Asian Journal of Fisheries and Aquatic Research

Volume 26, Issue 8, Page 75-82, 2024; Article no.AJFAR.120511
ISSN: 2582-3760

Optimizing Plankton Growth and Diversity in Biofloc Systems through Silica Supplementation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajfar/2024/v26i8797

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/120511

Original Research Article

Received: 28/05/2024
Accepted: 02/08/2024
Published: 09/08/2024

ABSTRACT

Biofloc is a fish cultivation system that relies on a collection of microorganisms, such as bacteria, protozoa, and microalgae, that live in the form of flocs or clumps. This study aims to determine the effect of varying silica concentrations on plankton abundance and diversity index in biofloc systems. Conducted from February to March 2024, the research employed a Completely Randomized Design (CRD) method with four treatments (0 ppm, 15 ppm, 20 ppm, and 25 ppm) and three replications each. The parameters observed were phytoplankton abundance, zooplankton abundance, and diversity index. Observation of plankton abundance using a 10 x 10 magnification microscope using SRC (Sedgewick Rafter-counting Cell) with a volume of 1 ml and diversity index using the Shannon

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Cite as: *Tafdrian, Muhammad Khofi Istakhfi, Ujang Subhan, Yuniar Mulyani, and Iskandar. 2024. "Optimizing Plankton Growth and Diversity in Biofloc Systems through Silica Supplementation". Asian Journal of Fisheries and Aquatic Research 26 (8):75-82. https://doi.org/10.9734/ajfar/2024/v26i8797.*

Wierner method. The results of this research are that the addition of a silica concentration of 15 ppm is the best concentration with a phytoplankton abundance value of 450,729 cells/L, a zooplankton abundance of 827,778 cells/L and a diversity index of 2,662.

Keywords: Plankton; microorganisms; ammonia.

1. INTRODUCTION

The biofloc system is a method of fish cultivation that has developed rapidly in recent years. This method is known for its efficiency in utilizing organic waste produced by farmed fish. Biofloc includes a number of microorganisms, such as bacteria and algae, which play a role in maintaining water quality and providing nutritional support for cultivated organisms [1]. Biofloc technology is a technique for improving water quality through adding extra carbon to aquaculture systems, through external carbon sources or increasing carbon content in feed [2]. This system not only improves water quality, but can also increase overall fishery productivity. This system can increase the growth rate of fish because the microorganisms in the biofloc also function as an additional food source, By having microorganisms as additional feed, feed costs can be reduced because the need for commercial feed can be reduced. Biofloc technology is one of the most profitable alternative solutions to aquaculture waste problems because apart from being able to reduce inorganic nitrogen waste, this technology can also provide additional protein feed so that it can increase growth and feed efficiency [3].

In a biofloc system, microorganisms convert ammonia to nitrite and then to the less toxic nitrate. Silica can increase the efficiency of this process by providing an environment that supports the growth of nitrifying microorganisms. One of the important elements in the biofloc system is plankton. Plankton functions as a natural food source that is rich in nutrients for fish. Plankton are aquatic organisms at the tropic level and function as energy providers. In general, plankton can be divided into two, namely phytoplankton in the form of plants, while those in the form of animals are often called zooplankton. Phytoplankton is a producer of oxygen in the aquatic environment because of its photosynthetic ability, and is the basis of the food chain of living organisms in water [4]. The role of zooplankton as the first consumers connecting phytoplankton with small and large carnivores can influence whether or not the food chain is complex in aquatic ecosystems [5]. Therefore, various efforts have been made to increase the abundance and diversity of plankton, one of which is by adding silica.

Silica is known as an important nutrient for several types of plankton, especially diatoms, which need silica to form cell walls. Diatoms are unicellular microalgae that have strong cell walls and are rich in silica [6]. It should be understood that the role of silica in biofloc is closely related to the presence of plankton, namely plankton. Therefore, if you want to increase the role of silica in a biofloc system, ensuring conditions that support plankton growth and diversity can be an important consideration.

