ponds under four treatments in Sutiakhali, Mymensingh, Bangladesh

A total of 22 species of *Cyanobacteria* belonging to 9 genera were identified of which *Microcystis* spp., *Anabaena* spp., and *Aphanizomenon* spp. abundantly occurred throughout the study period [Table 1].

The cell density of cyanophytes started to increase in all ponds in mid-July and showed heavy bloom in the ponds of T_1 and T_4 at the end of July when the temperature was 31.0 and 31.5°C in T_1 and T_4, respectively. The peak blooms were found in T_1 and T_4 in mid-August, and after that, the cell density started to decrease with decreasing water temperature [Figure 4].

The abundance of cyanophytes in relation to different pH values showed that the cell density increased at acidic pH (pH <7.0) and showed a declining trend with increasing pH value (pH >7.0) [Figure 5]. The highest cell density was recorded in the ponds of T_1 (duckweed treated ponds) and T_4 (control ponds) when pH was acidic. It was also observed that the density of cyanophytes was comparatively lower in lime treated ponds (T_2 and T_3) where pH value was alkaline (pH >7.0).

Table 1: List of blue-green algae identified during the study period

Species	
Microcystis aeruginosa	*Anabaena crassa*
Microcystis wesenbergii	*Anabaena curva*
Microcystis viridis	*Anabaena fusca*
Microcystis flos-aquae	*Anabaena mendota*
Microcystis natans	*Anabaena smithii*
Microcystis botrys	*Anabaena spiroides*
Microcystis robusta	*Anabaena flos-aquae*
Aphanocapsa delicatissima	*Snowella litoralis*
Anabaenopsis spp.	*Aphanizomenon elenkenii*
Chroococcus turgidus	*Oscillatoria* spp.
Chroococcus limneticus	*Gomphosphaeria aponica*

The relationship between cyanophytes cell density and nutrient concentrations is shown in Figures 6 and 7. During the early bloom of cyanophytes, both nitrate-nitrogen and phosphate-phosphorus were high, and there was a decreasing tendency of nutrient concentration from peak bloom period. Blooms of noxious algae were found to use a significant amount of nutrients of the water bodies for their growth. In relation to the role of the nutrients on phytoplankton abundance, it was observed that cyanophytes preferred higher nutrient concentration.

The size of cyanophytes population in the ponds appeared to be correlated with pH and the nutrients [Figures 5-7]. The population size of cyanophytes was positively correlated with phosphate (r = 0.23, P < 0.05) and nitrate concentration (r = 0.28, P < 0.05) while negatively related with pH (r = 0.30, P < 0.05).

DISCUSSION

Pollution due to residual effects of aquaculture inputs, domestic wastes, surface run-off, and nutrients from agricultural land is very common phenomena in fishponds of Bangladesh. Over the past decade, fish farmers are experiencing many new unexpected problems such as environmental degradation with noxious algal blooms, ammonia toxicity, and different fish diseases.[14]

The bloom of *Cyanobacteria* is very common in fish ponds of Bangladesh. It often leads to algal die-off and environmental

