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Abstract

This experiment aimed to study the effect of agriculture gypsum treatment in aquaculture ponds (to raise water total hardness) on the physico-chemical and biological parameters of pond water and fish performance in a polyculture system. In order to achieve this goal, twelve 0.1-Fed. earthen ponds were randomly assigned for three treatments and control each with three replicates, ponds were treated with sufficient gypsum amounts to raise total hardness from 207 – 218 mg/L as $CaCO_3$ (control) to approximately 300, 380 and 450 mg/l as $CaCO_3$ for I, II and III treatments respectively. Ponds were stocked with blue tilapia, common carp and silver carp in a polyculture system. All ponds were fertilized weekly with the same amount of superphosphate (40 kg/fed), urea (20 kg/fed) and chicken manure (35 kg/fed.). All fish were fed with artificial fish feed 25% crude protein at 50% of satiation level. Water samples were collected biweekly and analyzed for some water quality parameters (turbidity, temp., pH, SD, EC, DO, TH, T.Alk., NH_4, NO_3, TAN, OP and TP. and monthly for microscopic enumeration and classification of phytoplankton, zooplankton and chlorophyll "a" measurements. The results showed that gypsum treatment decreased the turbidity gradually by 54%, 53% and 72% for the I, II, III treatments respectively, pH values were lower in gypsum treated ponds than that in control ponds. Water quality parameters were however, within the favorable range for freshwater fish in all treatments, treated ponds had higher abundance of green algae and also zooplankton composition was of high quality especially rotifera and cladocera (small sized species) which is a good index for fish nutrition compared to control ponds, this provided suitable conditions for fish growth and exhibited highest fish survival and highest fish production at harvest in the treated ponds, fish production was 1519, 1292 and 1469 kg/f for the I, II and III treatments respectively compared to the control ponds (1090 kg/f). An economic evaluation was carried out to compare the profitability of using different quantities of gypsum (i.e. different hardness) which declared that the net return of the treatments follow this sequence, the I, III, II treatments and control (3563, 2620, 2132 and 1183 LE/fed. respectively), the I treatment had the highest relative rank followed in a decreasing order by III, II and control respectively.

Keywords: Gypsum treatment; Turbidity clearance; Water hardness; Polyculture system.

Introduction

Aquaculture, mainly referring to the farming of fish and shrimp, forms a major enterprise in the production sector. It represents around 25% of food fishery supply, and is expected to contribute an increasing share to meet the world's future food needs (Pattanaik and Prasad 2011).

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The aquaculture growth required to meet increasing protein demand by a growing world population, predicted to reach 9 billion people by 2050 (Ferreira et al., 2012). Egyptian aquaculture production increased through the past decade from 376.066 thousand tons in 2002 representing about 47% of the total fish production (801.466 thousand tons) to reach 986.820 thousand tons in 2011 representing more than 72% of the total national fish production (1362.174 thousand tons) GAFRD (2012).

A number of fertilizers (chemical and organic), feed and other substances are used in pond aquaculture for enhancing fish production. These substances along with dead phytoplankton, uneaten feed, and fish fecal materials, precipitate to the pond bottom and could release again or resuspend to the water column causing increase of water turbidity that prevents the penetration of the sun beams which reduces the photosynthesis activity since there is an inverse relationship between suspended particulate matter and photosynthesis (Furtado et al. ,2011) which in turn affect the utilization of all chemical compounds in the pond water into living planktonic organism.

The release of nutrients into the water column could be prevented by the addition of gypsum ($CaSO_4 \cdot 2H_2O$). Gypsum evidently acted as a slow-releasing source of sulphate in sediment, which likely enhanced the activity of sulphate-reducing bacteria and improved the overall mineralisation rate of organic matter. Varjo et al (2003).

This experiment aimed to study the effect of the agriculture gypsum treatment to pond waters to flocculate suspended clay particles and cause them to precipitate and to monitor its effect on water physico-chemical parameters along with phytoplankton and zooplankton composition and fish performance as well as the economic impact of the addition of gypsum to pond water at different rates.

Materials and methods

This experiment was conducted in twelve 0.1-Fed. earthen ponds located at the WorldFish Center, Abbassa, Abou Hammad – Sharkia – Egypt. Ponds were 1.2 m deep at standing drainpipes, had average depth of 0.9 - 1 m. Ponds were supplied with water from Ismailia canal and was moderate hard (total alkalinity and total hardness of 130 and 110 mg/L as $CaCO_3$

respectively), filterable orthophosphate of 0.1 mg/L, total phosphorus of 0.21 mg/L, total ammonia-nitrogen of 0.21 mg/L, nitrate-nitrogen of 0.3 mg/L and pH of 8.1.

