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Impact of Fish- farming Management on Water Quality, Plankton Abundance and Growth Performance of Fish in Earthen Ponds

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ABSTRACT

The study was performed in earthen ponds situated in North- Nile Delta, Egypt and adopted two fish farming systems. The first system was the feed fish farm that depended on pelleted diet (25% crude protein) as feed input, while the other system was the fertilizer fish farm which utilized both organic fertilizer and crushed macaroni as supplementary feed. Each system had four replicate ponds (8400 m^2 each). The experiment duration was one year, including four months of over-wintering. Nile tilapia (*Oreochromis niloticus*), mullet (*Mugil cephalus*) and catfish (*Clarias gariepinus*) were cultured in each pond at initial weight of 2, 30 and 5 grams, respectively. Samples were collected to determine water quality, plankton abundance and fish growth performance. The results showed that the fertilizer fish farm had significantly high levels of pH, dissolved oxygen and total nitrogen content (TAN, NH_3, NH_4, NO_2 and NO_3) ($P<0.05$). Significant increase ($P<0.05$) in phytoplankton and zooplankton abundance was observed in the fertilizer fish farm compared to the feed fish farm. Within different species, catfish had the highest daily weight gain followed by tilapia and mullet, respectively. Within the two compared systems, farmed fish in the feed farm had higher average daily weight gain and specific growth rate. The feed fish farm had significantly ($P<0.05$) higher production and higher total income, while the fertilizer fish farm had higher net income and lower total production costs.

INTRODUCTION

Worldwide, aquaculture is the fastest developing segment among animal food production sector and became the main contributor to the global aquatic food supply (Ottinger *et al*., 2016). Aquaculture is most probably more efficient in using land and water, when compared with farming terrestrial crops in generally poor agro-ecosystems (Edwards, 2015). Fish farming in Egypt is considered as a cash crop with higher revenues and net income compared to other agricultural activities. Therefore, aquaculture activities in Egypt had a higher economic competitive edge than terrestrial crop production sector in the Nile Delta, allowing their rapid growth in last two decades. Nile Delta region is the delta formed in Northern Egypt where the Nile

River spreads out and drains into the Mediterranean Sea. It is one of the world's largest river deltas and is famous for agriculture activities.

Water quality in fish farm ponds should fit in with the physiological requirements for optimal growth of the cultured species; thus good quality water is essential for fruitful fish production (Boyd and McNevin, 2015). Water quality is significantly impacted and can be deteriorated by pond management practices such as the daily feed input and the fertilization plan needed for plankton growth (Das *et al*., 2005; Sipaúba-Tavares *et al*., 2011). The increasing demand for Aquatic food can be met by improving management practices (Edwards, 2015).

Optimal fish growth demands the addition of necessary farm inputs, which have to contain balanced nutrients through fertilization and supplementary feeding (Sipaúba-Tavares *et al*., 2013). Supplementary feeding assumes a vital part in intensive and semi-intensive aquaculture systems and for example, the utilization of supplementary feed in carp culture turned out to be significant for successful fish culture (Nazish *et al*., 2012). Since ancient times, applying organic matter as fertilizers has been used for improving the productivity of earthen fish ponds (Terziyski *et al*., 2007). Plankton growth can be stimulated by supplying the ponds with soluble organic matter using manure (Sevilleja *et al*., 2001). Chicken manure tends to be preferable among used manures due to its ready solubility and high content of phosphorus. (Knud-Hansen *et al*., 1991), which is considered a limit element for phytoplankton growth (Rahman *et al*., 2008)

Phytoplankton and zooplankton play an important role in the biological productivity of aquatic ecosystems. Phytoplankton is the first trophic level and forms the basic food supply for the zooplankton organisms. It is observable that they constitute an important food component for some fish like tilapia and mullet.

Nile tilapia, *Oreochromis niloticus*, is the most important fish species cultured in Egypt and considered an omnivorous filter feeder (Ibrahim and El-Naggar, 2010). It is notable that particularly during the juvenile stage of growth, Nile tilapia could gain more than 50% of its nutritional requirements by feeding solely on phytoplankton and zooplankton (Tuker *et al*. 2003; Shaker and Abdel Aal, 2006; Elnady *et al*., 2010). Accordingly, utilizing low cost fertilization programs can effectively decrease nutritional requirements for dietary ration (Elnady *et al*., 2010).

For maximizing the harvest crop within the available resources, it is recommended to stock more than one species in the same pond in a polyculture farm. According to Ibrahim and El-Naggar (2010), polyculture farms can increase productivity by giving the opportunity of a wider choice of available foods.

The present study aimed to evaluate two fish farming systems, which are commonly applied in the Nile Delta region. The two systems differed in pond management procedures namely, the feed fish farm, which used complete diet input and the fertilizer fish farm that used organic fertilizer besides the supplemental feeding. The study was designed to compare water quality dynamics, plankton abundance and growth performance of the fish (tilapia, mullet and catfish) in the two fish farms on annual and seasonal basis during the production cycle.

MATERIALS AND METHODS

1- Study area and experimental design

The experiment was conducted in two fish farms (earthen ponds) in the north of Nile Delta, Egypt. The experiment duration was one year, from July 2014 to June 2015. Fish ponds were fed by water from agriculture drainage water and deep ground water wells. The ponds had 8400 m^2 each as surface area and 1.25 m as an average water depth. Each farm had four replicate ponds.