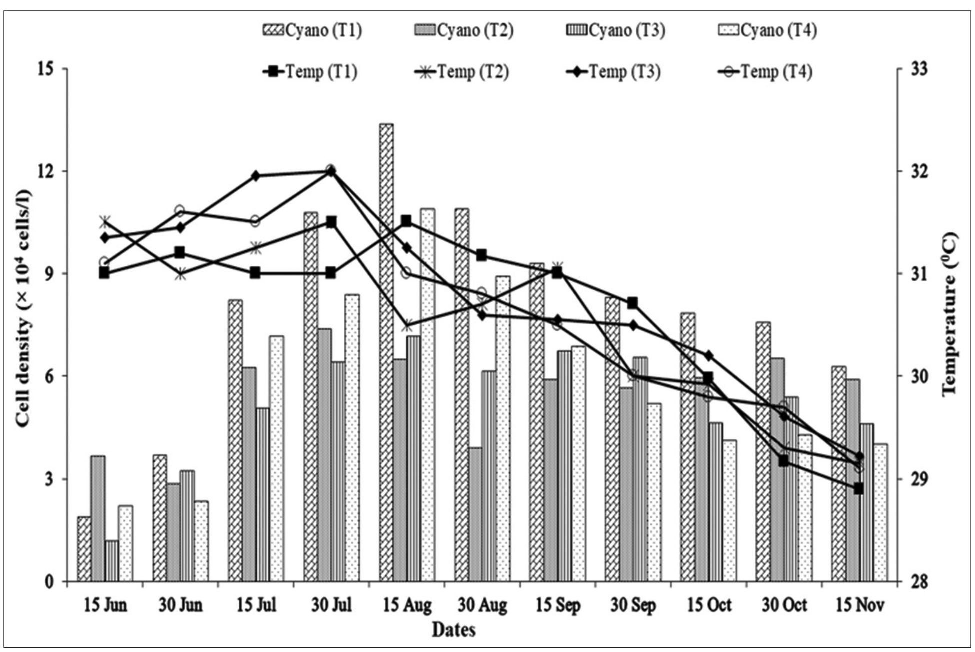

Figure 4: Relationship between cyanobacterial cell density and temperature in ponds of T_1, T_2, T_3, and T_4 in Sutiakhali, Mymensingh, Bangladesh

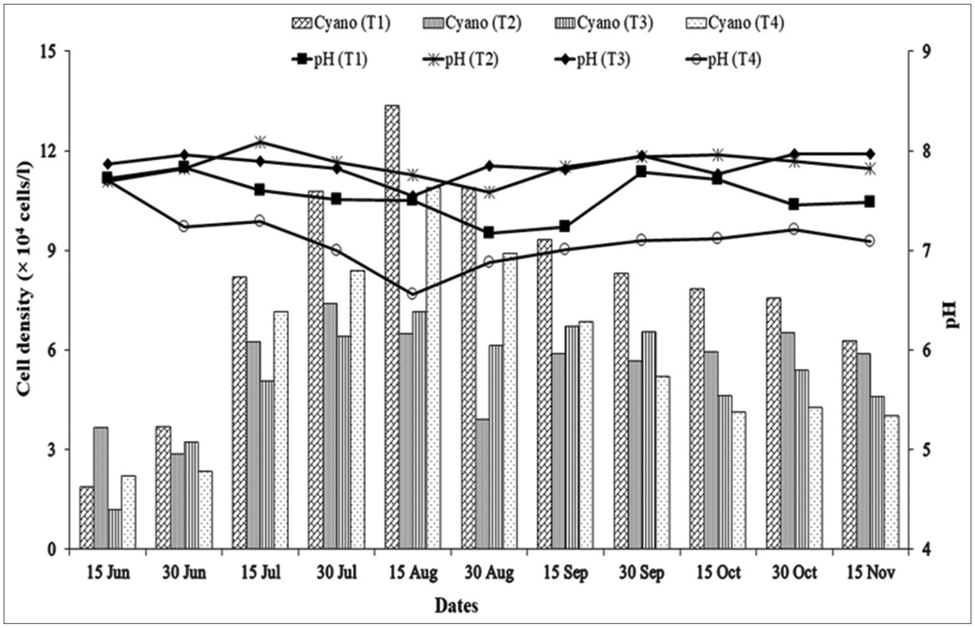

Figure 5: Relationship between cyanobacterial cell density and pH in ponds of T_1, T_2, T_3, and T_4 in Sutiakhali, Mymensingh, Bangladesh

