J. Bangladesh Agril. Univ. 15(1): 113–122, 2017 **ISSN 1810-3030**

Effect of aeration on growth and production of fish in intensive aquaculture system in earthen ponds

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Abstract

An experiment was conducted to assess the effect of aeration using blower on growth and production of tilapia (*Oreochromis niloticus*) in intensive aquaculture system in six (6) earthen ponds at BAU campus, Mymensingh from May to September, 2016. Treatment 1 (T_1) with 3 aerated ponds and Treatment 2 (T_2) with 3 non-aerated ponds were designed with similar stocking density (300/decimal) of tilapia. Oxygen supply was ensured by blower for 9 hours daily when oxygen depletion occurs in pond water. Fish growth, pond water and soil quality parameters were sampled and assessed. The DO content in the aerated ponds was higher (7.23 mg/l) from the beginning to the end of experiment compared to non-aerated ponds (2.33 mg/l). There were significant differences ($p<0.05$) of DO content between two treatments at first and last sampling stages. The higher length (15.64±1.56 cm) and weight gain (143.36±39.33 gm), higher SGR (% per day) for tilapia was (2.54±0.00) found in T_1 compared to T_2 (2.42±0.00) with significant differences ($p<0.05$) between two treatments. In addition, the higher production of tilapia was obtained in T_1 (9581.87±0.00 kg/ha/100 days) compared to T_2 (6490.80±0.00 kg/ha/100 days). The average phytoplankton production was relatively higher in T_2 and conversely zooplankton abundance was higher in T_1 without any significant differences ($p>0.05$) between the treatments for the abundances of various groups of phytoplankton and zooplankton. Different water quality parameters were found with the better range in aerated ponds. Various intrinsic relationships between DO and other water quality and weather parameters showed that DO content had negative relationships with rainfall, air pressure and humidity but the relationships were not statistically significant. Moreover, different soil quality parameters of pond sediments were found in ideal range for fish culture in both treatments. These results suggest that aeration can be a potential mechanism of aqua-farming to enhance the growth and production of tilapia and DO content in pond water synchronizing other water quality parameters in ponds.

Keywords: Intensive aquaculture, Aeration, Dissolved oxygen, Weather parameters, Growth performance

Introduction

Aquaculture is the fastest growing animal based food-producing sector, particularly in developing countries like Bangladesh and its production contributes to the livelihoods, employment and also fulfills the nutritional demand for millions of people. Bangladesh has achieved 6th position among the world's major aquaculture producing countries (FAO, 2016) and the total production of fish is around 3.6 million MT in 2014-2015, of which inland fisheries contributed 83.71% comprising 55.93% from aquaculture and 27.79% from capture fisheries (DoF, 2016). Any effort to increase animal protein production must be concentrated on aquaculture, since capture fisheries from open water bodies is stagnating due to declining open water resources. In Bangladesh, land area is declining with increasing population and the competition of aquaculture with other agricultural sectors is increasing in the context of land and water use. Therefore, intensive aquaculture is growing to enhance national fish production in the context of population growth and declining land resource that is required to construct ponds. Moreover, fish productions per unit area are much higher in intensive aquaculture system compared to semi-intensive and extensive system. Therefore, to fulfill the animal protein demand for teeming population in Bangladesh intensive fish culture system may be the alternative to enhance fish production since fish contributes about 60% of animal protein to our daily food (DoF, 2016).

Since in intensive aquaculture system, ponds are heavily stocked with fish as well as with high feed supply and in these artificially fed fish ponds, many problems like organic pollution, deficiency of oxygen, increased level of free carbon dioxide and total increase in ammonia-nitrogen, nitrite-nitrogen ratio are frequently occurring. However, the problem of oxygen depletion in rearing of freshwater fish species is a major threat and main limiting factor in intensive aquaculture because it leads to hypoxia which affects fish growth, food conversion levels and feeding efficiency etc. (Mallya, 2007) and fish always show high feed efficiency when they are fed at required DO in water (Boyd, 1998). The present study has taken tilapia as an experimental species for investigation the impacts of DO on tilapia's growth and production which is sensitive to the availability of DO in the water body as reported by Abdel-Tawwab *et al*. (2014). Along with the deficiency of DO content in water, another major problem in intensive aquaculture system is the presence of high concentrations of nutrients, especially phosphorus, ammonia, nitrite and nitrate. High concentrations of these nutrients can lead to excessive phytoplankton growth (phytoplankton bloom) and deterioration of pond water quality (Gilbert *et al.,* 2001).

