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Effects of sumithion on growth and production of phytoplankton and zooplankton in aquaculture ponds

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Abstract

Sumithion is an organophosphorous pesticide widely used to control tiger bugs in fish larval rearing pond. The present study was aimed to investigate the effects of sumithion on plankton population abundance in aquaculture pond. The experiment was carried out with three treatments, i.e. ponds with no sumithion (T1), ponds with 1.0 ppm sumithion (T2) and those with 2.0 ppm sumithion (T3). The water quality parameters, such as temperature, pH, dissolved oxygen and total alkalinity were almost unchanged throughout the study period whereas transparency, NO_3-N and PO_4-P values declined with an increase in sumithion concentrations but differences were not significant (p<0.05). No distinct changes were observed in population densities of phytoplankton (x cells L^{-1}). On the other hand, the zooplankton population densities (x Ind L^{-1}) significantly (p<0.05) decreased with toxicity of sumithion after 30 days up to the end of experimental period in both T2 and T3 compared to the control group (T1). The ranges of pH, organic carbon (%), available phosphorus (ppm) and total nitrogen (%) of pond bottom-sediment did not differ irrespective of the treatments. This study demonstrated that sumithion has adverse effects on zooplankton which may influence the production in aquaculture pond.

Keywords: Organophosphorous pesticide, Water quality parameters, Sediment, Environment, plankton.

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Introduction

Throughout the world, pesticides widely employed in the agricultural sector in order to elevate crop yields, finally reach aquatic environments through spray drift, surface runoff, and leaching (Murthy *et al.,* 2013). Pesticide exposure leads to toxicity in many non-target organisms, aquatic flora and fauna. Pesticides reach aquatic systems through different ways, such as surface runoff, organic substrates (mosses, algae, leaf litter, vascular hydrophytes and branches), and inorganic substrate including materials from sediments varying in size (Murthy *et al*., 2013). Standing water has higher concentrations of pesticides than lithic biotopes and the water column, while its quantity is negligible in sediments (Kingsbury and Kreutzweiser, 1980). Pesticides affect the aquatic ecosystem by interrupting the aquatic food chain (planktonic flora and fauna) of open water fish species and finally result in the loss of the abundance of natural species (Parveen *et al*., 2002; Cochard *et al*., 2014). Some pesticides e.g. herbicides may reduce the abundance of primary producers thus ultimately decreasing primary and secondary consumers (Brock *et al*., 2000; Halstead *et al*., 2014). The insecticides fall under four major groups *viz.* organochlorine, organophosphate, carbamate and pyrethroid. Sumithion, the O, O Dimethyl O-(3-methyl-4-nitrophenyl) is an organophosphate insecticide, which is widely used in aquaculture ponds for the eradication of aquatic insects (mainly tiger bugs) prior to the release of larvae.

Living organisms of the water consist of three major groups namely plankton, nekton and benthos. Among these, plankton is of fundamental importance to fisheries. Plankton is also a vital factor influencing fish production. Phytoplanktons are the basic primary producers of all types of water bodies and are used as food by fish directly or indirectly. The qualitative and quantitative abundance of phytoplankton indicate the productive status of a water body, whether it is an oligotrophic or a eutrophic one. Therefore, a thorough knowledge of the abundance of phytoplankton and its quality in time and space in relation to environmental conditions has become a prerequisite for fish production. Existence of zooplankton production primarily depends on the primary production. Zooplankton is a link in the food chain between the primary producers and nektonic and benthonic animals at higher trophic levels. Their functions decrease phytoplankton populations through grazing (Raymont, 1963); accelerate phytoplankton growth excreting nutrient substances which are finally metabolized (Ketchum, 1962); and supply themselves as food to predators. Because of its great importance, attention should be given to the study of abundance of zooplankton. Since sumithion is widely used for crop protection and for the eradication of aquatic insects in aquaculture ponds, little is known about its impact on the abundance and diversity of primary and secondary producers of aquaculture ponds. Therefore, this study has been carried out to evaluate the impacts of sumithion on phytoplankton and zooplankton populations in aquaculture ponds.

