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European Journal of Experimental Biology, 2013, 3(3):48-55

ISSN: 2248 –9215
CODEN (USA): EJEBAU

Effect of dietary supplementation of mannan oligosaccharide on water quality parameters in a recirculatory aquaculture system

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ABSTRACT

The effect of mannan oligosaccharide (MOS) on the water quality parameters of a recirculatory aquaculture system growing Indian major carp Labeo rohita was evaluated out for a period of 120 days. The basal diet in all trials contained 35% protein with different dosages of MOS at 0.0, 0.15, 0.30 and 0.45% in triplicates. Uniform sized fish fingerlings averaging 1.3g were used for the experiments. The different water quality parameters viz, temperature, PH, dissolved oxygen, free carbon dioxide, total alkalinity and ammonia-nitrogen were found to vary during the culture period.

INTRODUCTION

The global total production of fish, crustacean and molluscs has continued to increase and reached **154** million tonnes in 2011. While capture production has stagnated around 90.4 million tonnes since 2001. The aquaculture production has continued to show strong growth, increasing at an average annual growth rate of 6.5% from 36.8 million tonnes in 2002 to 63.6 million tonnes in 2011 (FAO, 2012). The role of aquaculture in helping to meet the world's food shortages has become more apparent recently. India ranks 2nd in the overall fish production of the world with a total fish production of 8.0 million tons and stand 2nd in aquaculture production next to China. It also accounts for over 5.42% of the global fish production. Indian freshwater aquaculture constitutes mainly the culture of Indian major carps (IMC) namely, catla *(Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). Carp culture in India constitutes 87% of total aquaculture production, consisting of 0.57 million tons of rohu (Ayyappan and Jena, 2003). Among IMC, rohu *(Labeo rohita)* is the most preferred fish for freshwater aquaculture. It is widely cultured in Indian subcontinent mainly in India and Bangladesh. Rohu has been contributing the highest production among the cultivable fishes in India during the last decade providing 35% of the total carp production in India (FAO, 2012).

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While extensive information in different animals on MOS as a feed additive is available, the information on the growth effects on water quality in aquaculture systems is extremely limited.

MATERIALS AND METHODS

An indoor closed water recirculatory system consisting of 24 fibre glass tank (dia. 66 cm) each of 120 l capacity and arranged in a 2 tier system was used for the study.

Biofilter tanks were comprised of fiberglass tanks. Three bigger rectangular tanks each of 1000 l capacity and one circular tank of 750 l were kept outside the field laboratory. These tanks were covered to avoid direct sunlight and subsequent algal growth. The tanks were connected to one another in such a way that waste water collected from outlets of the 12 experimental tanks was carried by a drain pipe and falls into first circular tank. The first biofilter tank was filled with graded sand and gravel. The water gets filtered in the graded layers of sand and gravel and enters from the bottom of first tank to the top of second rectangular tank. The second biofilter tank was filled with dry oyster shells for biological filtration. Water passes through this tank and enters third tank which was filled with clam shells for efficient biofilteration. The filtered water then enters fourth tank which serves as temporary storage tank.

The water was pumped from this tank to an overhead tank. The water flows from over head tank to each of the experimental tanks by gravity. The water flow rate in each experimental tank was normally maintained at the rate of 1 l/min. Separate control valve is provided for each tank to regulate water flow. A 1 HP air blower was continuously used to aerate all the 12 experimental tanks.

Uniform sized fingerlings of *Labeo rohita* with an average weight and length of 1.30g and 4.8cm respectively were stocked @ 25 numbers/tank. The experiment was carried out for a period of 120 days. Faecal matter and uneaten food was removed daily in the morning hours.

Three test diets namely F_1, F_2 and F_3 with 35% protein content were formulated using the square method (Hardy, 1980). Diet F_1 had 0.15% Mannan Oligosaccharide, F_2 had 0.30 % Mannan Oligosaccharide and F_3 had 0.45% Mannan Oligosaccharide, and diet without Mannan Oligosaccharide supplementation served as a control (F_0). Fish were fed at the rate of 5% of their body weight till the end of the experiment. The feed was broadcasted over the surface of water twice daily in the morning and evening. After each sampling the quantity of feed given was re-adjusted based on the increased weight of fish.