Ponds were stocked with the rate of 6000 fish/fed. of blue tilapia (*Oreochromis aureus*), 520 fish/fed. of common carp (*Cyprinus carpio*) and 400 fish/fed. of silver carp (*Hypophthalmichthys molitrix*) with an average initial weight of 20 ± 2.6, 3 ± 0.17 and 50 ±1.8 g respectively. Ponds were randomly assigned for three treatments and control each represented in three replicates, the experimental ponds were treated with sufficient gypsum to raise total hardness from 207 – 218 mg/L as $CaCO_3$ (control) to approximately 300, 380 and 450 mg/l as $CaCO_3$ for I, II and III treatments respectively.

Total hardness was measured weekly for each pond by EDTA titration according to APHA (1998), additional gypsum was added weekly to the three gypsum treated ponds to maintain the specific total hardness. All ponds were fertilized weekly with the same amount of superphosphate 15.5% P_2O_5 (40 kg/fed), urea 46% N (20 kg/fed) and chicken manure (35 kg/fed.).

Fish were fed daily with artificial feed (25% crude protein) at a rate of half satiation level. Satiation feeding level was determined for each pond by estimating the total amount of feed consumed during two feeding sessions (morning session "1000 – 1100 h" and afternoon session "1400 – 1500 h") every Sunday. The 50% of consumed amount by each pond (using a separate bucket) considered the 50% of satiation level then applied to the same pond from Monday to Saturday except Fridays.

Water samples were collected biweekly and analyzed for the following water quality parameters, water temperature (°C), pH, Secchi disk (SD) electric conductivity (EC), dissolved oxygen (DO), total hardness (TH), total alkalinity (T. Alk.), Ionized ammonia (NH_4), nitrate-nitrogen (NO_3), total ammonia nitrogen (TAN), orthophosphate (OP) and total phosphorus (TP). According to APHA (1998). Water samples were collected monthly for microscopic enumeration and classification of phytoplankton, zooplankton and measurement of Chlorophyll “a”.

Fish samples from each pond and each species were randomly collected monthly to monitor the growth rate of the fish then all fish were returned back to their relevant pond. After 140-day grow out period fish were harvested, sorted, classified and weighed.

Data were statistically analyzed using one-way Analysis Of Variance (ANOVA) and Duncan’s multiple Range Test was performed to determine differences between treatments means at significance level of 0.05. Standard errors of treatment means were also estimated. All statistics were carried out using Statistical Analysis Systems (SAS) program (SAS, 2009).

Results and discussion

Turbidity clearance

Water turbidity is the suspended materials consist mainly of soil particles, uneaten feed and any other metabolic materials suspended in the water column. Lawson (1995) stated that turbidity produced by dissolved and suspended substances, such as clay particles, humic substances, silt plankton, etc., can be troublesome in fish. Ferreira et al. (2011) found that the major source of turbidity comes from sporadic runoff episodes and high nutrient input. As tabulated in Table (1) samples of water which collected before gypsum treatments (initial) and after 3 days of gypsum treatment (final) showed that average water turbidity was decreased from 390 to 310 NTU for control and from 340 to 150, from 300 to 140 and from 380 to 105 NTU for the I, II and III treatments respectively which mean that gypsum treatment decreased the turbidity gradually by 54%, 53% and 72% for the I, II, III treatments respectively as illustrated in Figure (1).

Table (1) Effect of different gypsum treatments - different hardness - in turbidity (NTU) measured just before adding gypsum (initial) and after three days later (final) throughout the excremental period.

Treatment	Initial				Final				Average		Turbidity %	
	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct	Initial	Final	Clearance	Remain
Control	355	390	410	420	250	270	355	370	390	310	20.51	79.48 a ± 13.20
I	380	310	350	315	190	220	110	100	340	155	54.41	45.50 b ± 8.36
II	320	290	300	280	170	110	115	160	300	140	53.33	46.66 b ± 6.95
III	410	370	350	390	130	100	90	100	380	105	72.37	27.65 c ± 4.67