Materials and methods

Experimental design

This study was conducted in six earthen freshwater ponds (60 m^2 each) situated in the field laboratory of Fisheries Faculty, Bangladesh Agricultural University, Mymenshingh, Bangladesh for a period of 120 days (February to June 2014). The ponds were equal in size and similar in shape, depth, basin conformation, bottom type and exposure to sunlight. The water depth was maintained to a maximum of 1.5 m using water supply/drainage facilities. The experiment was carried out with three treatments each with two replications, i.e., ponds without sumithion (T1) with replications (R1 and R2), with sumithion at 1 ppm (T2) with replications (R1 and R2) and with sumithion at 2 ppm (T3) with replications (R1 and R2).

Water quality parameters

Some water quality parameters of the studied ponds such as water temperature (°C) measured using a digital thermometer, transparency (cm) determined with the secchi disk, dissolved oxygen (mg L^{-1}) measured with DO meter (Model DO5509, Lutron, made in Taiwan), pH measured with a portable pH meter (Model number- RI 02895, HANNA Instruments Co.) were determined fortnightly during the experimental period. Total alkalinity (mg L^{-1}) of water was measured by titrimetric method using phenolphthalein and 0.0227N NaOH titrant.

Study of plankton

Plankton population of the experimental ponds such as, phytoplankton density (cells L^{-1}) and zooplankton density (Individual L^{-1}) were estimated fortnightly. The counting of plankton (both phytoplankton and zooplankton) was performed using the Sedgwick-Rafter Counting Cell (S-R cell) under a compound binocular microscope (MICROS-MCX100, Austria). The plankton population was calculated by using a formula developed by Rahman (1992). Moreover, planktonic identification (phytoplankton and zooplankton) was determined up to generic level following identification keys of Needham and Needham (1963), Presscott (1964) and Belcher and Swale (1978).

Chemical parameters of pond bottom-soil (sediment)

Various chemical parameters such as pH, available phosphorus (ppm), total nitrogen (%), organic carbon (%) and organic matter (%) of the pond bottom (sediment) were estimated fortnightly using standard methods (Sattar and Rahman, 1987).

Statistical analysis

Values were presented as means±standard deviation (SD). Data were analyzed by one-way analysis of variance (ANOVA) followed by Tukey's post hoc test to assess statistically significant differences among the different sampling days and different treatments. Statistical significance was set at $p<0.05$. Statistical analyses were performed using SPSS Version 14.0 for Windows (SPSS Inc., Chicago, IL).

Results

Water quality parameters

We examined several physico-chemical parameters of water, such as temperature (°C), transparency (cm), pH, dissolved oxygen (ppm), total alkalinity (ppm), nitrate nitrogen (ppm) and phosphate phosphorus (ppm) in the study period (Table 1). Temperature, pH, dissolved oxygen and total alkalinity were almost similar throughout the study period irrespective of the treatment. Determined transparency, NO_3-N and PO_4-P values decreased with increasing sumithion concentrations although differences were not statistically significant ($p>0.05$).

Table 1: Fortnightly fluctuations of water quality parameters (Means ± SD; n=4) during the study period