In the recent years, the marketing of aquaculture drugs and chemical has been increased and the use of different oxygen enhancing chemicals which has already been reported to exert negative impact on fish growth. Moreover, different algaecides are available in the market to control phytoplankton bloom in such ponds. Algaecide treatments temporarily rid the pond of phytoplankton however in almost all cases phytoplankton re-growth occurs (Le Jeune *et al.,* 2006) and then repeated treatment is needed but it is expensive. Even very low concentrations of copper sulfate may kill the zooplankton (grazers), leading to an even greater 'rebound' of phytoplankton biomass once the chemical leaves the system (Cooke and Kennedy, 2001). Considering the negative impacts of different chemicals in terms of enhancing DO content, reducing excessive phytoplankton growth in pond water and improving aquatic environment by keeping different water quality parameters in suitable range for fish growth, aeration can be the alternative and efficient way to get rid of deficiency of oxygen and organic pollution in intensive aquaculture systems (Agarwal, 1999; Boyd, 1995) and artificial aeration has been proposed as an alternative to the use of toxic algaecides. Moreover, emergency aeration is the best technique for preventing fish kills during DO crisis since aeration is the dissolution of oxygen (O_2) from the atmosphere (21% O_2) into water (Boyd, 1998; Swingle, 1968, Grizzel *et al*. 1969; Mayer and Eschmeyer, 1973).

Therefore, in the present study, a blower machine (Air Compressor) has been used for oxygen supply in intensive aquaculture ponds and the use of such type of blower is cost effective as reported by previous study and has a long term positive effects on fish growth and production. Considering the above context, the present study was carried out to determine the effect of aeration using blower on DO content in pond water, growth and production of fish, on different water and soil quality parameters, and to explore the relationship between water quality, with special emphasis on DO and weather parameters.

Materials and Methods

Location of the study site and experimental design

The experiment was conducted in the ponds situated at the campus of Bangladesh Agricultural University (BAU), Mymensingh during May to September 2016 (Fig. 1). For the experiment, two treatments with three replications were designed namely T_1 and T_2 with similar stocking density (300/decimal) of tilapia fry (0.4 g initial weight) and three ponds in T_1 were treated with aeration through using blower and the rest three ponds in T_2 were non-aerated. Following pond preparation, a blower machine (Air compressor, Model: VB-125G) was installed in the experimental pond for aeration three times daily and for three hours each time (11 pm–2 am, 3 am–6 am and 9 am–12 pm) generally when oxygen depletion occurs in pond water. Moreover, the average area of pond was 1.00 decimal for all treatments with an average depth of 1 m.