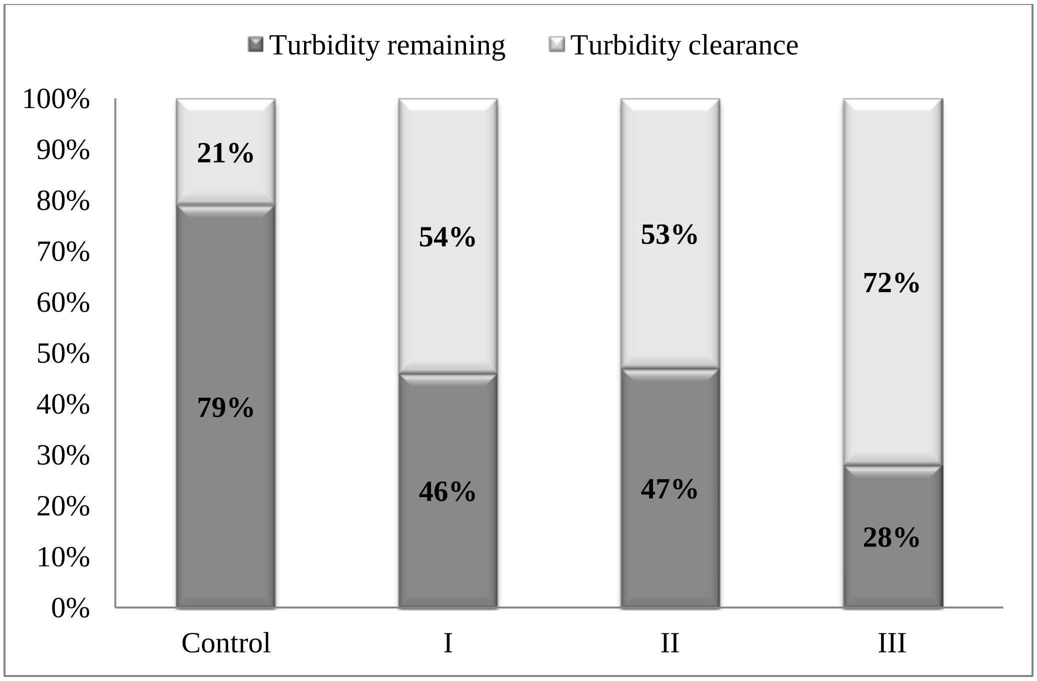

Figure (1) Percentages of turbidity remaining and clearance in the control and treated ponds.

This decrease in turbidity maybe due to the bonding effect of the gypsum on soil particles preventing it to resuspend again to the water column and the reduction in phytoplankton abundance in the treated ponds than control (Shahidul Islam et al., 2004, Table 3). These results are confirmed by the Secchi disk readings, the mean visibility was less in control ponds (e.g. lower Secchi disk readings) than that in treated ponds. Secchi disk readings were 13.2, 15.5, 16 and 17.3 cm for control, I, II, and III treatments respectively (Table 2).

pH reduction

pH is the most important factor regulating the transformation between many forms of chemical compounds to each other. The influence of gypsum treatment on pH during the day (diurnal values) is illustrated in Figure (2). Results of this figure showed that pH had its lowest values at 6am then it gradually increased to reach its peak at 2pm in all treatments and control this mainly due to the high algal abundance during the day that may cause increased photosynthetic activity resulting in high pH values (Ibrahim, 2001 and El Naggar et al., 2008). pH values were lower in gypsum treated ponds than that in control ponds, the reduction of pH increased with the increase of gypsum application, pH percentages were 98.7, 96.5 and 95.9 for I , II and III treatments compared to the control (Figure 3).