Parameters	T*	Sampling days								
		0	15	30	45	60	75	90	105	120
Temperature (^{O}C)	T1	23.68±0.2	28.23±0.1	31.15±0.6	27.90±0.1	29.78±0.1	31.70±0.5	31.40±0.2	31.93±0.1	26.58±0.4
	T2	23.80±0.1	27.78±0.1	31.18±0.6	27.80±0.1	29.80±0.2	31.15±0.3	31.28±0.4	32.05±0.5	27.98±0.6
	T3	23.70±0.3	27.70±0.3	31.02±0.2	27.83±0.3	29.80±0.4	31.20±0.5	31.23±0.2	32.03±0.4	27.98±0.5
Transparency (cm)	T1	26.50±0.9	25.63±0.4	10.83±0.1	13.00±0.1	14.23±1.2	14.58±2.4	19.63±1.4	17.15±0.1	21.28±3.2
	T2	28.78±3.2	20.83±1.9	25.15±0.1	20.38±2.9	23.00±1.2	18.20±1.4	27.78±1.4	22.28±2.6	26.30±6.3
	T3	27.20±2.6	22.50±2.1	32.50±3.2	20.70±0.4	20.90±2.4	22.75±1.4	30.28±6.0	37.55±7.4	30.93±9.1
pH	T1	8.20±0.4	8.75±0.1	8.68±0.1	8.70±0.1	8.53±0.1	8.45±0.3	8.45±0.1	8.38±0.1	8.35±0.2
	T2	8.13±0.3	8.45±0.2	8.33±0.4	8.53±0.1	8.35±0.2	8.38±0.1	8.40±0.1	8.20±0.2	7.80±0.4
	T3	8.15±0.3	8.50±0.1	8.10±0.1	8.43±0.4	8.45±0.1	8.30±0.3	8.35±0.2	8.28±0.1	8.08±0.3
Dissolved oxygen (ppm)	T1	5.70±1.1	3.63±0.2	3.28±0.1	3.23±0.1	2.03±0.1	3.40±0.1	3.30±0.2	3.53±0.1	3.45±0.4
	T2	6.08±0.3	3.65±0.2	3.20±0.2	3.48±0.1	1.80±0.3	3.38±0.2	3.48±0.3	3.35±0.3	3.28±0.2
	T3	5.78±0.3	3.60±0.1	3.03±0.2	3.33±0.2	2.53±0.1	3.18±0.1	3.23±0.1	3.25±0.2	3.15±0.3
Total alkalinity (ppm)	T1	128.5±5.3	143.2±9.2	123.2±6.7	113.2±5.7	113.4±7.5	108.2±6.6	105.4±2.2	110.0±2.9	112.3±2.1
	T2	132.6±9.8	123.3±8.2	113.2±7.5	98.4±7.3	101.2±4.0	98.0±2.6	100.0±3.0	98.0±5.9	102.0±1.4
	T3	130.0±6.3	125.0±7.4	117.0±7.3	107.0±3.1	102.3±9.1	95.0±7.6	85.0±6.7	90.0±2.1	95.0±2.4
PO_4-P (ppm)	T1	3.33±1.0	4.00±1.3	5.00±0.5	3.33±1.2	3.33±1.2	4.00±0.9	2.00±0.5	2.00±0.7	4.67±0.6
	T2	3.33±0.5	2.67±0.6	2.67±0.8	1.33±0.6	3.67±0.5	2.33±0.7	1.33±0.4	3.67±0.7	4.67±0.8
	T3	2.67±0.8	1.67±0.5	2.13±1.2	2.15±0.6	5.00±0.7	1.33±0.6	1.00±0.7	4.33±0.6	4.00±0.5
NO_3-N (ppm)	T1	1.50±0.6	2.25±0.5	2.50±0.6	2.65±0.7	3.15±0.4	3.00±0.9	2.50±0.7	2.25±0.6	2.00±0.5
	T2	1.75±0.5	1.65±0.6	1.00±0.7	1.50±0.8	1.50±0.6	2.60±0.7	2.35±0.8	2.00±0.9	1.50±0.7
	T3	1.50±0.8	1.50±0.5	1.00±0.8	1.50±0.5	1.35±0.9	2.00±0.5	1.90±0.6	2.05±0.8	1.25±0.6

*Treatments

Quantitative and qualitative study of phytoplankton

The fortnightly fluctuations of phytoplankton densities (x cells L^{-1}) ranged from 2.08±0.20 to 4.75±0.35 x 10^5 cells L^{-1}, 1.91±0.16 to 5.28±0.40 x 10^5 cells L^{-1} and 1.87±0.12 to 6.00±0.31 x 10^5 cells L^{-1} in the ponds of T1, T2 and T3, respectively (Fig. 1). There was an exponential increase in phytoplankton concentration with the progress in the study period in T1, T2 and T3 followed by a slight reduction at the end of the study period though it remained still higher in both T2 & T3 compared to T1. On the basis of mean values (Fig. 2), it was observed that phytoplankton population showed its highest density in T3 ($4.12\pm1.51 \times 10^5$ cells L^{-1}) followed by that in T2 ($3.71\pm1.15 \times 10^5$ cells L^{-1}) and T1 ($3.45\pm0.92 \times 10^5$ cells L^{-1}). However, no distinct changes were observed in phytoplankton population irrespective of treatments. A total of 20 genera in T1, 18 genera in T2 and 17 genera in T3 belonging to different groups of phytoplankton were recorded during the study periods (Table 2).