During the production cycle, the fish farms adopted two management systems. The feed fish farm was the first system, which depended on pelleted diet (25% crude protein) as feed input for the cultured fish, while the fertilizer fish farm was the second system that utilized both organic fertilizer and crushed macaroni as supplementary feed (Table 1). The feed fish farm adopted feeding fish with pelleted diet at the rate of 50 kg/pond/day, 6 days a week at the start of the production cycle (July 2014), which was gradually increased to 100 kg/pond/day by the end of October. Feeding was stopped during the overwintering period for four months (from November to the end of February). Feeding was resumed in March 2015 at 50 kg/pond/day and gradually increased to 70 kg/pond/day by the end of the production cycle in June 2015.

The fertilizer fish farm depended on both supplementary feeding and fertilization during the production cycle. Crushed macaroni as supplementary feeding was added at the beginning of the experiment at the rate of 50 kg/pond/day, six days a week, and was gradually increased to 100 kg/pond/day by the end of October. Supplementary feeding was stopped during the overwintering period. Feeding with crushed macaroni was resumed in spring 2015 at a rate of 50 kg/pond/day and gradually increased to 80 kg/pond/day by the end of the production cycle in June 2015. Fertilization with chicken manure was applied at the rate of two ton/pond/10 days, (equivalent to 200 kg/pond/day) during the whole experiment including the overwintering period.

Table 1: Chemical composition of the commercial diets and crushed macaroni (on dry matter basis).

Chemical analysis (%)	Commercial diet (25%)	crushed macaroni
Dry matter	91.25	90.40
Crude protein	25.04	14.32
Crude fat	5.94	3.50
Ash	5.73	2.9
Fiber	6.11	0.9
NFE	57.18	77.38
GE (kcal/kg)	4425	3946

NFE (nitrogen free extract) = 100 − (protein% + lipid% + ash% + fiber%), GE (gross energy): calculated after NRC (1993) as 5.64, 9.44, and 4.11 kcal/g for protein, lipid, and NFE, respectively.

Nile tilapia (*Oreochromis niloticus*), mullet (*Mugil cephalus*) and catfish (*Clarias gariepinus*) were stocked together in each pond at average initial weights of 2g for tilapia, 30g for mullet and 5g for catfish, respectively in both farms. The feed fish farm was stocked with 36000 tilapia, 4000 mullet and 1000 catfish per pond, while the fertilizer fish farm was stocked by 28000 tilapia, 4000 mullet and 1000 catfish in each pond.

Water quality parameters and plankton abundance were performed monthly from July 2014 to June 2015 to calculate the annual and seasonal averages. Growth performance was determined and economic efficiency was performed in terms of total costs and total revenues.

Water samples were taken with a vertical water sampler from three spots in the pond according to Boyd and Tucker (1992) and transferred to the limnology and plankton laboratories in the department of Limnology, Central Laboratory for Aquaculture Research (CLAR), Abbasa, (Egypt) for measuring some water quality parameters as well as plankton abundance assessments.

2- Water quality analysis

Temperature, Dissolved Oxygen (DO) and pH measurements were determined using water quality device model (YSI 5200a). Secchi disk (SD) visibility determinations were made according to Boyd and Tucker (1992). Orthophosphate (PO_4-P) was measured according to APHA (2000) by the stannous chloride method after filtering the water samples using spectrophotometer Thermo ELECTRON CORPORATION (model NICOLET evolution 100). Chlorophyll "a" concentration was determined photometrically by using spectrophotometer Thermo ELECTRON CORPORATION, model NICOLET evolution 100, according to APHA (2000). Total ammonia nitrogen (TAN) was measured by HACH comparison apparatus following the method reported by APHA (2000), while ionized ammonia (NH_4) and un-ionized ammonia (NH_3) were calculated according to Boyd (2000). Nitrite (NO_2-N) was measured by the diazoding method using the spectrophotometer (Thermo ELECTRON CORPORATION, model NICOLET evolution 100) at wave length of 543 nm according to Boyd and Tucker (1992). Nitrate (NO_3-N) was measured by phenoldisulphonic acid method according also to Boyd and Tucker (1992). The spectrophotometer used (Thermo ELECTRON CORPORATION, model NICOLET evolution 100) at wave length of 410 nm.

3- Biological analysis

Phytoplankton counts were estimated according to methods reported in APHA (2000) using Sedgwick-Rafter cell, and then microscopically examined. Zooplankton assessment was done by filtering representative samples of pond water throughout plankton net (40 micron mesh diameter) and preserved with few drops of 4% formalin solution. Subsequent microscopic qualitative and quantitative analysis for zooplankton organisms were conducted using a glass counting tray of 3 × 5 × 0.5 cm. The results were expressed according to APHA (2000).

4- Growth performance

Individual weights of fish were measured at the start and end of the experiment using digital balance and the growth performance parameters were calculated by the following equations:

Daily weight gain (DWG) = (final body weight–initial body weight)/experimental period (days)

Specific growth rate (SGR) = [(ln final weight–ln initial weight)/experimental period (days)] × 100

Net individual gain = final body weight – initial body weight

Total net gain (kg) = total harvest weight – initial stocking weight

Survival rate (%) = (final harvest density/initial stocking density) ×100

5- Statistical analysis

Two or one-way ANOVA was used to evaluate the significant differences of different parameters studied with respect to pond system and time. A probability level of 0.05 or less was considered significant. Standard errors were also estimated. All statistics were done using the SAS program (SAS, 2000).

RESULTS AND DISCUSSION

Water quality parameters

Water temperature

Annual average and seasonal variation in water temperature parameter are shown in Table (2). The highest value of water temperature was recorded during summer season (30.3°C) and was of medium magnitude during spring and autumn (22.8-26.5°C) while, the lowest value was observed during winter season (15.6°C), with insignificant differences between treatments ($P<0.05$).