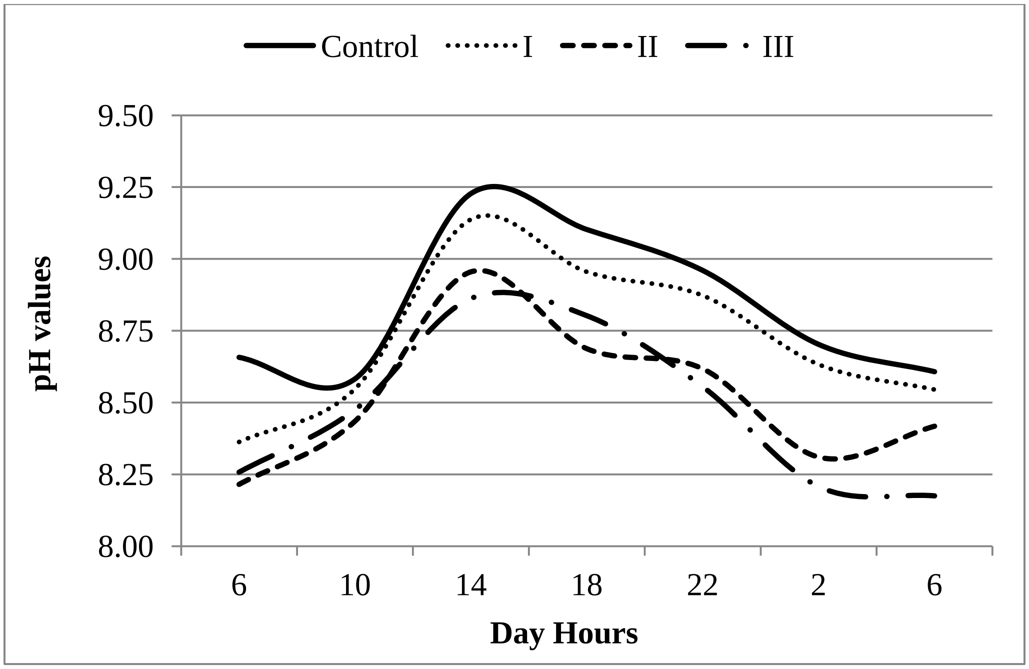

Figure (2) Average diurnal pH values in the control and the three gypsum treatments throughout the experimental period

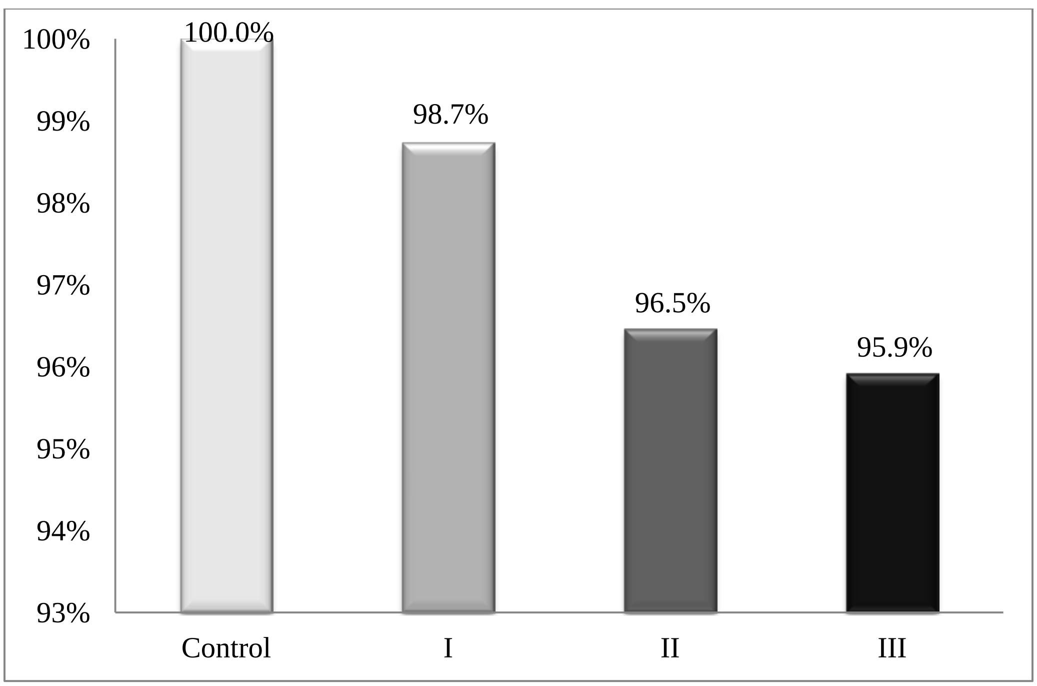

Figure (3) pH percentages in different gypsum treated ponds as compared to the control (100%)

The reduction in pH values may due to the effect of gypsum that reduced the phytoplankton abundance as a result of the decreased phosphorus concentrations in the treated ponds compared to control, which ultimately reduced the photosynthesis process which in turn reduced pH values. Similar results are found by Suomela et al. (2005) who stated that higher pH-levels usually result from intensive photosynthesis in eutrophic conditions.

Table (2) Physico-chemical parameters (mean ± SE) in fish ponds under different gypsum treatments.

