Effect of Fertilization and Low Quality Feed on Water Quality Dynamics and Growth Performance of Nile tilapia *(Oreochromis niloticus)*

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Abstract: This investigation was conducted to know the effect of low, medium and high doses of either chemical or organic fertilizers along with supplementary feeding on water quality in rearing tanks and growth performance of Nile tilapia. Dissolved oxygen concentrations in organic fertilizer treatments (10.03-10.71 mg/L) were lower than those of chemical fertilizer treatments (10.23-12.38 mg/L). Carbonate alkalinities were higher in the organic fertilizer treatments (42-53.8 mg/L) than those of the chemical fertilizer treatments (31.9-51.2 mg/L). This reflected a higher photosynthetic activities and increased algae production in the organic fertilizer treatments. Total Phosphorus concentrations had intermediate values in all treatments (0.214- 0.276 mg – P/L) except for that of the high organic fertilizer treatment (0.513 mg – P/L) which was significantly higher compared to all treatments ($P < 0.05$).Soluble reactive phosphorus concentrations were similar among all treatments (0.061 – 0.093 mg- p/L) except for that of the high organic fertilizer treatment which had significantly higher orthophosphate concentration (0.256 mg-P/L) ($P<0.05$). In the water quality experiment, growth rates of Nile tilapia were higher in organic fertilizer treatments (0.54-.62 gm/fish/day) compared to those of the chemical fertilizer treatments (0.47-0.51 gm/fish/day). In the fish production experiment, growth rate in terms of daily weight gain, was generally higher in Nile tilapia raised in the medium organic fertilizer treatment (0.92 gm/fish/day), followed by those of the medium chemical fertilizer and control treatments(0.83 and 0.82 gm/fish/day, respectively). The lowest daily weight gains were observed in the high chemical and high organic fertilizer treatments (0.46 and 0.58 gm/fish/day, respectively).
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1. Introduction:

Fish provides an average of 25% of animal proteins consumed world-wide, and in some countries, this value can reach 50 %(Muller -Feuga, 2000). Nile tilapia *Orechromis niloticus* is cultured world wide mostly in semi-intensive culture systems using fertilization. Nevertheless, variety of pond input schemes, including inorganic and /or organic fertilizers, formulated feed and combination of both, were involved in Nile tilapia production (Thakur et al., 2004).

Asian aquaculture is dominated by semi-intensive freshwater, earthen pond culture systems. In these systems natural productivity is enhanced with fertilizers and the fish or shrimp are provided with supplemental feeds (Silva and Hasan, 2007).

Among the new trends in fish culture, integrated semi-intensive system seems to be the most acceptable one due to the fact that various agriculture wastes and low value feedstuff can be utilized as a cost-effective source of fish feed The growth of fish is strongly correlated with increase in phytoplankton and zooplankton productivity as a result of fertilization (Abbas and Hafeez-Ur-Rehman, 2005). Fertilizers increase the level of primary productivity, dissolved oxygen, PH and total phosphorus (Qin et al., 1995).

This study aimed to establish a low cost sustainable aquaculture method for the production of a major animal protein source by comparing the growth pattern and water quality parameters among different fertilizer programs along with using a fixed amount of supplementary feed during the whole experiment.

2. Materials and methods

This study was conducted at the Fish Research Unit, Faculty of Agriculture, Cairo University. A static outdoor rearing system was used to carry out the experiment. Rectangular concrete tanks (2.2×1.2×1.0m) were filled with freshwater obtained from a well and were used as rearing units. Fourteen concrete tanks were used in the water quality experiment, while ten tanks were used in the fish production experiment.

Two trials were conducted to evaluate the effect of different fertilization programs (using different doses of chemical or organic fertilizers) along with a fixed amount of supplementary diet on water quality parameters and growth performances of Nile tilapia. The first trial tested mainly the water quality parameters and lasted 90 days. While the second trial was designed to assess the effect of these fertilizer-supplementary feeding programs on growth and production of larger Nile tilapia in rearing tanks after another rearing period of 90 days.