The observed range of water temperature during the experimental period was suitable for the survival and growth of farmed fish except for winter season where fish were overwintered. These results are in agreement with Saeed (2013) who reported that water temperature values closely matched air temperature being least (16.71°C) during winter season and highest (28.02°C) during summer season. Begum *et al.*, (2003) reported that the variations in water temperature were attributed to weather conditions.

The pH

The pH of pond water was situated on the alkaline side (>7.8) as illustrated in table (2) which indicated well-buffered capacity and showed remarkable difference between the two fish farm systems. The annual means of pH values were significantly higher ($P<0.05$) in the fertilizer fish farm (8.4 units) compared to those of the feed fish farm (8.0 units); which may be due to the increased photosynthetic activities in the fertilized ponds.

Significant variations in pond water pH among seasons were observed within the fertilizer fish farm where the lowest pH values (8.0 units) appeared in winter, and the highest value in summer (8.9 units), with medium values during spring and autumn ($P<0.05$). Approximate pH values (7.8-8.2 units) were observed in the feed fish farm, with slight significant differences among seasons ($P<0.05$). The pH values were significantly increased during warm season in the fertilizer fish ponds (8.9 units) compared to the feed fish ponds (8.1 units). These results may be due to the increased phytoplankton density and photosynthetic activities (i.e. shallower secchi disc readings) as a result of organic fertilizer degradation in the fertilizer fish ponds. During winter season, pH values were low in the two farming systems (7.8-8.0 units) due to the adverse effect of winter temperature and light intensity on photosynthetic activities.

The uptake of CO_2 and bicarbonate from the pond water during photosynthetic process helped to increase pH values in the fertilizer fish ponds. Saeed (2013) reported that differences in photosynthetic levels in fish farming may lead to alterations in pH values. The pH level ranging between 6.7 and 9.5 is favorable for fish culture, while above and below this level is stressful to fishes (Santhosh and Singh, 2007). The pH range observed during the current experiment was within the desirable range recommended for fish culture as reported by Boyd (2000) and Shaker *et al*. (2003).

Dawn and dusk dissolved oxygen (DO)

The annual averages and seasonal variations of dissolved oxygen concentration data are shown in Table (2). It was observed that averages of DO concentration at dawn and dusk were significantly slightly higher ($P<0.05$) in the fertilizer fish farm compared to the feed fish farm (1.22 versus 0.98) and (6.1 versus 5.06 mg/L), respectively. These results may be explained by the existing of higher phytoplankton abundance in the fertilizer fish farm (secchi disk = 12.6 cm) which resulted in higher photosynthetic rate and oxygen production.

Seasonal variations in dawn and dusk DO ranged from 0.93 to 1.05 mg/L for dawn DO and ranged from 4.88 to 5.16 mg/L for dusk DO in the feed ponds, being significantly lower ($P<0.05$) than those of the fertilizer ponds (Dawn DO: 1.10-1.30 mg/L and Dusk DO: 5.95-6.20 mg/L). Shaker *et al.* (2013) indicated that oxygen production and solubility in pond water may be affected by water temperature and photosynthesis level by phytoplankton. Fish usually die if exposed to concentration less than 0.3 mg/L of DO for long time, and minimum concentration of 1.0 mg/L DO is essential to keep fish alive for long period while, 5.0 mg/L DO concentration is satisfactory in fish ponds (Ekubo and Abowei, 2011).

Secchi disk (SD)

Annual averages and seasonal variations of SD readings are illustrated in Table (2). The average SD readings were 18.4 cm in the feed ponds, being significantly higher than those of the fertilizer ponds (12.6 cm) on annual basis (P<0.05). Feed ponds received slow inputs of ammonia and phosphate overtime as by-products of dietary protein metabolism in contrast to the high organic fertilizer inputs applied in the fertilizer ponds. The fertilizer inputs had positive effects on phytoplankton which were excessive in abundance compared with those of the feed inputs.

Table 2: Seasonal and annual fluctuations of water quality parameters in the feed and fertilizer fish farms during the experimental period.