Water quality parameters were maintained within the normal range throughout the experimental period. Water samples collected on each sampling day were analyzed for pH, temperature, dissolved oxygen, free carbon dioxide, NH_3-N and total alkalinity. Digital pH meter model LI 613 was used to record pH. Atmospheric temperature and water temperature were recorded by using thermometer. Dissolved oxygen was estimated by Winkler's method. Total alkalinity, NH_3 and free carbon dioxide were determined by following standard methods (APHA, 1995).

RESULTS

The results obtained are presented below.

Temperature
Table 1 and Fig. 1 show the fluctuation in air and water temperature recorded at 15 days interval during the experimental period. Temperature of air and water ranged from 26.7 ^{0}C to 28.0 ^{0}C and 25.4 ^{0}C to 26.9 ^{0}C respectively.

pH
The pH recorded during the study period was near neutral to alkaline, ranging from a mean value of 7.10 to 7.70 in F_0, 7.30 to 7.80 in F_1, 7.23 to 7.70 in F_2 and 7.0 to 7.70 in F_3 (Table 2 and Fig 2).

Dissolved oxygen
The values of dissolved oxygen are recorded on different sampling days are presented in Table 3 and an average values are depicted in Fig 3. The average values of dissolved oxygen were 7.20 to 7.67 mgl^{-1} in F_0, 7.20 to 7.80 mgl^{-1} in F_1, 7.27 to 7.73 mgl^{-1} in F_2 and 6.93 to 7.47 mgl^{-1} in F_3.

Free carbon dioxide
The values of free carbon dioxide recorded over the experimental period are shown in Table 4 and Fig 4. The average values of free carbon dioxide were 1.30 to 2.84 mgl^{-1} in F_0, 0.99 to 2.70 mgl^{-1} in F_1, 1.73 to 2.79 mgl^{-1} in F_2, 1.53 to 2.70 mgl^{-1} in F_3.

Total alkalinity
The total alkalinity values recorded in the different tanks during the experimental period are presented in Table 5 and the average values are presented in Fig 5. The total alkalinity value recorded during the experiment period were 61.80 to 76.20 mgl^{-1} of $CaCO_3$ in treatment F_0, 59.10 to 80.33 mgl^{-1} of $CaCO_3$ in treatment F_1, 66.33 to 79.80 mgl^{-1} of $CaCO_3$ in treatment $F_{2,}$ 59.33 to 76.20 mgl^{-1} of $CaCO_3$ in treatment $F_{3.}$

Ammonia-Nitrogen
The ammonia-nitrogen estimated during the experimental period is presented in Table 6 and the mean values presented in Fig 6. The average values of ammonia-nitrogen ranged from 0.042 to 0.252 µg l^{-1}in $F_{0,}$ 0.060 to 0.253 µg l^{-1}in $F_{1,}$ 0.052 to 0.258 µg l^{-1}in F_2 and 0.032 to 0.280 µg l^{-1}in $F_{0.}$

DISCUSSION

Effect of mannan oligosaccharides on water quality
Water is a primary component of all aquaculture ecosystems. Water quality is simply defined as the degree of excellence that given water possesses for the propagation of desirable aquatic organisms to achieve high survival, growth and reduction (Deo, 2006). A complete understanding of the relationship between water quality and aquatic productivity is a pre-requisite for optimum growth and survival (Boyd, 1982). Water quality management is an ongoing and never-ending process. An analysis of physical, chemical and biological properties of the proposed source of water must be conducted. In the present study, important water quality parameters such as temperature, pH, dissolved oxygen, free carbon dioxide, total alkalinity and ammonia-nitrogen were measured throughout the experimental period. The water quality parameters measured in different treatments thought the experimental period were found to be well within the acceptable range for *Labeo rohita* culture.

Temperature plays a major important role in fish physiology. It affects the growth, food intake, metabolic rate and enzyme activity in fish. Food intake increases with the increase in temperature up to optimum levels as the energy requirement for maintenance increases (Cho and Slinger, 1980). Optimum temperature range for many cold water and warm water species are 14-18^{0}C and 24-30^{0}C respectively. Indian major carps can tolerate temperature ranging from 10 to 37.8^{0}C (Jhingran and Pullin, 1985). Water and air temperature recorded during the present study ranged from 26.7 ^{0}C to 28.0 ^{0}C and 25.4 ^{0}C to 26.9 ^{0}C respectively, which is within the tolerance limit of *Labeo rohita*.