The presence of silica can strengthen the floc structure in biofloc. This can increase floc durability and stability, which is a critical aspect in maintaining water quality. If the water quality is not good, it will result in slow fish growth. Apart from water quality, oxygen plays an important role in the growth rate of tilapia. Oxygen levels are an important environmental factor, if the dissolved oxygen concentration is low, the appetite of the cultivated organism decreases thereby affecting growth and resistance to disease, conversely if the low dissolved oxygen concentration continues then it is likely that the cultivated organism will die due to lack of oxygen [7]. The provision of silica in the biofloc system is expected to encourage the growth of diatoms which in turn can increase the overall plankton abundance and diversity index.

2. MATERIALS AND METHODS

2.1 Research Area

The research was carried out for 45 days starting in February 2024 until March 2024 at PUI-PT Nano Powder Functional, Padjadjaran University for maintenance activities and plankton observation activities in the Aquaculture Laboratory Building 2, Faculty of Fisheries and Marine Sciences, Padjadjaran University.

2.2 Experimental Design

The materials used in this research are silica, molasses as a carbon source to increase carbon levels to achieve a C/N ratio of 16. EM4 is a probiotic that is quite good for ponds so that it can utilize microorganisms found in the water. Dolomite lime in a biofloc system can provide several benefits, especially in regulating water pH and providing nutrients for aquaculture organisms. Krosok salt to reduce acid levels in water. The containers used for the silica application test were 12 cylindrical tubes measuring 19 L, aeration equipment, a heater, a net, label paper, a microscope, a dropper, sedgewick rafter, and a 1 L measuring cup.

2.3 Silica Treatments

The method used in this research was a Completely Randomized Design (CRD) method with 4 treatments and 3 replications, giving silica concentration to each treatment includes:

Treatment A = (control) does not use silica or 0 ppm

Treatment B = addition of 15 ppm of silica

Treatment C = addition of 20 ppm of silica

Treatment D = addition of 25 ppm of silica

2.4 Statistical Analysis

2.4.1 Plankton abundance

Plankton abundance Observation of plankton under a 10 x 10 magnification microscope using SRC (Sedgewick Rafter-counting Cell). The formula for calculating plankton abundance using SRC is as follows [8].

$$N = n \times A/a \times v/vc \times 1/V$$

Information:

N = plankton abundance (cells/L)
n = number of phytoplankton enumerated (cells/L)
A = area of one field of view (1,000 mm2)
a = area of the cover glass (1,000 mm2)
v = volume of concentrated water (300 mL)
vc = volume of water under the cover glass (1 mL)
V = volume of water in the ring (100 L)

2.4.2 Diversity index

The Shannon Wierner species diversity index [9] is calculated using the formula:

$$H' = \sum \mathrm{Pi}\ \mathrm{InPi}$$

Information:

H' = Shannon-Wiener diversity index
Pi = Abundance index
Ni = Number of individuals of type i
N = Total number of individuals

Determination of criteria:

H' < 1 = low diversity
I < H' <3 = moderate diversity
H' < 3 = high diversity

3. RESULTS AND DISCUSSION

3.1 Abundance of Plankton

3.1.1 Abundance of phytoplankton

Based on the results of observations of the initial abundance of phytoplankton in the first to the last week during maintenance, it shows that there was an increase (Fig. 1). This shows that giving silica with different treatments can affect the abundance of phytoplankton. Differences in phytoplankton abundance during observations appeared to fluctuate, where the lowest phytoplankton observations were in week 1, namely in treatment A (control) with a value of 126,944 cells/L and the largest was in treatment B (15 ppm) with a value of 450,729 cells/L.

The abundance of phytoplankton in treatment B which was given additional silica concentration of 15 ppm was the highest treatment (Fig. 1) and the best treatment for the growth of phytoplankton (diatoms) (Fig. 2). This is caused by the role of silica. Silica (SiO_2) has a significant influence on the abundance of phytoplankton, especially diatoms, which require silica to form frustules or cell walls. Diatoms are a type of phytoplankton that rely heavily on silica to form cell walls.