Experimental Design

Nile tilapia juveniles were randomly distributed among experimental tanks and stocked at a rate of 6 juveniles (50.2-54.8 grams/fish) per tank in the first trial and 7 juveniles (131.3-137.7 grams/fish) per tank in the second trial, with two replicate tanks per treatment. The water quality experiment consisted of three organic fertilizer treatments, three chemical fertilizer treatments and control treatment. The organic fertilizer treatments included the application of chicken manure at low, medium and high doses (7, 14, 28 grams dry matter/m^2/week, respectively) while the chemical fertilizer treatments included a bi-weekly application of chemical fertilizers (ammonium nitrate, 33%N and superphosphate, 8%P) at low, medium and high doses (0.55, 1.1 and 1.65grams N/ m^2 for nitrogen and 0.125, 0.25 and 0.38gramP/ m^2 for phosphorus, respectively). The doses of chemical and organic fertilizers were calculated for each square meter surface water area in each tank according to the FAO training manual(1996) .All fertilizer treatments received supplementary diet (18% crude protein) at a fixed rate of 10.3 grams diet/tank/day, six days a week during the whole experiment. The control treatment included the application of complete diet (30% crude protein) as fish feed applied at a fixed rate of 10.3 grams diet/tank/day six days a week during the whole experiment.

The fish production experiment consisted of two organic fertilizer treatments (medium and high doses), two chemical fertilizer treatments (medium and high doses) and control treatment as described in the water quality experiment. The fish production experiment applied the same dose per square meter area at a weekly rate for both organic and chemical fertilizer and employed larger fish at the start of the experiment. Both supplementary diet (18% crude protein) and complete diet (30% crude protein) were provided at a fixed rate of 17 grams/tank/day, six days a week during the whole experiment.

Mean fish weights and lengths were measured at the start and the end of the experiment to determine specific growth rates, daily weight gain and condition factor of fish. Feed performances were determined in terms of feed conversion ratio (FCR) and protein efficiency ratio (PER).Water from each tank was tested bi-weekly for temperature, dissolved oxygen (DO), secchi disk visibility (SD), pH, alkalinity, total phosphorus (TP), orthophosphate-phosphorus (PO_4-P). All determinations were carried out at the Central Laboratory for Environmental Quality Monitoring (CLEQM) according to the Standard Methods American Public Health Association (APHA, 1992).

Statistical analysis was performed using the analysis of variance (ANOVA). Duncan's Multiple Range Test (Duncan, 1955) was used to evaluate differences among treatment means for all parameters at the 0.5 significance level. One-way analysis of variance was used to test the effect of fertilizer and supplementary feeding on water quality and growth performance of Nile tilapia in rearing tanks. All statistical analyses were performed using the software package SPSS (SPSS for windows, Release 8.0)

3. Results and Discussion:

1-Water quality experiment:

1-1-water quality parameters:

Water temperature

Averages of water temperature in culture units were similar among treatments during the experimental period and varied within a narrow range. At the start of the experiment, water temperature ranged 23-26 °C among treatments and gradually increased reaching 30.2-31.1 °C at the end of the study. The gradual increase in water temperature during the growing period was associated with the gradual rise in air temperature during summer season which affected the thermal pattern in water. Water temperature in rearing units was optimal for the growth of Nile tilapia during the experiment. These results are parallel with those mentioned by Chaudhair (2002) who reported that the optimum water temperature range for many species of warm water fishes is 24-30 °C. Water slightly warmer than optimum provides better growth and food conversion than low temperature.