The pH of water is a measure of hydrogen ion concentration and indicates whether the water is acidic or basic. The water having a pH range of 6.5-9.0 is more suitable for fish culture and values above 9.5 are unsuitable as carbon dioxide becomes unavailable at higher pH (Das *et al*., 1995). Fish dies at a pH of above 11.0. Acidic waters reduce the appetite and retard the growth. Das *et al*. (1995) suggested that a pH range of 6.12-8.6 is most suitable for survival of the Indian major carp fry. Variation in pH affects metabolism and other physiological processes. Neutral to slightly alkaline pH has been found to be most favorable for fish ponds (Swingle, 1961; Banerjee, 1967). The pH in the present study ranged between 7.0 and 7.78, which is in the desirable limits for the optimum growth of *Labeo rohita.*

Dissolved oxygen is the most important environmental factor influencing the health condition of fish in aquaculture systems. As the temperature increases, the solubility of oxygen in the water decreases. Oxygen consumption varies with species, size, activity, season and temperature. According to Banerjee (1967), cyprinids require 6-7 ppm oxygen for good growth, but they can tolerate levels as low as 3 ppm for short periods. DO value higher than 5 mgl^{-1} have often been recommended for intensive culture practices (Cheng *et al*., 2003). Banerjee (1967) reported that oxygen concentration above 5ppm is indicative of productivity, but dissolved oxygen below that level indicates that the water is unproductive. The dissolved oxygen content observed in the present study was 6.93 to 7.80 mgl^{-1}. It is in acceptable limit and suitable for the optimum growth of *Labeo rohita*.

Carbon dioxide is present in the atmosphere in very small quantity. For this reason, in spite of its high solubility in water, its concentration in most water bodies is low. High concentration of CO_2 reduces the capacity of blood to transport oxygen. The effect of CO_2 on aquatic animals is dependent on oxygen concentration in water. If there is sufficient oxygen in water fish can survive level of CO_2 as high as 60 ppm (Hart, 1944). CO_2 concentrations in intensively managed aquaculture waters normally fluctuate between 0 to > 20 ppm free CO_2 in a 24 hour cycle with the lowest concentrations during the hours of photosynthesis (Schmittou, 1998). The recorded free carbon dioxide in the present study ranged from 0.99 to 2.84 mg l^{-1} and considered as acceptable for optimum growth of *Labeo rohita*.

Alkalinity refers to the concentration of bases in water and the capacity of water to accept acidity i.e. the debuffering capacity. Water with a low alkalinity i.e. total alkalinity less than 20 mg l^{-1} has low buffering capacity, shows wide fluctuation of pH (Boyd, 1982). Ponds with alkalinity greater than 300 mg l^{-1} may be unproductive because of limitation to carbon dioxide availability at such high concentration (Adhikari, 2000). According to Boyd (1982), total alkalinity value range between 20 to 300 mg l^{-1} is ideal for fish and less than 20 mg l^{-1} alkalinity create stress in fish. The total alkalinity values in this study fluctuated between 59.10 to 80.33 mg l^{-1} and it was in the acceptable range for culture of *Labeo rohita*.

The source of ammonia-nitrogen in water is excreta of cultured animals and microbial decay of nitrogenous compounds. Ammonia occurs in both ionized (NH_4) and unionised (NH_3) forms. Tucker and Boyd (1982) opined that the amount of ammonia reaching pond water through fish metabolite is proportional to the feeding rate. In the present study, the levels of ammonia-nitrogen were insignificant in the first two sampling in all treatment and control tanks and gradual build up was observed in subsequent samplings due to increase in feeding rate. The ammonia values recorded during the present investigation were ranged from 0.032 to 0.280 mg l^{-1} and it was below the tolerance limit of the carps (Das *et al*., 2004; Jena *et al*., 2007a).