With sufficient silica, diatoms can grow and reproduce more quickly, thereby increasing the abundance of diatoms in aquatic ecosystems. the importance of silica in supporting diatom growth and changes in silica availability can have a significant impact on phytoplankton community structure and dynamics of aquatic ecosystems [10]. With high nutrient concentrations, the phytoplankton community is dominated by several species that can adapt to eutrophic conditions. In contrast, locations with low nutrient concentrations show a more balanced species diversity [11].

Based on observations, it shows that the highest percentage of phytoplankton abundance in the 6th week was obtained in treatment B (15 ppm) (Fig. 2). The phytoplankton in treatment B (15 ppm) which was given the best concentration of silica was dominated by diatoms (Bacillariophyta), while in the treatment which was not given the highest concentration of silica, the highest percentage of phytoplankton was dominated by Chlorophyta. This shows that the addition of silica can affect the growth of diatoms [12].

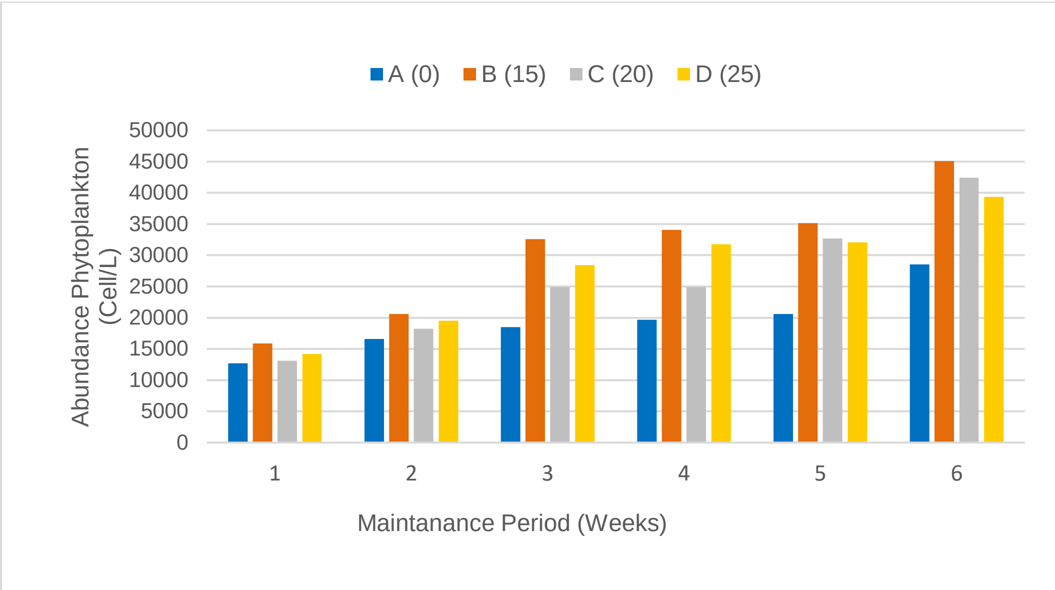