Season Locations	Summer-2014	Autumn- 2014	Winter-2015	Spring-2015	Annual mean
	Temperatures (°C)				
Feed Farm	30.3^{Aa} ±0.20	26.5^{Ab}±0.14	15.6^{Ad}±0.08	22.8^{Ac} ±0.06	23.8^{A} ±0.3
Fertilizer Farm	30.3^{Aa} ±0.25	26.5^{Ab}±0.13	15.6^{Ad}±0.07	22.8^{Ac} ±0.19	23.8^{A} ±0.3
	pH (Units)				
Feed Farm	8.1^{Ba} ±0.05	8.2^{Aa}±0.02	7.8^{Bc}±0.02	8.0^{Ab} ±0.01	8.0^{B} ±0.2
Fertilizer Farm	8.9^{Aa} ±0.05	8.5^{Ab}±0.04	8.0^{Ad}±0.06	8.3^{Ac} ±0.02	8.4^{A} ±0.3
	Dawn dissolved oxygen (mg/L)				
Feed Farm	1.04^{Ba} ±0.09	0.98^{Ba}±0.06	0.93^{Ba}±0.06	1.05^{Ba} ±0.05	0.98^{B} ±0.01
Fertilizer Farm	1.10^{Ab} ±0.04	1.30^{Aa}±0.16	1.14^{Ab}±0.03	1.27^{Aa} ±0.07	1.22^{A} ±0.03
	Dusk dissolved oxygen (mg/L)				
Feed Farm	5.16^{Ba} ±0.16	5.08^{Ba} ±0.13	4.98^{Bb} ±0.11	4.88^{Bb} ±0.08	5.06^{B} ±0.05
Fertilizer Farm	6.20^{Aa} ±0.14	6.07^{Ab} ±0.18	6.00^{Ab} ±0.14	5.95^{Ac} ±0.11	6.10^{A} ±0.11
	Secchi disc (cm)				
Feed Farm	22.0^{Aa} ±0.41	18.0^{Ab} ±0.41	16.8^{Ac} ±0.25	17.5^{Ab} ±0.29	18.4^{A} ±0.5
Fertilizer Farm	13.7^{Ba} ±0.23	12.5^{Bb} ±0.29	11.0^{Bc} ±0.0	13.0^{Bb} ±0.0	12.6^{B} ±0.5
	Orthophosphate (mg/L)				
Feed Farm	0.108^{Bd} ±0.009	0.14^{Bc} ±0.41	0.170^{Bb} ±0.005	0.224^{Ba} ±0.001	0.17^{B} ±0.011
Fertilizer Farm	0.316^{Ad} ±0.001	0.395^{Ab} ± 0.001	0.338^{Ac} ±0.001	0.40^{Aa} ±0.001	0.37^{A} ±0.014
	Chlorophyll "a" (µg/L)				
Feed Farm	20.15^{Bb} ±1.12	23.83^{Bb} ±1.73	22.37^{Bb} ±1.46	23.89^{Ba} ±1.09	22.8^{B} ±1.3
Fertilizer Farm	60.59^{Aa} ±2.21	66.62^{Aa} ±3.58	57.54^{Ab} ±4.22	41.01^{Ac} ±1.87	55.1^{A} ±4.5

A, B, C means with different letters (superscripts) in the same column are significantly different (P<0.05); a, b, c means with different letters (superscripts) in the same row are significantly different (P<0.05).

Slight differences were observed in secchi disc readings among different seasons in the fertilizer ponds, which ranged from 11.0 to 13.7 cm. This can be explained by the high organic manure inputs to pond water during all seasons including winter at two tons per pond every 10 days. However, secchi disc readings ranged from 16.8 to 22.0 cm among different seasons in the feed ponds due to the feeding with pelleted diets at a rate of 50-100 kg/pond/day throughout the production cycle except for the overwintering period. Secchi disc readings were low during winter season; which may be due to the reduced feeding pressure of zooplankton and fish on algae under low water temperature. Ekpenyong (2000) supported the last explanation also. According to Padmavathi and Prasad (2007) secchi disc visibility provides a rough measure of plankton abundance. Osman *et al*. (2010) observed lower value of secchi disc readings (13.0 – 16.3 cm) in pond water when comparing with the inlet water (22.5 cm).

Orthophosphate (PO_4-P) and chlorophyll “a”

Orthophosphate and chlorophyll “a” concentrations in water are presented in Table (2). The average values of orthophosphate and chlorophyll “a” were significantly higher ($P<0.05$) in the fertilizer ponds (0.37 mg/L PO_4-P and 55.1 µg/L Chlorophyll “a”) than those of the feed ponds (0.17 mg/L PO_4-P and 22.8 µg/L Chlorophyll “a”), respectively. According to Okbah and Hussein (2006) and Wang *et al.* (2008) chlorophyll “a” concentration is a decent indicator of the algal biomass.

Summer and autumn chlorophyll “a” concentrations of the fertilizer farm were significantly higher than those of the winter and spring values. However, no systematic pattern was observed in chlorophyll “a” concentration among seasons within the feed farm. This clarifies that orthophosphate and chlorophyll “a” had positive correlation with fertilizer and supports that the increase of organic fertilizer and water temperature affected positively chlorophyll content in water due to the elevated organic fertilizer decomposition rate.

The fertilizer ponds received chicken manure at the rate of two ton/pond/10 days during the whole experimental period. According to Mataka & Kang’ombe (2007) chicken manure plays a vital role in phytoplankton production in ponds through containing high levels of nitrogen (N), phosphorus (P) and potassium (K). PO_4-P had the strongest overall correlation with phytoplankton density which might indicate that phytoplankton biomass was limited by PO_4-P concentrations (Rahman *et al.*, 2008). Boyd (2000) indicated that phosphate concentration above 0.1 mg/L is enough to induce algal bloom in water. The rise of nutrients concentration in pond water has a positive effect on algal and chlorophyll concentrations (Ekpenyong, 2000).

Nitrogen component

Data which are shown in Table (3), present the annual and seasonal averages of inorganic nitrogen compounds (TAN, NH_4, NH_3, NO_2 and NO_3) found in pond water of the two fish farms. The average values of nitrogen components were significantly ($P<0.05$) higher in the fertilizer fish farm when compared to the feed fish farm. These results accentuated that the organic fertilization leads to increased production of ammonia, nitrite and nitrate due to the decomposition processes.

Total ammonia nitrogen (TAN) was the major form of inorganic nitrogen and averaged 1.26 mg/L and 1.63 mg/L in the feed and fertilizer ponds, respectively with significant differences among the two treatments ($P<0.05$). Total ammonia nitrogen originates from organic matter decomposition (waste feed, dead algae and feces) as well as metabolic end product of protein catabolism by fish and aquatic fauna. TAN values were significantly lower in the feed ponds when compared to the fertilizer ponds ($P<0.05$), since feeding always provide slow release of metabolic ammonia and phosphate over longer period.