Table 1. Air and water temperatures (°C) recorded during different sampling days of the experimental period

Days after stocking	Air temperature (°C)	Water temperature (°C)	Difference (°C)
0	26.7	25.4	1.3
15	27.4	26.3	1.1
30	27.7	26.9	0.8
45	27.6	26.9	0.7
60	26.8	26.5	0.3
75	27.2	26.9	0.3
90	27.8	26.4	1.2
105	27.5	26.8	0.7
120	28.0	26.9	1.1

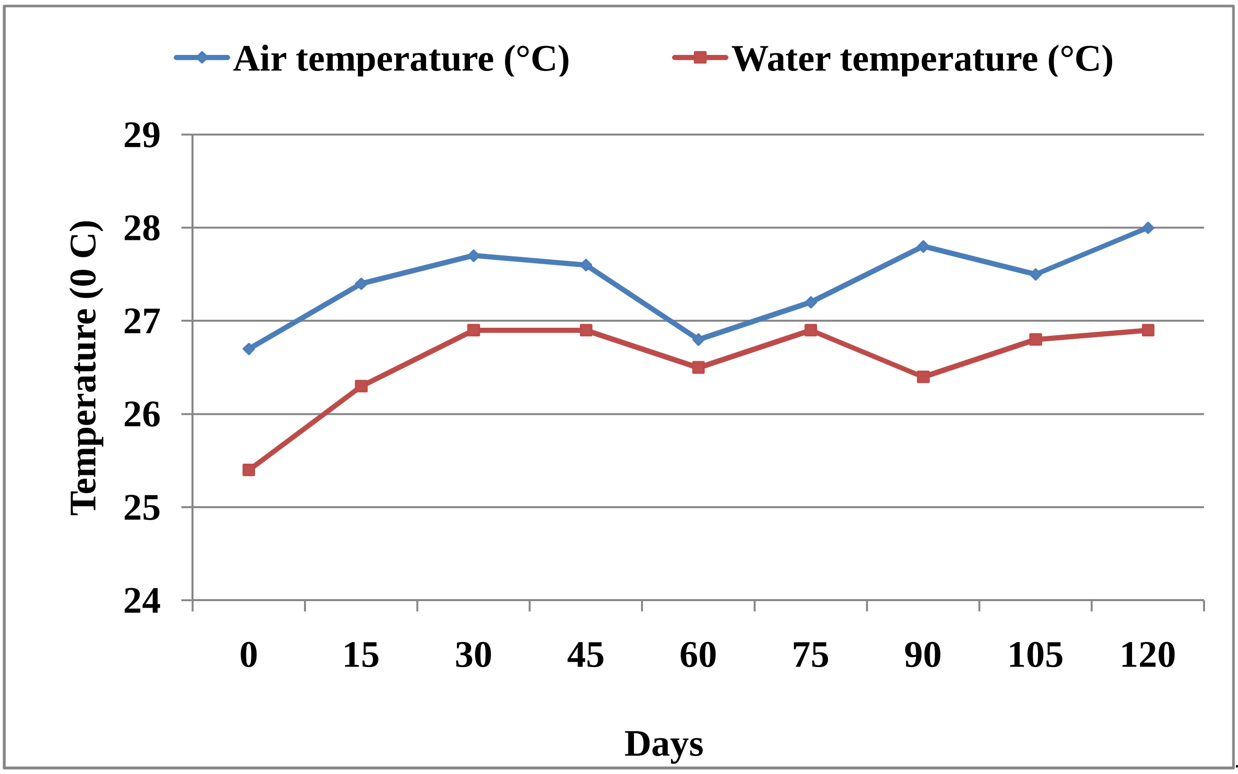

Fig 1: Profile of water and air temperatures (°C) recorded during different sampling days of the experimental period

Table 2. pH of water recorded during different sampling days of the experimental period