Fig. 1. Abundance Phyplankton

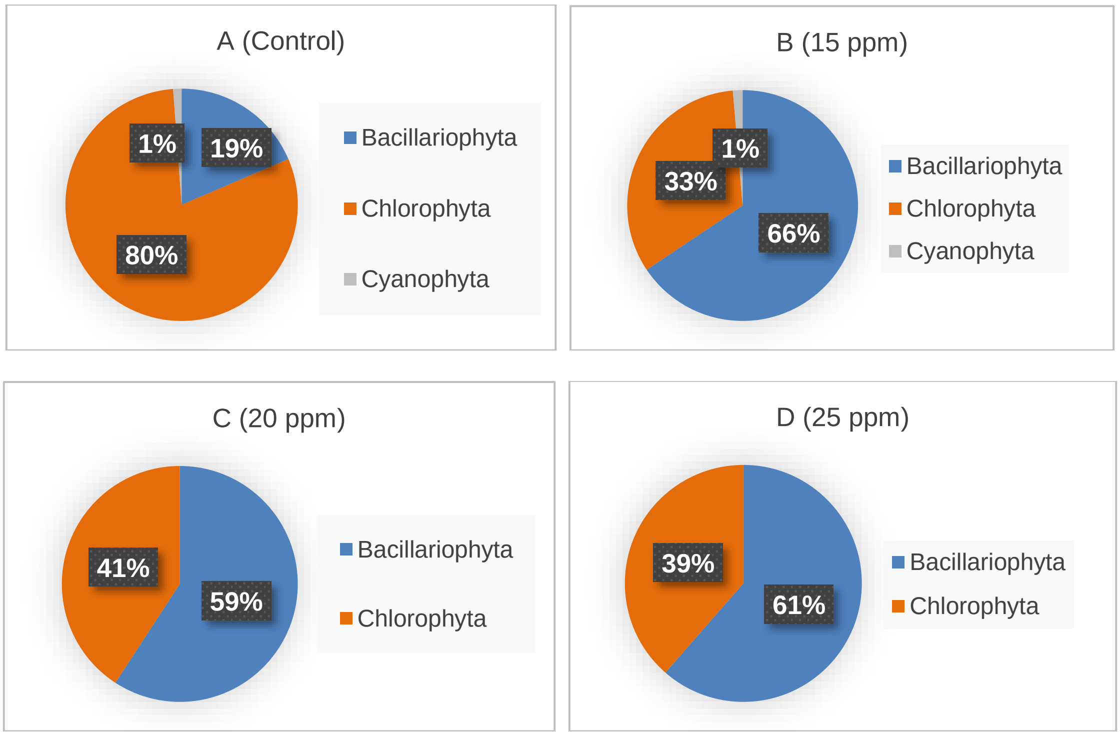

Fig. 2. Percentage of plankton abundance in week 6

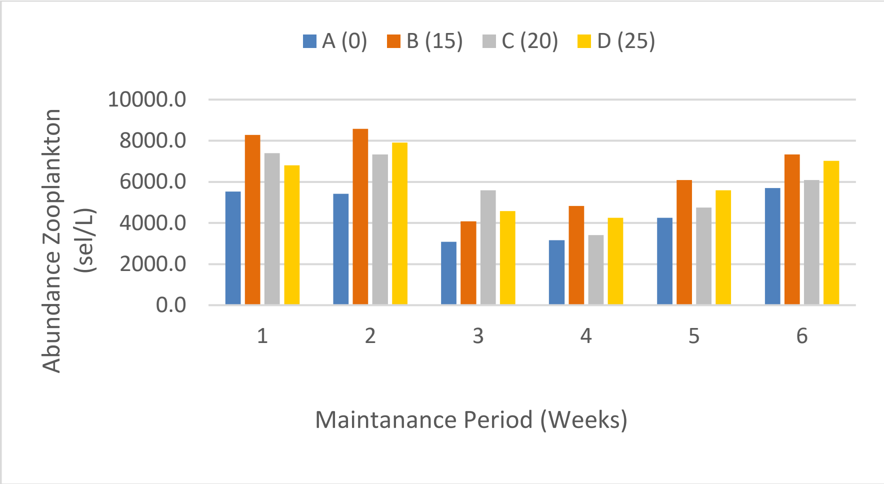

Fig. 3. Abundance Zooplankton

In accordance with the opinion of silica is a very essential macro nutrient that is needed for the growth of microalgae. Bacillariophyceae dominates in all treatments, this is because the Bacillariophyceae class is a phytoplankton class that has a high level of adaptation so that it can easily adapt to the surrounding environment compared to other phytoplankton [13]. classes Some algae, especially diatoms, need silica to form frustules (cell walls). Diatom cells can divide within 24 hours and high diatom abundance can occur quickly in line with changes in the aquatic environment. Silica allows Bacillariophyta (diatoms) to dominate phytoplankton communities, especially in conditions where silica is a limiting factor. By supporting the growth of diatoms, silica can reduce the dominance of other phytoplankton species that do not require silica, creating a better balance in the ecosystem.