Average values of toxic NH_3 component had positive correlation with pH and water temperature. pH values in the feed pond was optimal for fish culture (8.0 units) which produced less toxic ammonia (0.08 mg NH_3-N/L) than those of the fertilizer ponds (8.4 units) which produced higher levels of toxic ammonia (0.26 mg NH_3-N/L), being less favorable for fish growth. The application of large amount of chicken manure in the fertilizer ponds enhanced primary production and raised pond pH values to excessive levels. This was reflected in higher toxic ammonia, being positively correlated with pond pH. Slow growth rate of fish would always be correlated with high toxic ammonia levels above 0.1 mg/L (Boyd, 1990; Boyd and

Tucker, 1998). The recorded values of TAN and toxic ammonia (NH_3) were high in summer and autumn due to the warmth of these seasons.

The nitrate and nitrite concentrations in the feed and fertilizer ponds were very low (0.07-0.29 and 0.04-0.13mg/L, respectively) compared to TAN on annual basis, indicating the major role of TAN in fertilizing pond water and augmenting photosynthetic activities. The results showed that TAN, NO_2 and NO_3 concentrations were significantly ($P<0.05$) increased in the fertilizer fish ponds compared to the feed fish ponds on annual and seasonal basis.

Table 3: Seasonal and annual fluctuations of Nitrogen component parameters in the feed and fertilizer fish farms during the experimental period.

Season **Locations**	**Summer-2014**	**Autumn- 2014**	**Winter- 2015**	**Spring- 2015**	**Annual mean**
	TAN (mg/L)				
Feed Farm	1.20^{Bb} ±0.019	1.55^{Ba} ±0.022	1.05^{Bc} ±0.08	1.25^{Bb} ±0.013	1.26^{B} ±0.016
Fertilizer Farm	1.65^{Ab} ±0.026	1.92^{Aa} ±0.026	1.40^{Ad} ±0.012	1.55^{Ac} ±0.015	1.63^{A} ±0.015
	NH_3 (mg/L)				
Feed Farm	0.103^{Ba} ±0.013	0.110^{Ba} ±0.005	0.014^{Bc} ±0.00	0.088^{Bb} ±0.014	0.078^{B} ±0.013
Fertilizer Farm	0.526^{Aa} ±0.026	0.232^{Ab} ±0.024	0.034^{Ac} ±0.005	0.260^{Ab} ±0.026	0.263^{A} ±0.263
	NH_4 (mg/L)				
Feed Farm	1.10^{Bb} ±0.029	1.44^{Ba} ±0.032	1.03^{Bc} ±0.031	1.16^{Bb} ±0.041	1.18^{B} ±0.013
Fertilizer Farm	1.25^{Ac} ±0.141	1.77^{Aa} ±0.046	1.38^{Ab} ±0.027	1.37^{Ab} ±0.056	1.44^{A} ±0.015
	NO_2 (mg/L)				
Feed Farm	0.026^{Bb} ±0.101	0.043^{Ba} ±0.001	0.031^{Bb} ±0.001	0.041^{Ba} ±0.002	0.036^{B} ±0.001
Fertilizer Farm	0.098^{Ac} ±0.002	0.173^{Aa} ±0.002	0.109^{Ad} ±0.002	0.123^{Ab} ±0.003	0.126^{A} ±0.011
	NO_3 (mg/L)				
Feed Farm	0.045^{Bb} ±0.002	0.106^{Ba} ±0.012	0.084^{Bb} ±0.006	0.046^{Bb} ±0.003	0.07^{B} ±0.001
Fertilizer Farm	0.159^{Ab} ±0.007	0.606^{Aa} ±0.018	0.234^{Ad} ±0.002	0.186^{Ac} ±0.010	0.29^{A} ±0.021

A, B, C means with different letters (superscripts) in the same column are significantly different ($P<0.05$);

a, b, c means with different letters (superscripts) in the same row are significantly different ($P<0.05$).

Nitrate concentrations were lower during summer and spring seasons in all treatments, which may be induced by lower, DO, required for nitrification at the sediment-water interface. The availability of oxygen during autumn and winter seasons is expected to be high enhancing nitrification by nitrifiers. In the fertilizer fish farm, nitrate averaged 0.23-0.61 mg/L during autumn-winter period and decreased to 0.16-0.19 mg/L during spring- summer period. The same trend was found in the feed fish farm. The results were supported by the findings of Saeed (2013) who indicated that lower concentrations of nitrate during summer season may be attributed to the high algal uptake and intense photosynthesis under warm water and intense radiation. Nitrification rates are known to increase with the availability of oxygen at the sediment-water interface. However, nitrate concentrations during most of the year, except for autumn season, were significantly low and their effect on algal productivity may be limited when compared to TAN concentrations. Nitrate is less toxic and its concentrations in water are usually stable over wide range of environmental conditions (Priyamvada *et al*., 2013). Consequently, algal dynamics were mostly affected by TAN concentrations originating from chicken manure decomposition and metabolic excretion by fish and aquatic fauna. Santhosh and Singh (2007) recommended that nitrite concentration in water should not exceed 0.5

mg/L. Saeed (2013) reported that lower values of nitrite concentration in water were estimated in summer and spring in his trial.