Treatment	Temp (^{o}C)	pH	SD (cm)	EC (mmohs /cm)	DO (mg/l)	T.H. as $CaCO_3$	T. Alk. as $CaCO_3$	NH_4 (mg/l)	NO_3 (mg/l)	T.N. (mg/l)	PO_4 (mg/l)	T.P. (mg/l)
Control	25.97^{a} ± 1.01	8.91^{a} ± 0.93	13.20^{c} ± 1.85	1.05^{a} ± 0.21	7.89^{a} ± 1.23	210^{d}	289.67^{c} ± 22.13	1.98^{a} ± 0.29	0.637^{a} ± 0.08	2.43^{a} ± 0.37	1.92^{a} ± 0.19	2.53^{a} ± 0.25
I	26.03^{a} ± 1.93	8.57^{b} ± 0.21	15.49^{b} ± 0.51	1.15^{a} ± 0.03	6.97^{b} ± 1.30	300^{c}	355.30^{b} ± 9.81	1.29^{b} ± 0.19	0.614^{a} ± 0.22	1.69^{b} ± 0.29	1.16^{b} ± 0.06	1.41^{b} ± 0.16
II	25.98^{a} ± 1.80	8.43^{b} ± 0.37	15.96^{b} ± 0.42	1.09^{a} ± 0.11	6.19^{b} ± 0.92	380^{b}	384.20^{b} ± 18.08	1.38^{b} ± 0.23	0.557^{b} ± 0.17	1.77^{b} ± 0.31	1.03^{b} ± 0.04	1.36^{b} ± 0.12
III	25.84^{a} ± 1.34	8.02^{c} ± 0.32	17.34^{a} ± 0.84	1.32^{a} ± 0.21	4.56^{c} ± 1.09	450^{a}	400.83^{a} ± 9.24	1.08^{c} ± 0.14	0.563^{b} ± 0.19	1.53^{b} ± 0.83	0.88^{c} ± 0.21	1.04^{c} ± 0.35

Means in the same column with different superscript are significantly different

Results of Table (2) revealed that although all experimental ponds received the same amounts of phosphate in the fertilizers, the concentrations of total phosphate and dissolved orthophosphate were significantly ($P<0.05$) higher in the control ponds than the treated ponds due to the effect of gypsum on precipitation of phosphorus through lowering the pH values in treated ponds compared to the control ones. The reduction in orthophosphate reduced consequently the abundance of phytoplankton in the treated ponds as reported by Boyd (1990). In spite of phytoplankton reduction in gypsum treated ponds, such ponds appeared to be still fertile, thus chlorophyll “a” concentrations were 204.5, 203.3 and 108.3 µg/L in treatments I, II and III respectively (Table 3). Algae are certainly capable of taking up soluble inorganic P from the water, as well as many forms of soluble organic P produced by the enzymatic breakdown of organic molecules (Azevedo et al. 2011). Furthermore some algae are capable of extracting P adsorbed to sediments resuspended in the water column (Grobbelaar, 1983). Ponds with total hardness of 300 and 380 mg/l (I and II treatments) showed no significant difference in chlorophyll “a” as an indicator of phytoplankton abundance as reported by Ibrahim (2001).

The most important parameter for fish culture is the concentration of dissolved oxygen (DO). There was a significant difference ($P<0.05$) in the average of water content of dissolved oxygen among the treatments III in one side (4.56 mg/l) and I and II in the other side (6.97 and 6.17 mg/l respectively) while control had the significantly higher average water content of oxygen (7.89 mg/l) this mainly due to the lower concentration of phytoplankton in the treated ponds compared to the control and to the increased fish biomass that consumes oxygen in respiration in the treated ponds than control, fish biomass was 1090, 1519, 1292 and 1469 kg/fed for the control, I, II and III treatments respectively (Table 4). Generally dissolved oxygen was in the desired level for all treatments and control which in agreement with the findings of Ibrahim (1997).

The overall average of total alkalinity was the lowest in the control ponds (289.7 mg $CaCO_3$/l) followed by I and II treatments (355.3 and 384.2 mg $CaCO_3$/l, respectively) while III treatment was significantly the highest (400.8 mg $CaCO_3$/l). Increased alkalinity buffers water against drastic daily changes in pH common in eutrophic ponds with soft water (Boyd and Massaut (1999) and Degefu et al. (2011). This significant difference in total alkalinity could be described by the increased consumption of CO_2 by the active photosynthesis of dense algae and dissociation of HCO_3 to replace the consumed CO_2 molecules (Ibrahim 1997 and Furtado et al. 2011).