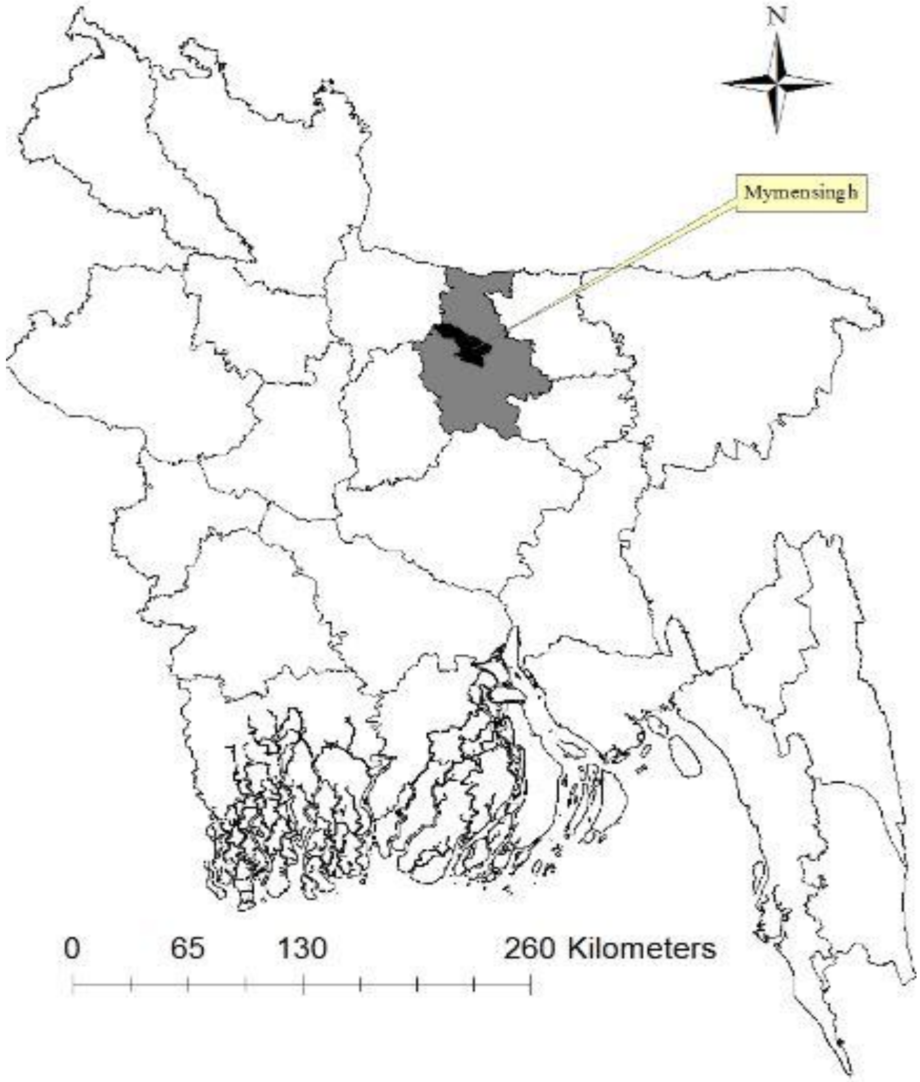

Fig. 1. Map of Bangladesh showing the study site at BAU campus in Mymensingh

Study of growth parameters of fish

For evaluating the growth of fish, different growth parameters such as length gain (cm), weight gain (g), percent (%) weight gain, specific growth rate (SGR % per day), and production (kg/ha/100 days) were taken into consideration and were measured using the following formula. The length and weight of fish were measured using centimeter scale and electric balance (Model: HKD-620AS-LED) in grams.

Weight gain (g) = Mean final weight (g) – Mean initial weight (g)

$$\text{Percent weight gain} = \frac{\text{Mean final weight (g)} - \text{Mean initial weight (g)}}{\text{Mean initial weight (g)}} \times 100$$

$$\text{SGR (\%) per day} = \frac{\log W_2 - \log W_1}{T_2 - T_1} \times 100$$

Production = No. of harvested fishes $\times$ average final weight increase of fishes

Study of water quality parameters

Different physico-chemical parameters including DO was measured at seven days interval using both HACH test kit (FF-1A, cat. No. 2430-02) and DO meter (Model: DO-5509). Other water quality parameters including water temperature (using celsius thermometer), pH, ammonia, and nitrite were measured using HACH test kit (FF-1A, Cat. No. 2430-02) at 15 days interval during the study period in the Aquaculture Laboratory under the Department of Aquaculture, BAU, Mymensingh.

Study of plankton as biological parameter

Plankton population of ponds water such as phytoplankton and zooplankton were identified to generic level and counted using Sedgwick-Rafter Counting Cell (S-R cell) under a compound binocular microscope (Model: Primo Star HAL/LED microscope) at the mid and end of the trial in the Limnology Laboratory under the Department of Fisheries Management, BAU, Mymensingh. Moreover, plankton population (cells/L) was determined by using the formula of Rahman (1992).

Study of chemical parameters of pond bottom soil

For the measurement of different chemical parameters such as, soil pH, organic matter, total nitrogen, available phosphorus, available potassium of pond bottom soil, soil samples were collected before the beginning and after end of trial using soil core sampler (agar) from the experimental ponds. Following air drying of soil samples in brown paper, these samples were then analyzed using different standard methods in Humboldt Soil Testing Laboratory under the Department of Soil Science, BAU, Mymensingh.

Study of relationship between major water quality and weather parameters

Different weather parameters including air temperature, rainfall, air pressure and humidity were recorded from the study site throughout the study period. Therefore, a real-time mini weather station (Vantage PRO 2) was established at the rooftop of the Faculty of Fisheries, BAU in order to facilitate this activity. The 24 hours data of different weather parameters were recorded using computer connected data logger.