Biological characteristics:

Phytoplankton

In this study, Phytoplankton in fish ponds was classified into four main genera, namely Chlorophyta, Bacillariophyta, Cyanophyta and Euglenophyta. Average annual and seasonal data of phytoplankton abundance per liter of water (10^6/L) are presented in Table (4). Total number of algal cells of different genera averaged 5.48 million cells per Liter in the feed ponds, while those of the fertilizer ponds were significantly higher and averaged 13.76 million cells per Liter. Phytoplankton abundance in pond water depends on nitrogen and phosphorus inputs in water as influenced by metabolic wastes excretions by aquatic fauna and manure decomposition by bacterial activities. Nutrient inputs in the fertilizer ponds were higher than those of the feed ponds as indicated by their higher abundance of algae of different genera. Chlorophyta density was higher than Bacillariophyta on annual basis (P<0.05), followed by Cynanophyta, while the least algal density was observed in Euglenophyta in both the fertilizer and feed farms (P<0.05). The annual average of phytoplankton groups in the feed ponds were 2.4, 1.52, 1.03 and 0.53 million cells/L, while in the fertilizer ponds were 6.55, 4.77, 1.53 and 0.91 million cells/L for the same order, respectively.

Table 4: Seasonal and annual fluctuations of phytoplankton abundance (Org. /L × 10^6) in the feed and fertilizer fish farms during the experimental period.

Seasons / Genera	Summer-2014		Autumn-2014		Winter-2015		Spring-2015		Annual mean	
	Feed Farm	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**
Chlorophyta	2.65^{Ad} ±0.025	7.60^{Aa} ±0.112	2.49^{Ad} ±0.011	7.01^{Aa} ±0.131	2.15^{Ad} ±0.01	5.23^{Ac} ±0.11	2.33^{Ad} ±0.012	6.35^{Ab} ±0.121	2.40^{Ab} ±0.013	6.55^{Aa} ±0.054
Bacillariophyta	1.64^{Bd} ±0.023	5.72^{Ba} ±0.106	1.57^{Bd} ±0.023	5.09^{Ba} ±0.104	1.37^{Bd} ±0.024	3.77^{Bc} ±0.022	1.50^{Bd} ±0.032	4.52^{Bb} ±0.023	1.52^{Bb} ±0.011	4.77^{Ba} ±0.044
Cyanophyta	1.178^{Cc} ±0.033	2.063^{Ca} ±0.025	1.112^{Cc} ±0.022	1.767^{Cb} ±0.025	0.923^{Cd} ±0.018	0.968^{Cd} ±0.017	1.01^{Cd} ±0.024	1.303^{Cc} ±0.013	$1.\ 03^{Cb}$ ±0.004	1.53^{Ca} ±0.013
Euglenophyta	0.614^{Dc} ±0.027	1.093^{Db} ±0.017	0.544^{Dd} ±0.011	1.250^{Da} ±0.017	0.450^{Dd} ±0.011	0.610^{Dc} ±0.013	0.524^{Dd} ±0.011	0.680^{Dc} ±0.013	0.53^{Db} ±0.003	0.91^{Da} ±0.011

A, B, C means with different letters (superscripts) in the same column are significantly different (P<0.05); a, b, c means with different letters (superscripts) in the same row are significantly different (P<0.05).

Chlorophyta, Bacillariophyta, Cyanonphyta and Euglenophyta were all higher in fertilizer ponds than in feed ponds, during all seasons. Algal density (million cells/ L) of all genera did not have wide variations among seasons in the feed farm. Seasonal abundance in the feed farm ranged 2.15-2.65 million cells/L for Chlorophyta, 1.37-1.64 million cells/L for Bacillariophyta, 0.92-1.17 million cells/L for Cyanophyta, and 0.45-0.61 million cells/L for Euglenophyta. This may be due to the slow and an even release of metabolic waste products (ammonia and phosphate) during different seasons. However, algal abundance of all genera in the fertilizer farm had significantly higher density in water during summer and autumn warm periods (15.12-16.48 million cells/L) compared to winter and spring which are considered as cold period (10.58 -12.85 million cells/L). This may be attributed to the effect of cold water during winter and early spring on photosynthetic activities and algal abundance.

Phytoplankton abundance and algal quality determine the availability of natural food to fish such as Nile tilapia and mullet. The controlled application of fertilizer in earthen ponds is known to enhance plankton productivities (Abbas, 2001; Wang *et al*., 2008). Nitrogen and phosphorus are vital nutrients required for the production of algal communities which are considered as ecological indicators (Lindo, 1991; Webber and Webber, 1998). High nutrient inputs in fish ponds boost algal production, which increase biological turbidity and reduce photic depth (Lindo, 1991; Webber and Webber, 1998).

Zooplankton

Annual and seasonal data of zooplankton abundance per liter of water (10^4/L) are presented in Table (5). Faunal composition of zooplankton was divided into four main groups, namely Cladocera, Copepoda, Ostracoda and Rotifera. The total number of zooplankton organisms averaged 10.22 x10^4 organims/L in the feed fish ponds, while those in the fertilizer fish ponds averaged 26.58 x10^4 organisms/L and were significantly higher ($P<0.05$). Zooplankton densities were enhanced by the application of chicken manure in the fertilized ponds, producing higher zooplankton densities compared to the feed ponds which depended solely on feed input as source of nutrition.

Table 5: Seasonal and annual fluctuations of zooplankton abundance (Org. /L × 10^4) in the feed and fertilizer fish farms during the experimental period.