Treatments		No. of days								
		0	15	30	45	60	75	90	105	120
F0	Mean	7.10	7.20	7.26	7.50	7.60	7.63	7.70	7.60	7.50
	SE	0.11	0.10	0.20	0.20	0.11	0.06	0.05	0.05	0.11
F1	Mean	7.30	7.40	7.57	7.63	7.70	7.80	7.77	7.67	7.53
	SE	0.10	0.10	0.24	0.06	0.10	0.05	0.06	0.08	0.21
F2	Mean	7.23	7.47	7.50	7.43	7.50	7.73	7.63	7.70	7.53
	SE	0.08	0.06	0.15	0.17	0.05	0.08	0.12	0.20	0.17
F3	Mean	7.00	7.33	7.37	7.27	7.43	7.57	7.40	7.70	7.53
	SE	0.1	0.12	0.20	0.08	0.08	0.12	0.17	0.20	0.12

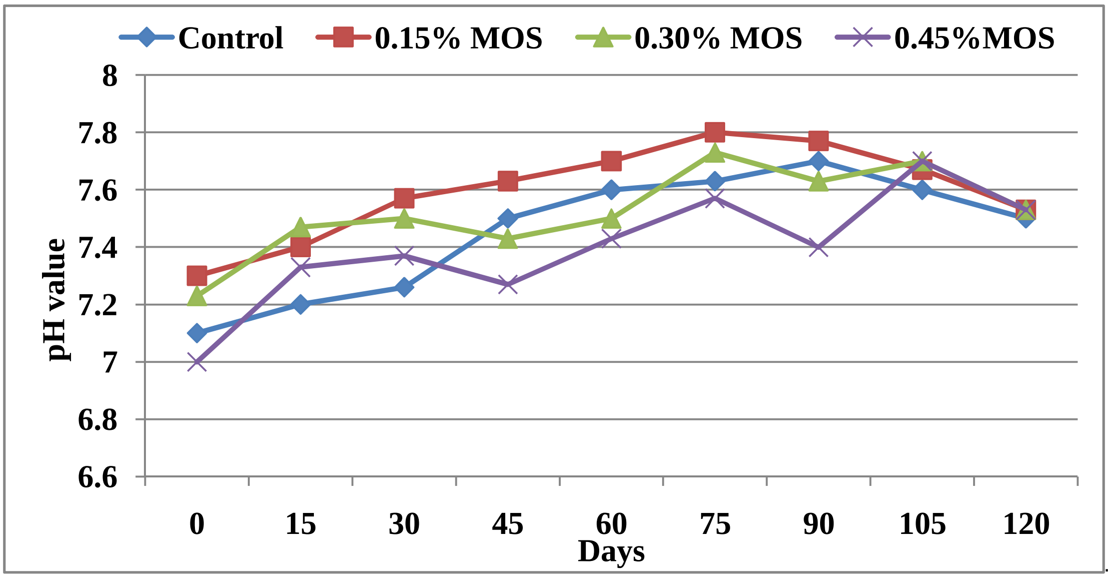

Fig 2: pH of water recorded during different sampling days of the experimental period