Data processing and analysis

The recorded data were entered into the spreadsheet of MS Excel 2007 and then summarized properly before statistical analysis. An independent sample T-test was done to assess the differences between T_1 and T_2 in terms of DO content, fish production, water quality parameters, plankton abundance and different chemical parameters of pond bottom soil. Moreover, correlation analysis was done to determine the positive or negative relationships between water quality and weather parameters. The inferential T-test and bivariate correlation analysis was carried out using SPSS (Statistical Package for Social Sciences) version 16.

Results

Dissolved oxygen (DO) content

The mean values of the DO content of the pond water were 6.24±1.14 and 5.54±1.43 mg/l in T_1 and T_2, respectively. There were significant differences ($p<0.05$) of DO between two treatments at first and last sampling stages. The DO content in the ponds of T_1 was higher from the beginning to the end of experiment except at one stage of sampling (31-May-16) where mean values of dissolved oxygen were similar in both treatments possibly due to technical problem of blower (Fig. 2).

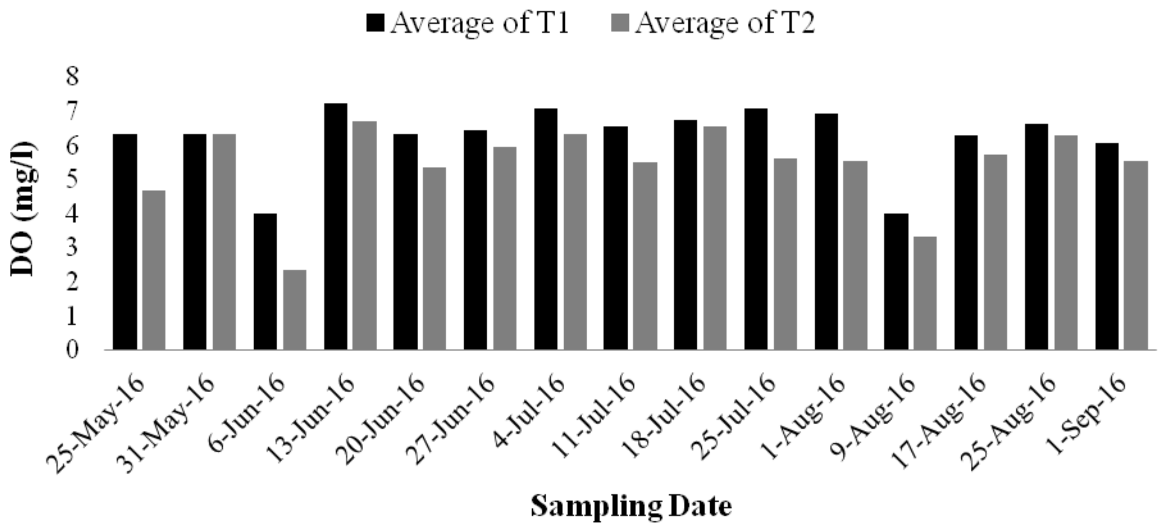

Fig. 2. Variation of dissolved oxygen between two treatments throughout the study period

Growth performance of fish in different treatments

The average final lengths of tilapia were 18.50±1.56 cm and 17.23±1.84 cm in T_1 and $T_{2,}$ respectively where initial average length in both treatments was 2.86±0.00 cm. Similarly the initial weight of tilapia (0.40±0.00) increased up to 143.76±39.33 g and 111.0±33.06 g in T_1 and $T_{2,}$ respectively during final harvest, where mean weight gain were 143.36±39.33 g and 110.6±33.06 g with significant difference ($p<0.05$) between T_1 and T_2. Moreover, percent weight gain, specific growth rates and production of tilapia were found significantly ($p<0.05$) higher in T_1 compared to T_2 (Table 1).

Table 1. Growth performance (mean ± SD) of tilapia in the experimental ponds

Growth parameters of tilapia	Treatments		T-test p-value
	T_1 (Aerated)	T_2 (Non-aerated)	
Final length (cm)	18.50±1.56	17.23±1.84	0.005*
Final weight (g)	143.76±39.33	111.0±33.06	0.001*
Weight gain (g)	143.36±39.33	110.6±33.06	0.000*
% weight gain	35842.5±0.00	27650±0.00	0.000*
Specific growth rate (SGR % per day)	2.54±0.00	2.42±0.00	0.000*
Production (kg/ha/100 days)	9581.87±0.00	6490.80±0.00	0.000*

*indicates significant difference between T_1 and T_2 at $p < 0.05$.