Seasons Genera	Summer-2014		Autumn-2014		Winter-2015		Spring-2015		Annual mean	
	Feed Farm	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**
Cladocera	2.798^{Bd} ±0.023	7.278^{Ba} ±0.121	2.929^{Bd} ±0.022	7.599^{Ca} ±0.107	2.189^{Cd} ±0.022	5.685^{Cc} ±0.034	2.331^{Bd} ±0.024	6.072^{Bb} ±0.046	2.52^{Cb} ±0.004	6.56^{Ca} ±0.034
Copepoda	3.12^{Ad} ±0.032	8.09^{Ac} ±0.107	3.49^{Ad} ±0.033	9.07^{Aa} ±0.132	2.82^{Ad} ±0.026	7.34^{Ac} ±0.065	2.70^{Ad} ±0.031	7.02^{Ab} ±0.054	3.00^{Ab} ±0.011	7.79^{Aa} ±0.107
Ostracoda	2.91^{Bd} ±0.024	7.53^{Bb} ±0.055	3.19^{Ad} ±0.025	8.29^{Ba} ±0.089	2.64^{Be} ±0.013	6.85^{Bc} ±0.038	2.37^{Be} ±0.027	6.16^{Bc} ±0.056	2.73^{Bb} ±0.005	7.10^{Ba} ±0.105
Rotifera	2.00^{Cd} ±0.013	5.20^{Cb} ±0.057	2.26^{Cd} ±0.031	5.86^{Da} ±0.047	1.96^{De} ±0.023	5.09^{Dc} ±0.024	1.76^{Ce} ±0.014	4.57^{Cc} ±0.051	1.97^{Db} ±0.003	5.13^{Da} ±0.045

A, B, C means with different letters (superscripts) in the same column are significantly different ($P<0.05$); a, b, c means with different letters (superscripts) in the same row are significantly different ($P<0.05$).

The positive correlation between zooplankton abundance and phytoplankton densities enhanced zooplankton abundance under warm water conditions in summer and autumn (total abundance: 28.10-30.82 x10^4 organisms/L) compared to cold water conditions during winter and spring (23.82-24.97 x10^4 organisms/L) in the fertilizer ponds. The lack of organic fertilizer effects on zooplankton abundance in the feed ponds, greatly reduced biomass of zooplankton due to the absence of manuring.

Total zooplankton abundances in the feed ponds ranged 10.83-11.87 x10^4 organisms/L during warm summer and autumn, and were reduced to 9.16-9.61 x10^4 organisms/L during cold winter and spring seasons. The effect of water temperature on zooplankton abundance was evident when warm seasons were compared to cold seasons. Comparing abundance of the same group among different seasons produced similar results in terms of the positive effect of warm temperature on zooplankton abundance and development.

Natural food abundance in ponds supplements nutritional requirements of fish in terms of energy and protein, reducing the requirements for artificial feed inputs. Zooplankton not only depends on phytoplankton as a nutritional source but also consumes bacterial detritus and organic manure in pond water, which lower feeding pressure on phytoplankton (Bwala and Omoregie, 2009). Our results accentuated that manuring ponds had a positive effect on zooplankton abundance, resulting in increased zooplankton abundance more than two folds in the fertilizer fish farm compared to that of the feed fish farm. This will be reflected in terms of lower feeding costs and improved farm revenues. Chicken manure is considered as best organic manure used at widespread fashion in fish ponds for increasing natural food abundance (i.e. zooplankton). Our results were supported also by Elnady *et al.* (2010).

Growth performance

The growth performance and harvest volume of Nile tilapia, mullet and catfish in the two farming systems are shown in Table (6). The survival rates (%) of catfish (100%) and tilapia (89.3-97.2%) were significantly higher than those of mullet (80-87.5%) during the experimental period. The survival rate within tilapia was significantly higher in the feed fish farm. The net individual gain of fish in the feed system was significantly higher than the fertilizer system (248 versus 183, 180 versus 170 and 845 versus 745g/fish for tilapia, mullet and catfish, respectively). The daily weight gain (DWG) averaged 0.68 and 0.50g for tilapia, 0.49 and 0.47g for mullet and 2.32 and 2.04 g for catfish in the feed and fertilizer fish farms, respectively. It was observed that within tilapia and catfish, the daily weight gain was significantly higher ($P<0.05$) in the feed ponds when compared to the fertilizer ponds. This cleared that the feed fish farm ponds produced significantly heavier fish ($P<0.05$). The results also indicated that the daily weight gain of catfish was higher than tilapia and mullet. The same trend was observed in specific growth rate (SGR). Shaker and Abdel-Aal (2006) who reported that the daily weight gain of catfish was higher than the daily weight gain of tilapia, silver carp, common carp and mullet confirmed these results.

Table 6: Growth performance of Nile tilapia, mullet and catfish in the feed and fertilizer fish farms during the experimental period.