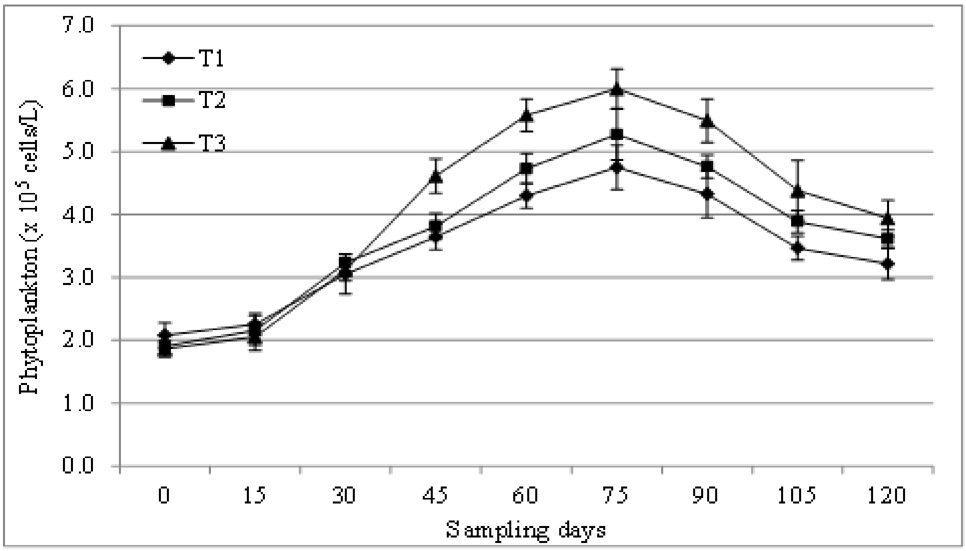

Figure 1: Fortnightly fluctuations of phytoplankton (x cells L^{-1}) found in the experimental ponds during the sampling periods.

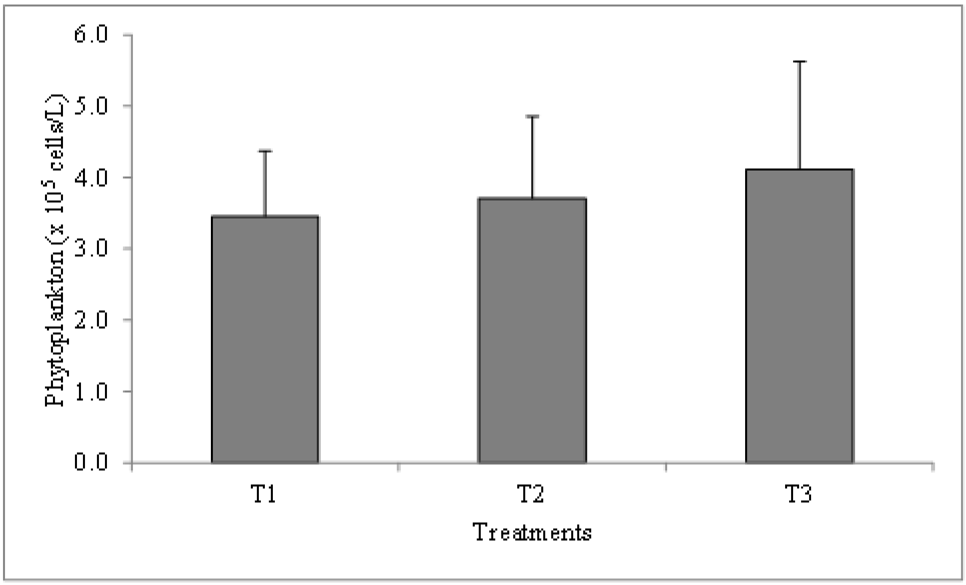

Figure 2: Phytoplankton population densities (Means±SD) in different treatments during the study period.

Table 2: Generic status of phytoplankton under different major groups found in the aquaculture ponds during the experimental periods.

Major groups	Generic names		
	T1	**T2**	**T3**
Chlorophyceae	*Chlorella* *Oocystis* *Pediastrum* *Scenedesmus* *Ulothrix* *Closterium* *Actinastrum*	*Chlorella* *Oocystis* *Pediastrum* *Scenedesmus* *Ulothrix* *Closterium*	*Chlorella* *Oocystis* *Pediastrum* *Scenedesmus* *Ulothrix* *Closteriu*
Cyanophyceae	*Anabaena* *Gomphospaeria* *Microcystis* *Oscillatoria* *Aphanocapsa*	*Anabaena* *Gomphospaeria* *Microcystis.* *Oscillatoria*	*Anabaena* *Gomphospaeria* *Microcystis* *Oscillatoria*
Bacillariophyceae	*Asterionella* *Cyclotella* *Diatoma* *Fragillaria* *Tabellaria.*	*Asterionella* *Cyclotella* *Diatoma* *Fragillaria* *Tabellaria.*	*Asterionella* *Cyclotella* *Diatoma* *Fragillaria*
Euglenophyceae	*Euglena* *Phacus*	*Euglena* *Phacus*	*Euglena* *Phacus*
Dinophyceae	*Ceratium*	*Ceratium*	*Ceratium*