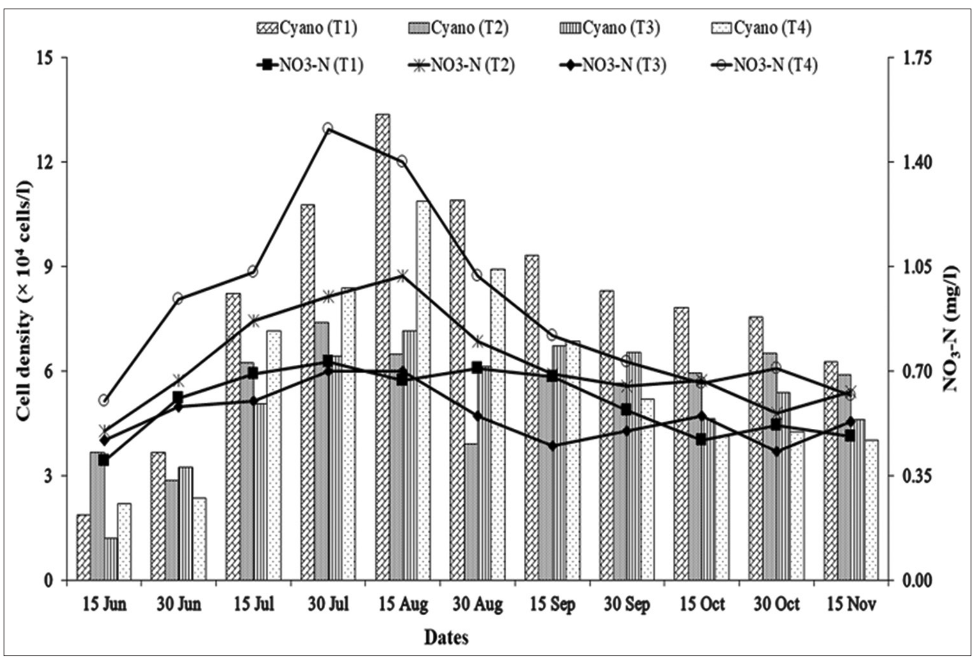

Figure 6: Relationship between cyanobacterial cell density and nitrate-nitrogen in ponds of T_1, T_2, T_3, and T_4 in Sutiakhali, Mymensingh, Bangladesh

degradation that ultimately hamper or reduce fish production. Cyanobacterial bloom can cause problems through biomass effects, shading of submerged vegetation, disruption of food web dynamics and structure, and oxygen depletion as the bloom decay. Some bloom-forming genera of noxious algae have significant effect in reducing the number of other algal species in aquaculture ponds.[15] During heavy bloom of harmful algae, the fishes breathe with difficulty at the surface and the algae attach to the gill in some cases. As a result, the fishes eat less and lose their weight markedly.[16] The present experiment was planned to minimize or control the negative impacts of cyanophytes bloom as well as improve the water quality for sustainable low-cost input based fish production using duckweed (*Lemna minor*) and lime in the experimental fish ponds.

The growth and development of cyanophytes depend on the combination of a set of factors such as sunlight,