Locations	**Tilapia**		**Mullet**		**Catfish**	
Items	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**	**Feed Farm**	**Fertilizer Farm**
Initial weight (g/fish)	2^{a}±0.0	2^{a} ±0.0	30^{a} ±1.5	30^{a} ±2.0	5^{a} ±0.5	5^{a} ±0.5
Initial number/ pond (units)	36000	28000	4000	4000	1000	1000
Total initial Weight (kg/pond)	72^{a} ±0.2	56^{b} ±0.2	120^{a} ±0.5	120^{a} ±0.5	50^{a} ±0.15	50^{a} ±0.15
Final Weight (g/fish)	250^{a} ±25	185^{b} ±15	210^{a} ±15	200^{a} ±12	850^{a} ±25	750^{b} ±20
Final Number (units)	35000^{a} ±120	25000^{b} ±120	3200^{b} ±50	3500^{a} ± 45	1000^{a} ±5	1000^{a} ±5
Net individual gain (g/fish)	248^{a} ±14	183^{b} ±11	180^{a} ±11	170^{b} ±10	845^{a} ±25	745^{b} ±20
Daily weight gain (g)	0.68^{a} ±0.12	0.50^{b} ±0.09	0.49^{a} ±0.01	0.47^{a} ±.01	2.32^{a} ±0.21	2.04^{b} ±0.18
S.G.R.	1.32^{a} ±0.11	1.24^{b} ±0.13	0.53^{a} ±0.03	0.52^{a} ±0.02	1.41^{a} ±0.1	1.37^{b} ±0.1
Total net gain (kg/pond)	8678^{a} ±145	4569^{b} ±114	552^{b} ±17	580^{a} ±18	800^{a} ±24	700^{b} ±22
Total Final harvest (kg/pond)	8750^{a} ±72	4625^{b} ±55	672^{a} ±14	700^{a} ±15	850^{a} ±22	750^{b} ±20
Survival Rate %	97.22^{a} ±1.2	89.3^{b} ±3.5	80^{b} ±2	87.5^{a} ±2.5	100^{a} ±0.0	100^{a} ±0.0
Total production (Kg/pond)	10272^{a} ±120 (feed farm)			6075^{b} ±94 (fertilizer farm)		

a, b means with different letters (superscripts) in the same row within each fish species are significantly different ($P<0.05$).

The total harvest of fish within each fish farm averaged 10272 and 6075kg/pond for the feed and fertilizer fish farms, respectively. This clarified that the feed system production was higher by 41% more than the fertilizer system, although the number of fish at the beginning of the trial was lower by only 22% in the fertilizer farm. However our results indicated that the fertilizer system produced a moderate fish yield. The application of organic and inorganic fertilizer in pond water enhances plankton productivity and abundance, which support fish production (Jha *et al.*, 2008). Our results assumed that the fertilizer system solely might not be suitable for tilapia (main farmed fish species) growth during all stages. Nile tilapia could gain more than 50% of its nutritional requirements by feeding solely on plankton especially during the juvenile stage (Tuker *et al*. 2003; Shaker and Abdel Aal, 2006; Elnady *et al*., 2010). Manipulation of organic manure and feed inputs can increase production in earthen ponds especially for fish such as tilapia, common carp and mullet (Edwards *et al*., 1994).

Overall, the cost of fish production based on local price data in the fertilizer system was lower than that of the artificial feed system (total cost: 10396$ and 3422$/pond for the feed and fertilizer farms, respectively). Although the highest total return was observed in the feed fish farm (13948$) when compared to the fertilizer fish ponds (8704$/pond), the net income was higher in the fertilizer fish farm due to its lower operating production costs.

CONCLUSION

Our study concluded that pond management influences the water quality and plankton abundance. The present observation indicated that the fertilizer system produced a moderate fish yield but might not be suitable during the whole period of growth for Nile tilapia and catfish. However, the artificial feed system offered more nutritional support during different stages of fish development producing higher fish yield. Consequently, the fertilization fish ponds need additional doses of artificial feed during approximately the last two months of the production cycle. The amount of chicken manure that used as organic matter should be decreased as it can deteriorate the water quality in fish ponds.

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ARABIC SUMMARY

تأثير نظم الرعايه فى المزارع السمكية على جوده المياه، ووفره البلانكتون و أداء نمو الأسماك في الأحواض الترابيه

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٢- معمل الليمنولوجي- المعمل المركزي لبحوث الثروه السمكيه بالعباسه - مركز البحوث الزراعيه.

تمت الدراسه في مزرعتين واقعتين في شمال دلتا مصر بالاعتماد على استخدام نظامين مختلفين من نظم الرعايه. النظام الأول هو نظام التغذيه الصناعيه و اعتمد على استخدام العليقه الكامله التي تحتوي على ٢٥% بروتين و النظام الثاني هو نظام السماد و اعتمد على استخدام السماد العضوي مع التغذيه التكميليه على المكرونه المجروشه. اتسم كل نظام بوجود اربعه تكرارات من الاحواض الترابيه و كانت مساحه كل حوض ٨٤٠٠م^{٢}، واستمرت التجربه لمده عام كامل تخلله اربعه اشهر فتره تشتيه. تم استزراع أسماك البلطي النيلي و البوري الأصيل و القراميط الافريقيه معاً في كل حوض بأوزان ٢، ٣٠، ٥ جم على التوالي. تم اخذ عينات من المياه و الاسماك لتحديد جوده المياه و وفره البلانكتون و اداء نمو الأسماك.

اظهرت النتائج الارتفاع المعنوي لمستوى درجة الحموضه، الأكسجين الذائب و محتوى النيتروجين الكلي (الأمونيا الكليه، الأمونيا الحره، الأمونيوم، النيتريت والنترات) في معامله السماد، لوحظ كذلك ارتفاع معدل وفره البلانكتون النباتي و الحيواني في معامله السماد عند مقارنتها بمعامله التغذيه الصناعيه. داخل الأنواع المختلفه سجلت اسماك القراميط اعلى معدل نمو يومي يليها أسماك البلطي ثم أسماك البوري. داخل النظامين حققت الأسماك المستزرعه في نظام التغذيه الصناعيه اداء نمو افضل، وبينما كان معدل الإنتاج اعلى معنوياً و كذلك كان الدخل الكلي اعلى في نظام التغذيه الصناعيه، حقق نظام السماد دخل صافي اعلى و تكاليف انتاج كليه اقل.