Quantitative and qualitative study of zooplankton

The fortnightly variations of zooplankton densities (× Ind L^{-1}) are shown in Fig. 3. The zooplankton densities (× Ind L^{-3}) ranged from 2.75±0.21 to 3.85±0.35 × 10^4 Ind L^{-1}, 1.05±0.21 to 3.70±0.47 × 10^4 Ind L^{-1} and 1.05±0.14 to 3.90±0.57 × 10^4 Ind L^{-1} in the ponds of T1, T2 and T3, respectively (Fig. 3). The zooplankton population densities (× Ind L^{-1}) significantly decreased with toxicity of sumithion after 30 days of the experimental period in both T2 and T3 compared to the control group (T1). On the basis of mean values (Fig. 4), it was observed that zooplankton population showed its highest density in T1 (3.00±0.35 × 10^4 Ind L^{-1}) followed by that in T2 (2.03±0.81 ×10^4 Ind L^{-1}) and T3 (1.99±0.94 × 10^4 Ind L^{-1}). The assessment of zooplankton diversity in the present study detected zooplankton belonging to three crustacean groups (Cladocera, Copepoda and Crustacean larva) including another group named Rotifera. Although, 7 crustacean species and 6 species of Rotifera were identified from sumithion free experimental ponds (control treatment), comparatively lower numbers of these planktonic fauna (6 crustacean species and 5 rotiferan species) were detected from both the sumithion treated ponds, T2 and T3.

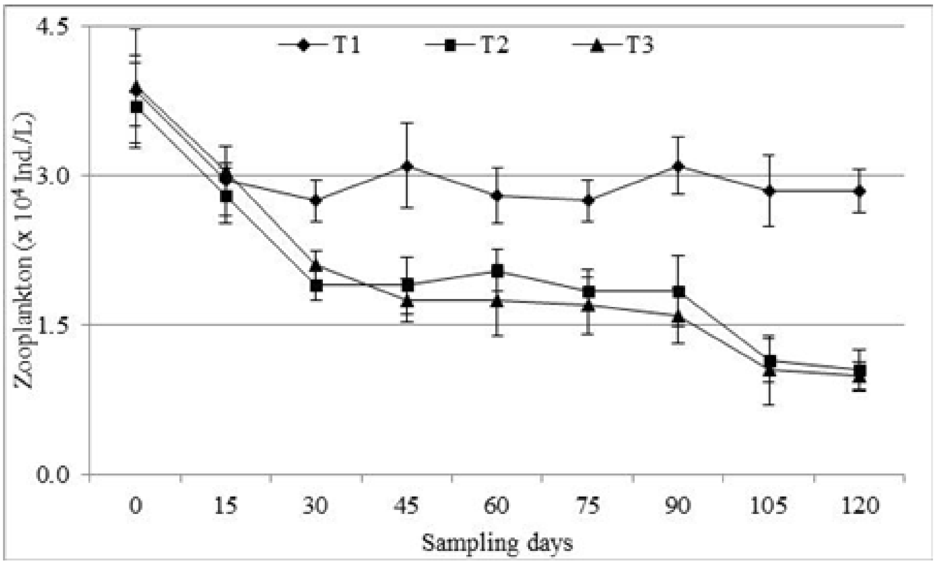

Figure 3: Fortnightly variations in abundance of zooplankton (x Ind L^{-1}) in the experimental ponds under three treatments during the study periods.