As presented in Table (2) ionized ammonia concentrations were found to be 1.89, 1.29, 1.38 and 1.08 mg/l in the control, I, II and III treatments respectively, the statistical evaluation of results revealed that control ponds had significantly ($P<0.05$) the highest ionized ammonia concentrations compared to the treated ponds, however differences in this parameter. The reduction in ionized ammonia in treated ponds may probably due to the decreased concentration of dissolved oxygen in the treated ponds than control which led to reduce the nitrification process that reduces the concentrations of ammonia, nitrate and consequently the total nitrogen which follow the same pattern of ammonia (Table 2). The decreased concentration of total nitrogen in the treated ponds (1.69, 1.77 and 1.53 mg/l in the I, II and III treatment compared to control 2.43 mg/l) may also referred to the lower concentration of the blue-green algae in the treated ponds (49, 45 and 14 organism x 10^5/l for I, II and III treatments respectively while it was 263 organism x 10^5/l in the control) this mainly due to the fact that blue-green algae posses to fix the atmospheric nitrogen (Ibrahim 2001). All prokaryotes convert atmospheric nitrogen into ammonia which may explain why nitrogenous compounds occur frequently in blue–green algae (El Gamal 2010).

Phytoplankton & Zooplankton abundance:

Phytoplankton

As presented in Table (3) although total phytoplankton abundance was reduced by gypsum treatment as a result of reducing blue-green algae, the concentration of green algae was increased in the treated ponds which make a favorable conditions for fish growth (Degefu et al., 2011); the III treatment had the lowest abundance of phytoplankton than the other treatments and control ponds while the concentration of chlorophyll “a” for the III treatment was 108.3 μg/l which means that these ponds still productive. Ibrahim (1997 and 2001) stated that there is a positive correlation between chlorophyll “a” content and algal density and both have inverse correlation with Secchi disk readings in fish ponds. In this study increasing hardness concentrations in the treated ponds encouraged the growth of green algae while control had the highest abundance of the blue-green algae (Figure 4), the percentages of the blue-green algae concentration was 43.2%, 9.6%, 10.3% and 5.1% of the total phytoplankton count in the control, I, II and III treatments respectively. It is known that blue-green algae release toxins which causes fish stress and/or death according to its concentration, species and time of exposure (Dodds et al., 2009 and Sharaf 2010). These toxins could be found in some edible parts of the fish such as muscles which could be a risk of transferring such toxins to humans (Nyakairu et al., 2010).

Table (3) Phytoplankton average and overall means ($x10^5$/L) of green algae (Green); blue green algae (B.Gr.); diatom (Dia) and Euglena (Eug). And zooplankton average (organism/L) with overall mean of Rotifera (Rot); Cladocera (Clad); Copepoda (Cope) and Ostracoda (Ost). and Chlorophyll "a" (µ/L) under three gypsum treatments.

Treatment	Phytoplankton count ($x 10^5$)/L				Total average	Zooplankton count organsim/L				Total average	Chlorophyll "a" (µ/L)
	Green	B.Gr	Dia	Eug.		Rot	Clad	Cope	Ost		
Control	147	263	42	157	609	7	15	18	7	47	259.57 ^{a} ± 8.73
I	301	49	37	122	509	18	38	10	2	68	204.46 ^{b} ± 7.31
II	266	45	34	90	435	19	35	3	5	62	203.27 ^{b} ± 5.92
III	177	14	19	63	273	9	29	19	1	58	108.33 ^{c} ± 3.61

Means in the same column with different superscript are significantly different

Zooplankton

As tabulated in Table (3), resulted show that the abundance of zooplankton was affected by gypsum treatment and related to the abundance of blue green algal production. The lowest zooplankton density was in control ponds (Table 4) this may be due to the fact that most of algal density in the control ponds was almost blue-green algae which are not acceptable by zooplankton. A number of blue-green species are known to produce off-flavors, including species from the genera Anabaena, Aphanizimenon, Lyngbya, Oscillatoria, Planktothrix, and Phormidium (Zimba and Grimm 2003). These results were confirmed by a correlation matrix (Table 4) which clarify the strong positive correlation between green algae and small sized zooplankton species rotifra and cladocera (correlation coefficients were 0.96 and 0.91 respectively) while blue green algae had a reverse correlation with them (-0.58 and -0.87 for rotifera and cladocera respectively). Zooplankton composition (Figure 5) was of high quality in the I, II and III treatments especially rotifera and cladocera (small sized species) which is a good index for fish nutrition compared to control which had the lowest concentration of total zooplankton count and small sized species.