3.1.2 Abundance of zooplankton

Based on the results of observations of the initial abundance of zooplankton during maintenance, it was found that treatment with the addition of silica had an influence on the abundance of zooplankton. The differences in zooplankton abundance that occurred during the study seemed quite fluctuating. In the 1st week, the abundance of zooplankton in treatment B (15 ppm) was the highest, namely 827,778 cells/L and the lowest was treatment A (0 ppm) with a value of 552,278 cells/L.

Based on Fig. 3, the highest abundance of zooplankton was in the 2nd week, namely 858,333 cells/L. The high levels in treatment B (15 ppm) were probably influenced by the availability of zooplankton food sources. Feed has a big influence on the growth of zooplankton. Zooplankton are the first consumers of the main phytoplankton products [14]. The role of zooplankton as a link between large and small primary producers has the potential to influence the complexity of the food chain in aquatic ecosystems, so that the presence of zooplankton is directly proportional to the presence of phytoplankton [4].

heterotrophic zooplankton will eat phytoplankton directly, while indirectly herbivorous zooplankton will be eaten by carnivorous zooplankton and other larger animals, including fish. Phytoplankton is food for zooplankton and functions as natural food in water bodies [15]. The availability of phytoplankton which contains proteins, carbohydrates, fats, vitamins and minerals fulfills nutritional needs and influences the survival of fish and other organisms in the aquatic environment. Phytoplankton not only functions as a food producer but also as an indicator of the fertility of a water body [16]. With the presence of silica, phytoplankton (diatoms) can form cell walls that are stronger and resistant to predation, thereby increasing the production of diatom biomass in a system, which ultimately contributes to increasing the overall abundance of phytoplankton. This is because silica can affect the abundance of phytoplankton and phytoplankton are used by zooplankton as food which causes zooplankton to become abundant.

3.2 Diversity Index

Based on the results of observing the diversity index (Fig. 4), plankton in each treatment with different doses of silica in treatment B (20 ppm) was the highest at 2.662. This shows that giving silica with different treatments can affect the diversity index of plankton including diatoms. The differences between the treatments were not too different, where the lowest treatment was treatment A (control) with a value of 2.409 and the highest treatment was treatment B (15 ppm) with a value of 2.662**.**

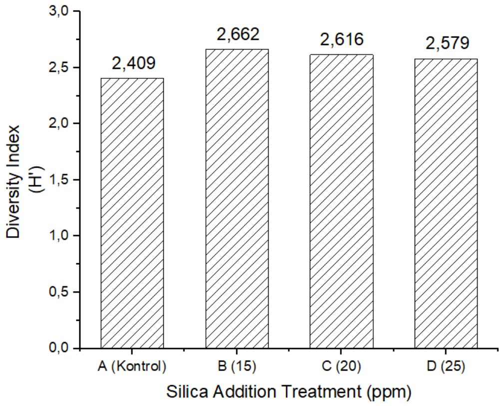

Fig. 4. Diversity Index

The plankton diversity index (diversity) in the control treatment with different silica addition treatments ranged from 2.409 - 2.662, meaning moderate diversity. This value describes the stability of the plankton community in a fairly stable condition. So that the condition of the aquatic environment throughout the sampling treatment can be said to be good. Moderate diversity can support good ecosystem productivity, with various phytoplankton playing a role in the aquatic food chain and supporting other organisms such as zooplankton and fish.