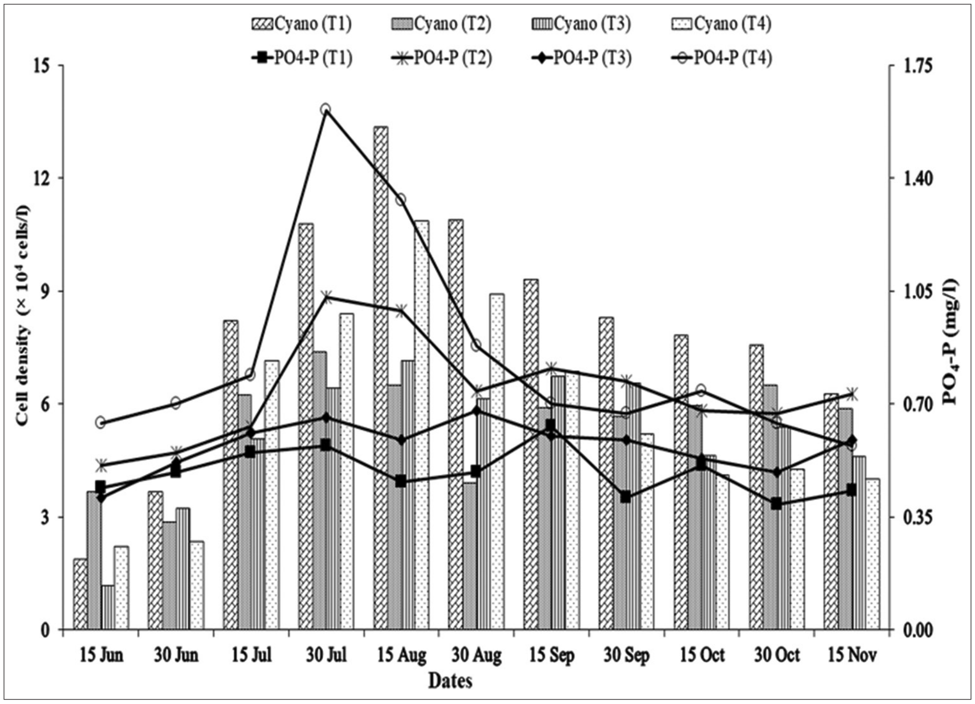

Figure 7: Relationship between cyanobacterial cell density and phosphate-phosphorus in ponds of T_1, T_2, T_3, and T_4 in Sutiakhali, Mymensingh, Bangladesh

temperature, pH, and nutrients. The higher number of cyanobacterial species was recorded in acidic pH when water temperature, nutrient values, and BOD were high.[16-20] In the present study, bloom of *Cyanobacteria* was observed in the duckweed treated ponds (T_1) where pH was more or less neutral whereas in the lime treated ponds (T_2), the bloom did not occur where pH was alkaline. In our study, the lowest cell density of *Cyanobacteria* was found in duckweed and lime treated ponds (T_3), where pH was alkaline, and nutrients were comparatively lower. The bloom of *Cyanobacteria* was also found in the control ponds (T_4) where pH was acidic, and nutrients contents were comparatively higher.

From our results, the lower cell density of cyanophytes was observed in the lime and duckweed treated ponds, which might be due to alkaline pH and nutrient absorption by the duckweed. Zakrys and Walne,[18] Olaveson and Nalewajko,[19] Xavier *et al*.,[16] and Olaveson and Stokes[20] concluded that noxious algal blooms prefer acidic pH. Bergmann *et al*.,[21] Perniel *et al*.,[22] Cheng *et al*.,[23] Steward,[24] and Sutton and Ornes[25] found the use of duckweed (*L. minor*) as an effective measure in reducing total nitrogen, NH_3-N, total phosphorus, orthophosphate-P, and total organic carbon from the aquatic environment. In our study, it is obvious that *Cyanobacteria* can develop in small number at alkaline pH (pH >7.0) and lower nutrients contents as it occurred in our duckweed treated ponds but acidic pH (pH <7.0) and higher nutrients contents are essential for its bloom formation.

From our results, it was observed that euglenophytes and cyanophytes were the most dominant groups followed by chlorophytes and bacillariophytes. These findings agree with the findings of Mishra and Saksena[26] who reported that in nutrient-rich water bodies, the percentage of cyanophytes and euglenophytes were higher compared to bacillariophytes and chlorophytes. Hosmani[27] reported that the blooms of noxious algae have a significant effect in reducing the number of other algal species in aquaculture ponds. This phenomenon was also supported by Leupold[15] who reported that some bloom-forming phytoplankton has significant effect in reducing the number of other algal species in aquaculture ponds.

CONCLUSION

From the aforesaid research findings and data in the literature, it can be concluded that both duckweed and lime together are better to minimize the negative impacts of cyanobacterial blooms as well as for getting higher fish production since duckweed is used as fish food and it reduces the nutrients through bio-filtration from the pond water and lime keeps the environment alkaline which is unfavorable for heavy growth of harmful blue-green algae.

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