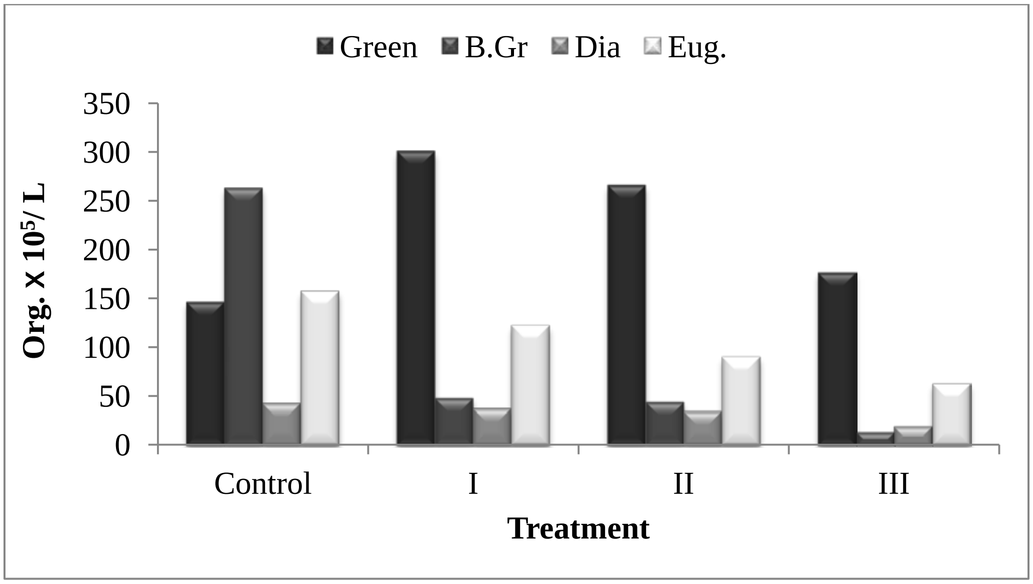

Figure (4) Phytoplankton species abundance in the control and three gypsum treatments

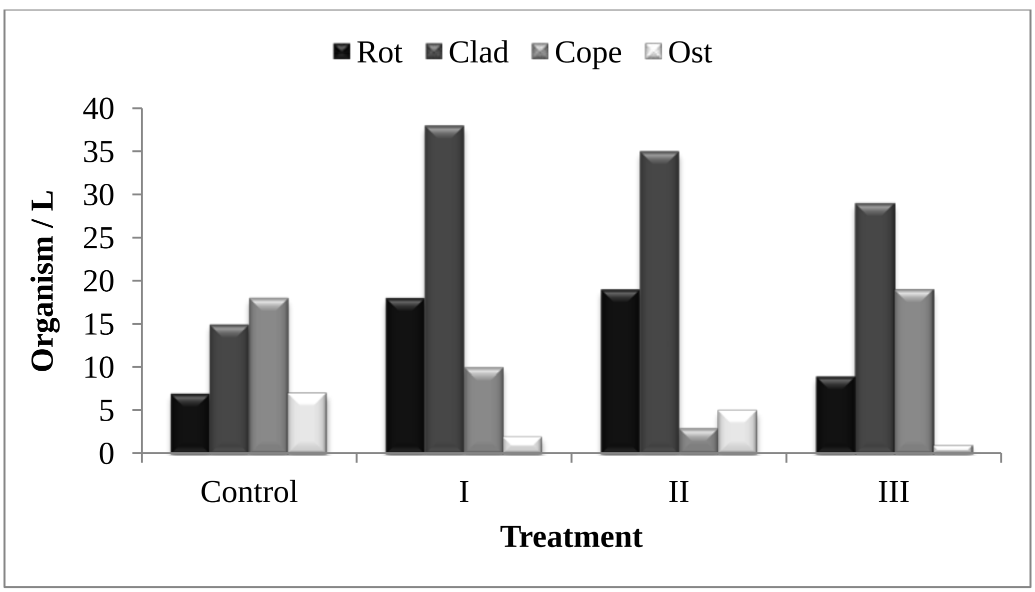

Figure (5) Zooplankton species abundance in the control and three gypsum treatments

Table (4) Correlation matrix between average count of phytoplankton and zooplankton species

Variables	Green	B.Gr	Dia	Eug.	Rot	Clad	Cope	Ost
Green	**1**							
B.Gr	-0.592	**1**						
Dia	0.146	0.709	**1**					
Eug.	-0.151	0.869	0.920	**1**				
Rot	0.964	-0.575	0.154	-0.204	**1**			
Clad	0.910	-0.873	-0.277	-0.537	0.877	**1**		
Cope	-0.807	0.383	-0.274	0.124	-0.931	-0.681	**1**	
Ost	-0.339	0.831	0.758	0.704	-0.193	-0.637	-0.121	**1**

Fish production

The results of fish production as affected by the applied treatments are presented in Table (5). Ponds treated with gypsum provide suitable conditions for fish growth and exhibited highest fish survival (98.7%, 99.1% and 97.8% for I, II and III treatments respectively) than control ponds (85.9%) for tilapia while silver carp and common carp had the same survival percentage of 100% in treated and control ponds.