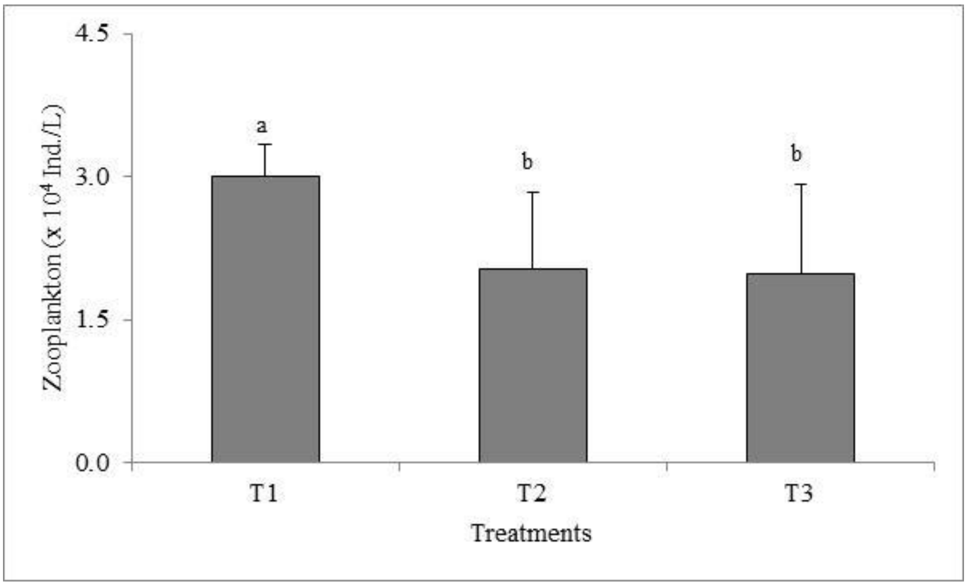

Figure 4: Zooplankton population densities (Means±SD) in different treatments during the study period. Values accompanied by different letters are statistically significantly different (*p*<0.05).

Chemical parameters of pond sediments

The fortnightly fluctuations of pH, organic carbon (%), total nitrogen (%) and available phosphorus (ppm) are shown in Table 3. No distinct changes were observed among treatments during the experimental period.

Table 3: Fortnightly fluctuations of chemical parameters of pond bottom-soil (means ± SD; n = 4) during the experimental periods.

Parameters	T*	Sampling days								
		0	15	30	45	60	75	90	105	120
pH	T1	6.78±0.16	6.75±0.05	6.54±0.03	6.68±0.18	6.48±0.12	6.01±0.08	6.04±0.04	6.15±0.14	6.03±0.04
	T2	6.62±0.14	6.76±0.05	6.69±0.11	6.61±0.04	6.61±0.08	6.06±0.04	6.07±0.03	6.12±0.07	6.01±0.04
	T3	6.66±0.09	6.43±0.09	6.47±0.02	6.50±0.03	6.26±0.30	6.07±0.09	5.95±0.11	6.03±0.05	6.02±0.06
Organic carbon (%)	T1	1.17±0.17	0.78±0.09	0.81±0.02	0.85±0.08	0.90±0.17	0.87±0.03	0.93±0.09	1.01±0.01	1.01±0.02
	T2	1.25±0.15	1.09±0.14	0.68±0.07	0.96±0.04	0.84±0.09	0.95±0.10	1.01±0.07	0.77±0.13	0.94±0.06
	T3	1.15±0.20	1.05±0.13	0.67±0.27	0.99±0.01	0.94±0.20	1.15±0.19	0.88±0.01	0.92±0.09	0.81±0.06
Total Nitrogen (%)	T1	0.11±0.01	0.08±0.01	0.08±0.01	0.08±0.02	0.08±0.01	0.09±0.01	0.09±0.01	0.09±0.01	0.09±0.01
	T2	0.12±0.01	0.10±0.01	0.09±0.02	0.10±0.01	0.10±0.02	0.10±0.02	0.10±0.01	0.10±0.01	0.09±0.01
	T3	0.11±0.02	0.12±0.02	0.09±0.05	0.10±0.01	0.10±0.01	0.10±0.01	0.10±0.02	0.09±0.01	0.10±0.02
Available Phosphorous (ppm)	T1	19.59±1.8	14.55±1.1	12.09±2.2	16.51±4.8	17.97±3.5	14.03±0.2	15.91±0.4	15.05±0.4	15.08±1.6
	T2	18.60±2.9	15.89±2.5	15.92±1.9	20.99±4.4	21.57±0.7	16.80±1.5	16.40±1.6	17.60±3.4	17.11±4.6
	T3	19.79±2.0	22.64±6.0	23.57±1.9	23.48±2.9	23.91±3.3	24.12±1.2	25.57±1.6	28.87±4.1	27.17±6.5

*Treatments

Discussion

In the present study, we investigated the effects of an organophosphorous pesticide sumithion on plankton population densities in aquaculture ponds. We demonstrated that phytoplankton population densities were not affected by sumithion application, while zooplankton populations were significantly affected by sumithion which might influence the production in aquaculture ponds.