Physico-chemical parameters of water

Water quality is determined by various physico-chemical and biological factors, as they may directly or indirectly affect its quality and consequently its solubility for the distribution and production of fish and other aquatic animals (Moses, 1983). The mean values of tested water quality parameters such as temperature, pH, ammonia and nitrite of the experimental ponds are presented in Table 2 where water temperature, pH were slightly higher but ammonia and nitrite level were found lower in aerated ponds (T_1) compared to non-aerated ponds (T_2). Various water quality parameters were not significantly ($p>0.05$) differed between T_1 and T_2.

Table 2. Various physico-chemical parameters of water (mean ± SD) in two different treatments

Treatments	Temperature (°C)	pH	Ammonia (mg/l)	Nitrite (mg/l)
T_1	30.00±1.44	7.61±0.26	0.01±0.01	0.016±0.028
T_2	30.24±1.30	7.43±0.28	0.13±0.030	0.044±0.048

Abundance of plankton

About 27 genera of phytoplankton were identified of which 6 were belonged to Bacillariophyceae, 14 to Chlorophyceae, 2 to Euglenophyceae, 1 to Rhodophyceae and 4 to Cyanophyceae in present study. Moreover, about 8 genera of zooplankton were identified from the present study of which 2 were belonged to Copepoda, 4 to Rotifera and 2 to Cladocera (Table 3). No significant ($p>0.05$) differences were found between T_1 and T_2 for the abundance of both phytoplankton and zooplankton in the present study, however the abundance of phytoplankton was higher in T_2 and abundance of zooplankton was higher in T_1 (Table 4).

Table 3. Generic status of plankton under different major groups found in the aquaculture ponds during the experimental periods

Major groups	**T_1**	**T_2**
	Generic name of phytoplankton	
Chlorophyceae	*Actinestrum* *Ankistrodesmus* *Chlorella* *Pediastrum* *Scenedesmus* *Tetraedon* *Stichococcus* *Ulothrix* *Closterium* *Crucigenia*	*Actinistrum* *Ankistrodesmus* *Chlorella* *Closterium* *Crucigenia* *Pleorococcus* *Pediastrum* *Scenedesmus* *Tetraedon* *Stichococcus* *Ulothrix* *Uroglena* *Spirogyra* *Volvox*
Cyanophyceae	*Anabaena* *Microcystis* *Oscillatoria*	*Anabaena* *Microcystis* *Oscillatoria* *Spirulina*
Bacillariophyceae	*Cosmarium* *Fragillaria* *Navicula* *Nitzschia* *Surilella*	*Cosmarium* *Cyclotella* *Fragillaria* *Navicula* *Nitzschia* *Surilella*
Euglenophyceae	*Euglena* *Phacus*	*Euglena* *Phacus*
Rhodophyceae	*Hildenbrandia*	*Hildenbrandia*
Major groups	**Generic name of zooplankton**	
Copepoda	*Cyclops* *Diaptomus*	*Cyclops*
Rotifera	*Asplanchna* *Brachionus* *Polyarthra* *Trichocera*	*Asplanchna* *Brachionus* *Polyarthra*
Cladocera	*Daphnia* *Diaphanosoma*	-

Table 4. Variations in mean abundance of total phytoplankton (×10^5 cells/L) and zooplankton (×10^3 cells/ L) in the experimental ponds under two treatments during the study period

Mean (±SD) abundance of plankton	Treatments	Samplings	
		Initial	Final
Phytoplankton (cells/L)	T_1	$26.1×10^5±22.7×10^5$	$26.5×10^5±22.8×10^5$
	T_2	$34.0×10^5±25.2×10^4$	$36.2×10^5±19.5×10^5$
Zooplankton (cells/L)	T_1	$23.3×10^3±25.1×10^3$	$30.0×10^3±17.3×10^3$
	T_2	$6.6×10^3±11.5×10^3$	$13.3×10^3±11.5×10^3$

Chemical parameters of pond bottom soil (sediments)

Different chemical parameters of pond bottom soil such as, soil pH, organic matter, total nitrogen, available phosphorus were found within suitable range for aquaculture with no significant differences ($p>0.05$) between two treatments. Conversely available potassium content was found much lower than optimum range for aquaculture in the ponds of both treatments. Mean values of various chemical parameters of pond bottom soil are presented in Table 5.