The plankton species identified during the research consisted of the phytoplankton group, namely from the Bacillariophyta, Chlorophyta, Cyanophyta classes, while the zooplankton group was dominated by the Rotifera group. Nutrients such as nitrogen and silica can influence phytoplankton growth. Adequate and balanced nutrient availability supports higher diversity by allowing different types of phytoplankton to grow.

Table 1. Abundance of Plankton

Class	Genus	Number of Plankton (sel/L)				Total
		A	B	C	D	
Bacillariophyta	Navicula rinchocephala	209	661	635	651	2156
	Pinnularia legumen	40	325	426	342	1133
	Gomphonema lancylatum	18	198	142	180	538
	Navicula brachysira	31	0	40	24	95
	Cyclotella operculata	370	638	403	486	1897
	Pleurosigma delicatum	18	237	21	60	336
	Nitzschia vernicularis	13	168	18	23	222
	Diatomae vulgare	15	144	76	210	445
	Cocconeis placentula	378	398	420	420	1616
	Total	**1092**	**2769**	**2181**	**2396**	
Chlorophyta	Dimorphococcus lunatus. A. Br	84	194	160	100	538
	Eudorina wallichii. Tum	176	118	0	24	318
	Hydrodiction rutuculutua	31	0	26	17	74
	Oocystus Naegelii	137	30	72	126	365
	Botryococcus braunii	129	100	188	15	432
	Netrium digitus	32	184	120	65	401
	Hydrodictyon reticulatum	39	0	226	17	282
	Volvox	22	0	162	61	245
	Sceneadesmus quadricauda	63	42	13	0	118
	Total	**713**	**668**	**967**	**425**	
Cyanophyta	Coelosphaerium dubium Gronow	30	22	9	14	75
Rotifera	Brachionus falcatus	75	0	0	0	75
	Euchlanis dilatata	193	231	0	98	522
	Cathypna ungulata	269	489	301	110	1169
	Dipleuchlanis propatula	0	0	0	0	0
	Asplanchna herricki	0	120	168	60	348
	Brachionus bakeri	342	0	0	0	342
	branchionus	889	520	627	68	2104
	Diurella tunuior	0	0	0	76	76
	Total	**1768**	**1360**	**1096**	**412**	**15922**

Based on Table 1, in treatment A (0 ppm) the plankton group is dominated by the Rotifera class, namely the Branchionus genus, with 889 cells/L, while in treatment B (15 ppm), the plankton group is dominated by the Bacillariophyta class, namely the Navicula rinchocephala genus, with 661 cells/L, and in treatment C (20 ppm), the plankton group is dominated by the Bacillariophyta class. namely the genus Navicula rinchocephala at 635 cells/L, and treatment D (25 ppm) in the plankton group was dominated by the Bacillariophyta class, namely the genus Navicula rinchocephala at 652 cells/L. Bacillariophytes such as Navicula rinchocephala help reduce excess nutrient concentrations, which is important for maintaining good water quality in a biofloc system [17]. In accordance with the opinion of the importance of the silica cycle in aquatic ecosystems and how silica affects the growth and distribution of diatoms (Bacillariophyta) [18].

Phytoplankton play an important role in nutrient cycling and water oxygenation. High phytoplankton abundance can help reduce excess nutrient concentrations (such as ammonia and nitrate) through assimilation processes, which improves water quality and reduces the risk of eutrophication. The presence of diatoms in a biofloc system can have several potentially positive influences on the performance of the aquaculture system and organisms. Diatoms carry out photosynthesis and produce oxygen. The presence of diatoms in biofloc can increase oxygen production in the water. Sufficient oxygen is very important for the health of aquaculture organisms and the stability of the biofloc ecosystem.

4. CONCLUSION

The addition of silica with different concentrations can affect the abundance of plankton in the floc, The results indicate that a silica concentration of 15 ppm is optimal with a phytoplankton abundance value of 450,729 cells/L, zooplankton abundance of 858,333 cells/L and the addition of silica with a concentration of 15 ppm on Treatment B is the best treatment for the diversity index, namely with a value of 2.662.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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