Water quality parameters have a great role in causing the toxicity of different pesticides that ultimately have harmful effects on diversity, abundance and dynamics of aquatic flora and fauna. It has been reported that mass mortalities of grass carp attributed to a multi-factorial disease primarily caused by bacterial agents and might be triggered by unsuitable environmental factors, such as poor water quality, limited oxygen supply, poor feed bases and chronic or acute exposure to pesticides dissolved in water or included in feeds (Van *et al.,* 2002; Pucher *et al.,* 2012). In the present study, the water quality parameters monitored during the experimental period did not differ in response to sumithion application and were within suitable ranges (Table 1). The limited variation in the physicochemical variables might be due to the addition of water and sumithion every two weeks. Such water quality parameters have also been observed by a number of authors (Uddin *et al.,* 2007; Chowdhury *et al.,* 2008; Rahman *et al.,* 2012; Siddika *et al.,* 2012; Talukdar *et al.,* 2012; Uddin *et al.,* 2012) in the aquaculture ponds of our experimental area. However, transparency, NO_3-N and PO_4-P values tended to decrease with increasing concentrations of the sumithion among treatments (Table 1) in the present study indicating the adverse effects of sumithion on water quality in aquaculture ponds.

In the present study, phytoplanktonic density was slightly enhanced by the increasing doses of sumithion. This might be possible due to decreased grazing rate by zooplankton on phytoplankton. The identified number of phytoplankton species (Table 2) was found assertive in the sumithion free control group (T1) rather than in the sumithion treated (T2 and T3) groups. These findings suggest that sumithion had insignificant negative influence on their diversity. On the other hand, in case of zooplankton density a reverse scenario was observed, where the abundance of zooplankton was significantly reduced with increasing doses of sumithion (T2 and T3) compared to the control group (T1). The toxic effects of pesticides on zooplankton have been reported through mesocosm experiments as well as acute and chronic toxicity tests (Willis *et al*., 2004; Mangas-Ramirez *et al*., 2007). It has been reported that pesticides greatly reduced the abundance of food organisms including zooplankton for fish in aquatic bodies (Helfrich *et al.*, 2009). By this, it indirectly interrupts availability of phytoplankton and zooplankton (Maskaoui *et al*., 2005). According to Parveen *et al.* (2002), fish and other beneficial aquatic organisms were killed by pesticides and pesticides affected the aquatic ecosystem by interrupting the aquatic food chain of open water fish species and finally resulted in the loss of the abundance of natural species. Rohar and Crumrine (2005) also reported that the application of the herbicide atrazine to a lentic system resulted in lower periphyton abundance. A recent study conducted by Macken *et al.* (2015) demonstrated that some pesticides used in aquaculture to control lice have low toxicity to aquatic flora but they have significant adverse effects on non-target species including macrozoobenthos. In the present study, population densities of phytoplankton and zooplankton showed a direct inter-relationship. The study suggested that when the density of zooplankton reduced, the density of phytoplankton increased. Inter-relationship between phytoplankton and zooplankton was also reported in the Halda River (Patra and Azadi, 1987) and in a pond (Ali *et al*., 1985). The density of zooplankton became significantly lower due to its exposure in sumithion. This might be because of the toxic nature of the pesticide to zooplankton.

Sediments are important sinks for various pollutants like pesticides and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediment and pesticide residual problems in the fish tissues are serious, as reflected by the high pesticides concentrations recorded in the water and sediments (Amaraneni, 2006). In the present study, pH, organic carbon (%), available phosphorus (ppm) and total nitrogen (%) of pond sediment was found within suitable ranges for the growth and production of macro-benthos and aquatic fauna. Some other researchers also demonstrated similar findings (Nupur *et al*., 2013). No distinct changes were observed among treatments during the experimental period. Therefore, it can be noted that sumithion has no direct detrimental impact on the sediment in aquaculture ponds.

To conclude, the organophosphorous pesticide sumithion has inhibitory effects on zooplankton regardless of phytoplankton which has been demonstrated by the present experiment. Therefore, the issue should be taken into attention during the use of sumithion to control beetles in paddy fields and tiger bugs in the larval rearing ponds.

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