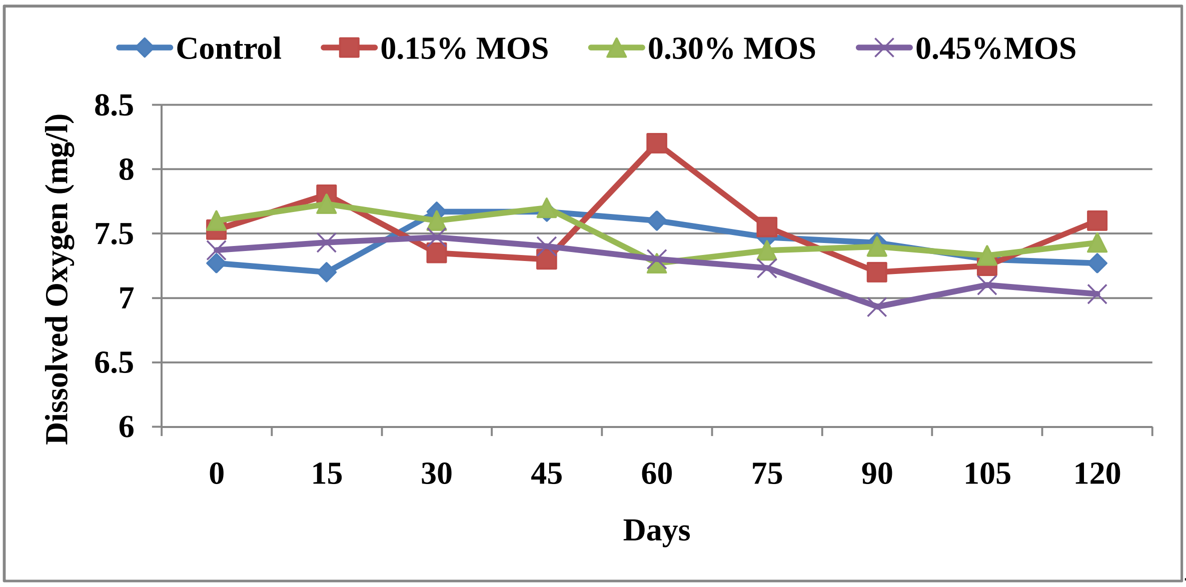

Fig. 3: Dissolved oxygen (mg l^{-1}) recorded on different sampling days during the experimental period

Table 3. Profile of dissolved oxygen (mg l^{-1}) of water recorded during different sampling days of the experimental period

Treatments		No. of days								
		0	15	30	45	60	75	90	105	120
F0	Mean	7.27	7.20	7.67	7.67	7.60	7.47	7.43	7.30	7.27
	SE	0.13	0.12	0.10	0.18	0.12	0.08	0.05	0.06	0.05
F1	Mean	7.53	7.80	7.35	7.30	7.80	7.55	7.20	7.25	7.60
	SE	0.08	0.12	0.05	0.10	0.23	0.08	0.03	0.05	0.05
F2	Mean	7.60	7.73	7.60	7.70	7.27	7.37	7.40	7.33	7.43
	SE	0.06	0.05	0.08	0.11	0.05	0.01	0.05	0.08	0.09
F3	Mean	7.37	7.43	7.47	7.40	7.30	7.23	6.93	7.10	7.03
	SE	0.09	0.05	0.08	0.06	0.03	0.07	0.10	0.06	0.10

Table 4. Free carbon dioxide profile of water (mg l^{-1}) recorded during different sampling days of the experimental period

Treatments		No. of days								
		0	15	30	45	60	75	90	105	120
F0	Mean	1.30	1.87	1.97	2.43	2.17	2.76	2.73	2.84	2.80
	SE	0.14	0.23	0.06	0.11	0.08	0.09	0.08	0.12	0.11
F1	Mean	1.13	0.99	1.60	1.26	2.27	2.04	2.70	2.51	2.43
	SE	0.03	0.03	0.12	0.10	0.13	0.11	0.19	0.16	0.15
F2	Mean	1.66	1.37	2.35	2.68	1.80	2.69	2.75	2.79	2.68
	SE	0.12	0.17	0.24	0.18	0.10	0.22	0.13	0.15	0.11
F3	Mean	1.53	1.93	1.80	2.56	2.48	2.37	2.70	2.30	2.46
	SE	0.24	0.08	0.15	0.30	0.22	0.26	0.08	0.23	0.22