Table (5) Fish production for tilapia, silver carp and common carp in the three gypsum treatments and control ponds after 140 days.

Treatment	Fish production (kg/f)	Species production (kg/f)			Tilapia classes (kg/f)				Tilapia survival (%)
		tilapia	silver	c.carp	1st	2nd	3rd	4th	
Control	1090 ^{c} ± 17.26	817	174	99	170	263	260	124	85.9
I	1519 ^{a} ± 14.37	1036	289	195	203	507	207	119	98.7
II	1292 ^{b} ± 20.21	952	194	146	179	441	235	97	99.1
III	1469 ^{a} ± 19.34	998	308	163	167	449	259	127	97.8

Means in the same column with different superscript are significantly different

Table (6) Economic evaluation* (LE/Fed.) of the three gypsum treatments and control

Item	Unit	Unit price	Treatments							
			Control		I		II		III	
			Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Gross revenues										
Silver carp	kg	5	174	870	289	1445	194	970	308	1540
Common carp	kg	6.5	99	643.5	195	1267.5	146	949	163	1059.5
Tilapia 1st class	kg	8.5	170	1445	203	1725.5	179	1521.5	167	1419.5
2nd class	kg	7	263	1841	507	3549	441	3087	449	3143
3rd class	kg	5	260	1300	207	1035	235	1175	259	1295
4th class	kg	2.25	124	279	119	267.75	97	218.25	127	285.75
Total revenue				6379		9290		7921		8743
Gross costs										
Fingerlings	Thousand			500		500		500		500
Feed	Ton	2300	0.915	2104.5	1.04	2392	1.05	2415	1.145	2633.5
Superphosphate	50kg bag	55	16	880	16	880	16	880	16	880
Urea	50kg bag	85	8	680	8	680	8	680	8	680
Chicken litter	m^3	105	2.2	231	2.2	231	2.2	231	2.2	231
Gypsum	Ton	220	0	0	1.111	244.42	1.287	283.14	1.808	397.76
Other costs				800		800		800		800
Total costs				5196		5727		5789		6122
Net return				1183		3562		2132		2620

* Based on local market prices of 2009.

The significantly highest fish yield at harvest was reported in the I and III treatments (1519 and 1469 kg/f) without significant difference among these treatments and followed in a significant ($P<0.05$) decreasing order by the II treatment (1292 kg/f) and control (1090 kg/f) respectively.

Economic evaluation

An economic evaluation (Table 6) was carried out to compare the profitability of applying different quantities of gypsum (i.e. different hardness) in fish ponds, results revealed that the I treatment (hardness of 300 mg/L as $CaCO_3$) showed the highest net return of 3562 LE/fed. the III treatment came the second with net return of 2620 LE/fed. followed by the II treatment (2132 LE/fed.) while control came the last with the lowest net return of 1183 LE/fed.

Table (7) provides a nonparametric analysis for the four treatments as a helping tool for choosing one of them based on their relative ranks (i.e. the highest treatment had the highest rank of 100 and the others were computed as percent of it), for some positive variables (needed to increased) and some negative variables (needed to be decreased). The relative rank for the treatments of present study was as follows I, II, III and control.

Table (7) Ranking of some positive (needed to be increased) and negative (needed to be decreased) variables in each treatment, the highest value was considered as 100 and the other values were computed as related to 100

Variable	Control	I	II	III
Do	100	88	78	58
Green algae	49	100	88	59
Rotifera	38	95	100	47
Fish production	72	100	85	97
Net return	33	100	60	73
Positive subtotal	292	483	411	334
Turbidity	-100	-57	-59	-35
TAN	-100	-70	-73	-63
Blue-green algae	-100	-19	-17	-5
Negative subtotal	-300	-146	-149	-103

relative rank	**-8**	**337**	**262**	**231**

The present results indicated that the I treatment (total hardness of 300 mg $CaCO_3$/L) increased the fertilization efficiency and supported the best phytoplankton abundance especially green algae as well as zooplankton density especially small sized species (rotifera and cladocera) which is a good index for fish nutrition and water quality was generally suitable for fish growth and gave good fish production (1519 kg/fed) with high survival rate (98.7%) after 140 days with the highest net return of 3562 LE/fed. The nonparametric analysis also indicated that the I treatment was the best, where it had the highest relative rank compared to the other treatment as well as the control.

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