Table 5. Various chemical parameters (mean ± SD) of pond bottom soil in the experimental ponds

Treatments	Soil pH	Organic matter (%)	Total nitrogen (%)	Available phosphorus (ppm)	Available potassium (ppm)
T_1	6.75±0.15	2.05±0.43	0.12±0.02	15.32±2.95	87.81±22.50
T_2	6.79±0.13	1.94±0.31	0.10±0.01	9.64±3.77	65.00±10.81

Relationship between major water quality and weather parameters

Correlation-matrix shows a various intrinsic relationships between DO and other water quality and weather parameters (Table 6). A non-significant positive relationship was found between DO and the temperature of pond water and atmosphere. However, it had negative relationships with rainfall, air pressure and humidity. There was a significant ($p<0.05$) positive relationship between air and pond water temperature. However, the relationships of pond water temperature with rainfall, air pressure and humidity were negative but not statistically significant.

Table 6. Correlation-matrix showing the relationship between dissolved oxygen content of experimental pond water and weather parameters

		Pond water DO (ppm)	Pond water temperature (°C)	Air temperature (°C)	Rainfall (mm)	Air pressure	Humidity (%)
Pond water DO (ppm)	Pearson Correlation	1					
	Sig. (2-tailed)						
Pond water temperature (°C)	Pearson Correlation	0.649	1				
	Sig. (2-tailed)	0.236					
Air temperature (°C)	Pearson Correlation	0.523	.892*	1			
	Sig. (2-tailed)	0.366	0.042				
Rainfall (mm)	Pearson Correlation	–0.58	–0.395	–0.007	1		
	Sig. (2-tailed)	0.305	0.511	0.992			
Air pressure	Pearson Correlation	–0.445	–0.789	–.919*	–0.215	1	
	Sig. (2-tailed)	0.453	0.113	0.027	0.729		
Humidity (%)	Pearson Correlation	–0.41	–0.845	–.991**	–0.08	.902*	1
	Sig. (2-tailed)	0.493	0.072	0.001	0.898	0.036	

Discussion

Dissolved oxygen (DO) is one of the most important physico-chemical parameter of water because low DO content adversely affects fish growth, feed utilization and fish even die at this low DO concentration. In the present study, the level of DO in the ponds of T_1 and T_2 varied from 4.5 to 8.0 mg/l and 2.0 to 7.7 mg/l which was more or less similar to the result of Qayyum *et al.* (2005) who recorded DO ranging from 4-9 mg/l and 2-8 mg/l in aerated and non-aerated ponds, respectively. The higher DO content in the aerated ponds in present study might be due to proper and continuous periodical aeration facilities.

Growth performance of tilapia in terms of length gain, weight gain, percent weight gain, specific growth rate and production were found to be significantly ($p<0.05$) higher in the ponds of T_1 compared to T_2 . Conversely FCR in the present study was found lower (1.2) in T_1 compared to T_2 (1.7) which was within the expected FCR for tilapia (Watanabe *et al*., 2002). The higher length and weight gain, specific growth rate, survival rate, production and low FCR obtained in the aerated ponds of present study compared to non-aerated ponds might be due to proper feeding, controlled condition, differences in DO content due to aeration facilities since fish growth, feed efficiency and FCR were affected by DO availability and fish always showed good feed efficiency and low FCR when fed at required DO in water (Bergheim *et al.*, 2006 and Duan *et al.*, 2011).

Water temperature plays a crucial role in regulating the metabolic process of fish (Battes *et al*, 1979). The water temperature (28-32°C) of ponds in present study was within the suitable range (26-33°C) for tilapia culture (Tyson and Simonne, 2014). Moreover, pH values (7.0-7.9) found in T_1 and T_2 were within the tolerable range of tilapia for aquaculture (Chervinski, 1982) and were within the acceptable range of 6.5 to 8.5 required for fish culture (DoF, 1996). In the present study, the ammonia (0.00-0.09 mg/l) and nitrite contents (0.00-0.066 mg/l) of pond water were found within desirable range of aquaculture (Bhatnagar and Singh, 2010; Stone and Thomforde, 2004). The higher ammonia and nitrite content in T_2 (non-aerated) than T_1 (aerated) might be due to the aeration system since benefit of aeration is to cycle the ammonia to nitrite faster and nitrite could be readily oxidized to non-toxic nitrates in aerobic condition.