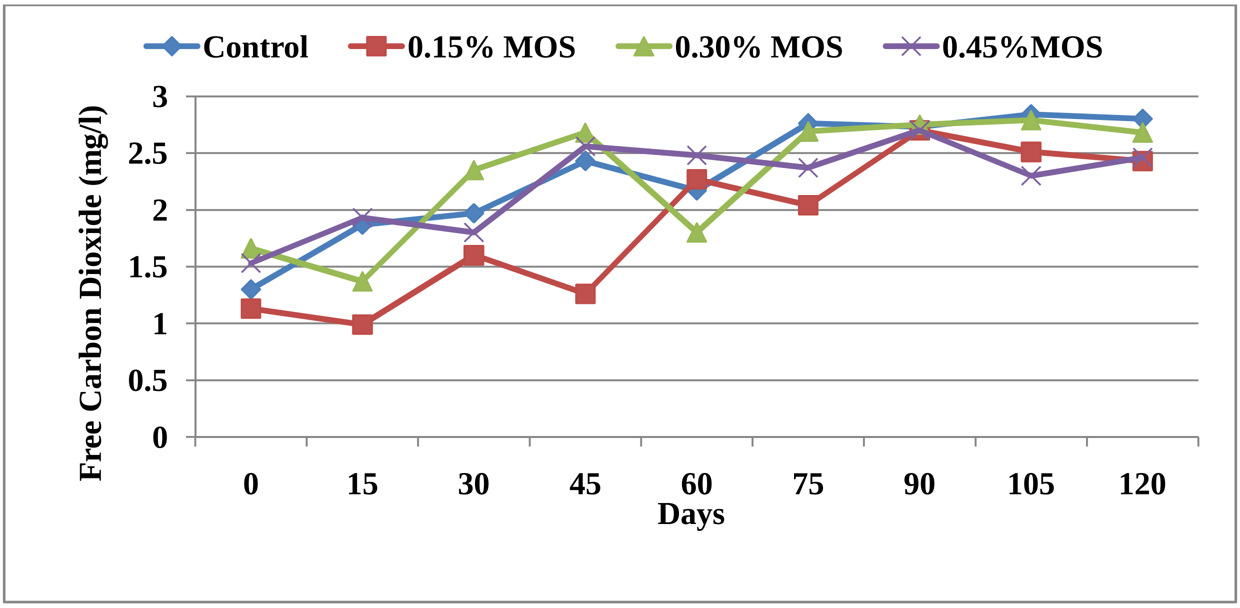

Fig. 4: Free carbon dioxide profile of water (mg l^{-1}) recorded during different sampling days of the experimental period

Table 5. Total alkalinity Profile of water (mg l^{-1}) recorded during different sampling days of the experimental period

Treatments		No. of days								
		0	15	30	45	60	75	90	105	120
F0	Mean	63.07	62.90	61.80	65.47	66.00	74.53	74.83	76.20	75.12
	SE	1.47	4.22	4.71	1.51	2.70	3.68	3.67	1.51	3.29
F1	Mean	59.10	71.17	75.50	76.77	80.03	78.90	80.33	79.80	77.30
	SE	2.53	0.83	3.15	2.26	1.63	1.30	0.60	0.85	1.25
F2	Mean	66.33	70.57	71.27	74.80	79.07	79.80	77.17	78.33	76.97
	SE	1.61	2.51	1.70	2.70	2.29	5.10	1.35	1.41	1.48
F3	Mean	59.33	67.60	66.13	73.97	76.17	74.20	76.20	75.03	75.07
	SE	3.13	3.66	0.98	2.76	1.53	0.90	1.58	0.96	2.84

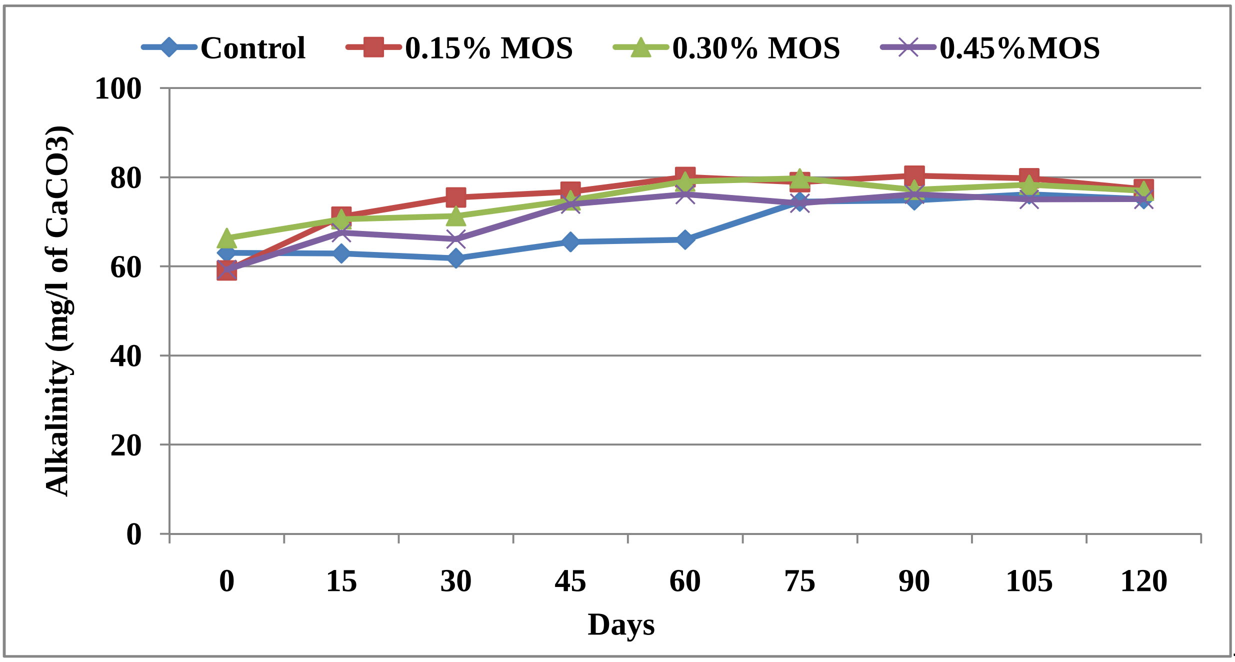

Fig. 5: Total alkalinity Profile of water (mg l^{-1}) recorded during different sampling days of the experimental period

Table 6. Ammonia-Nitrogen (μg l^{-1}) of water recorded during different sampling days of the experimental period

Treatments		No. of days								
		0	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**
F0	**Mean**	**0.04**	**0.11**	**0.19**	**0.16**	**0.22**	**0.25**	**0.25**	**0.22**	**0.24**
	SE	0.00	0.03	0.01	0.02	0.019	0.02	0.03	0.02	0.03
F1	**Mean**	**0.06**	**0.14**	**0.18**	**0.19**	**0.23**	**0.21**	**0.24**	**0.25**	**0.24**
	SE	0.01	0.03	0.03	0.01	0.01	0.05	0.00	0.03	0.02
F2	**Mean**	**0.05**	**0.13**	**0.20**	**0.20**	**0.199**	**0.21**	**0.24**	**0.25**	**0.20**
	SE	0.00	0.02	0.01	0.02	0.008	0.02	0.02	0.02	0.027
F3	**Mean**	**0.03**	**0.20**	**0.25**	**0.26**	**0.264**	**0.26**	**0.27**	**0.28**	**0.210**
	SE	0.00	0.03	0.02	0.03	0.024	0.00	0.02	0.03	0.048

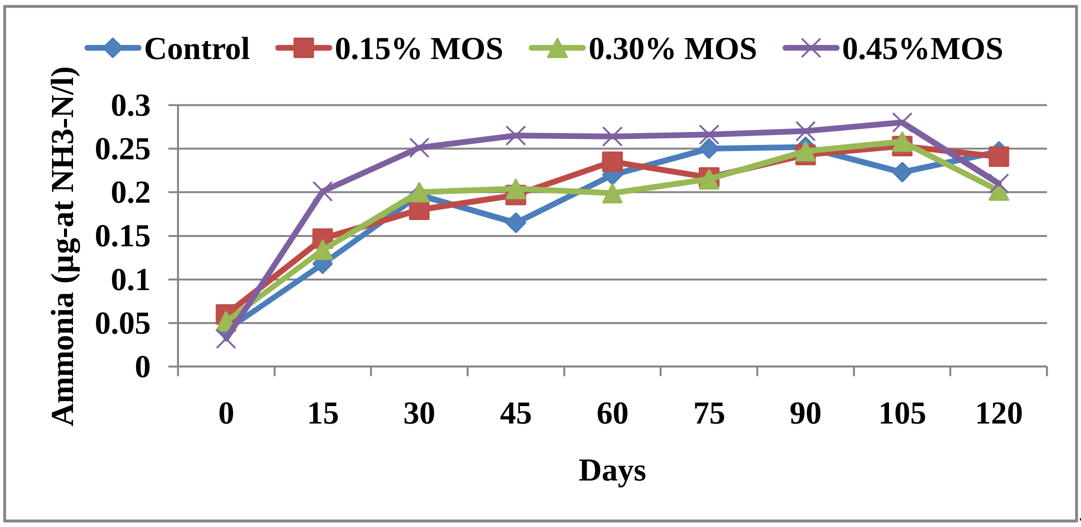

Fig. 6: Ammonia-Nitrogen (µgl^{-1}) of water recorded during different sampling days of the experimental period

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