In intensive aquaculture system, high concentrations of nutrients in water column, especially phosphorus, ammonia and nitrate, cause phytoplankton blooms (Gilbert *et al.,* 2001) and deterioration of pond water quality. About 27 genera of phytoplankton were identified in the present study belonging to Bacillariophyceae, Chlorophyceae, Euglenophyceae, Rhodophyceae and Cyanophyceae which were similar to the result of Dewan *et al.* (1991). Besides, about 8 genera of zooplankton were identified from the ponds of present study belonging to Copepoda, Rotifera and Cladocera which was more or less similar to the results of Rahman and Hussain (2008). There were no significant differences ($p>0.05$) between two treatments for the abundance of phytoplankton in all the sampling stages of present study, however the abundance was higher in T_2 ($36.2\times10^5\pm19.5\times10^5$ cells/L) compared to T_1 ($26.5\times10^5\pm22.8\times10^5$ cells/L). The findings of present study were much higher than the result of Siddika *et. al*. (2012) and this higher phytoplankton production in present study might be practicing intensive aquaculture with high stocking density and high feeding regime. Moreover, zooplankton abundance was found higher in T_1 compared to T_2 and this might be due to aeration facilities in T_1 because growth of zooplankton was related to optimum DO content and other physico-chemical parameters of water in aerated ponds.

Although no significant differences were found between two treatments for various chemical parameters of pond bottom soil but soil pH (6.68 to 6.88), organic matter content (1.40 to 2.47%) in present study were within the optimum range for fish culture (Boyd *et al.*, 1994). Moreover, total nitrogen content (0.09 to 0.13%) of experimental pond bottom soil indicates higher productivity since IASRI (2015) reported that more than 0.05% of total nitrogen in pond bottom soil was highly productive and available phosphorus content (9.64 to 19.32 ppm) in present study indicates moderate to poor productivity of fish culture pond since below 13.0 ppm of available phosphorus in bottom soil have been suggested as the index of poor productivity of fish ponds by Banerjea (1967). But available potassium contents (76.0 to 116.0 ppm) were much lower than the result of Thakur and Chattopadhyay (2015) who reported available potassium ranging from 187.89 to 301.09 ppm in fish ponds. This lower available potassium content in present study may be attributed to the occurrence of poor organic carbon, lighter texture and consequently low cation exchange capacity in the pond soil. These all the soil quality parameters indicate that the increased growth and production of tilapia through applying aeration did not change the pond soil quality.

Meteorology plays an important role in fisheries and aquaculture because solar radiation and air temperature influence water temperature, which in turn affects the natural productivity of inland and marine waters and the growth of fisheries species (Kapetsky, 2000). In the present study, bivariate correlationship showed that DO content increased in pond water with the increase of water and air temperature and DO content decreased with the increase of air pressure. These results were different from the findings of Wurts (2013); Bhatnagar and Devi (2013); and Fondriest (2013). The difference in the result of present study does not have any broader implications as the relationship between the parameters was not statistically significant. Moreover, correlation matrix showed that DO content decreased with the increase of rainfall, air pressure and humidity or vice versa. The result of decreasing DO content with the increase of humidity and rainfall in present study was similar to the findings of (Bhatnagar and Devi*,* 2013) and Wurts (2013). There was a significant ($p<0.05$) positive relationship between air and pond water temperature which was similar to the observations of Morrissy (1976) who reported that water temperature in aquaculture ponds closely followed air temperatures.

Conclusion

Overall, aeration improved DO content in pond water and also showed a difference for water quality parameters between aerated and non-aerated ponds. Along with DO, other water quality parameters such as temperature, pH, nitrite, ammonia in the aerated ponds were within the better range of aquaculture compared to non-aerated ponds. The effect of aeration also showed a significant difference ($p<0.05$) between two treatments for length gain, weight gain and SGR of tilapia. Moreover, DO content had complex relationships with local weather parameters that means if different weather parameters of locality are known to farmers then farmers will be able to predict the level of water temperature and DO in pond water. Therefore, it can be argued that aeration is a potential mechanism of aqua-farming to enhance growth and production of fish at higher stocking densities. Further action research is required at the field level for building awareness among the farmers on aeration and its impacts on pond productivity.

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