Dissolved oxygen

Dissolved oxygen concentrations in the organic fertilizer treatments (10.03-10.71 mg/L) were lower than those of chemical fertilizer treatments (10.23-12.38 mg/L). The decline in dissolved oxygen concentrations in organic fertilizer treatments could be due to the higher respiration demand of aerobic bacterial activities working on manure decomposition. Heterotrophic bacteria consume oxygen and release carbon dioxide while oxidizing organic matter content of chicken manure. This result is consistent with those reported by Qin et al(1995) who indicated that dissolved oxygen in ponds with organic fertilizer was significantly lower than that in pond without organic input and those reported by Zhu et al. (1990) who indicated that in manured ponds, the biological oxygen demand of the pond water increased by47%, indicating high concentration of organic material. The rate of bacterial decomposition in the water increased by 36% and the NH_4 concentration by 45%, indicating a higher rate of mineralization of the organic material.

Dawn dissolved oxygen declined with increased manure loading rate. Moreover, when concentration at 60 kg dry matter of manure per hectare per day plus rice bran was applied, DO was frequently zero or close to zero Edwards et al (1994a). The adverse dissolved oxygen regime in buffalo manured ponds was probably due to the respiration demand of bacterial activity caused by high loading of buffalo manure (Edwards et al., 1994b).

During this investigation dissolved oxygen concentrations in the control treatment (11.99 mg/L) was higher than other organic fertilizer treatments which may be due to the low organic load in water and lower bacterial activities in tanks without organic manuring.

Dry chicken manure contains 60% organic matter and the chemical oxygen demand of particulate organic matter was 0.96 gram oxygen for each gram dry organic matter. Since chicken manure was applied at the rate of 2-4 grams dry manure/m^2/day, the daily oxygen demand consumed during bacterial decomposition of manure could range 1.15-2.3 mg O_2/m^2/day in organic fertilizer treatments. Since manure loading rates range 2.5-10gram dry manure/m^2/day in semi-intensive integrated aquaculture, a considerable amount of dissolved oxygen is consumed due to the respiration demand of bacterial activity (Boyd, 1990).

Total alkalinity, bicarbonate and carbonate alkalinities

In the present study, total alkalinities ranged between 292.2-355.5mg/L among treatments. Waters of higher alkalinity are considered more productive in terms of daily oxygen production and algal photosynthesis. Natural waters of river Nile in Egypt have higher total alkalinities (150-200 mg/L) and are considered the most productive water in terms of aquaculture production.

Bicarbonate alkalinities were higher in the organic fertilizer treatments (321.5-355.5 mg/L) compared to those of chemical fertilizer treatments (292.2-306.9 mg/L). While bicarbonate alkalinity of the control treatment was (333.1 mg/L). The higher bicarbonate alkalinities in the organic fertilizer treatments could be explained by an increase in CO_2 production as a function of manure decomposition through bacterial activities. Organic matter decomposition serves as a continuous source of carbon dioxide (Boyd, 1990).

Studies conducted else where, indicated that pond total alkalinity was significantly greater where organic fertilization and feeds were applied (Kumar et al., 2005). Alkalinity increased with organic fertilization because bacterially generated CO_2 from manure decomposition dissolves calcium and magnesium carbonate in pond water into calcium and magnesium bicarbonate (Boyd, 1990, Mcnabb et al., 1991; Teichert-Coddington et al., 1992). In addition, alkalinity was gradually increased influenced by the chemical composition of the manure applied (Kumar et al, 2005).

Higher bicarbonate alkalinities in the organic fertilizer treatments could be attributed to the increased CO_2 production resulting from the organic fertilizer decomposition by bacteria. Carbon dioxide reacts with calcium and magnesium carbonate in water and sediment forming calcium and magnesium bicarbonate in great volume compared to other treatments. These results were in agreement with those of Boyd (1990), Mcnabb et al. (1991) Teichertcoddington et al. (1992) and Kumar et al. (2005) who indicated that pond total alkalinity was significantly greater where organic fertilization and feed were applied.

Carbonate alkalinities were higher in the organic fertilizer treatments (42.0-53.8)mg/L than those of the chemical fertilizer treatments (31.9-51.2 mg/L). This reflected a higher photosynthetic activities and increased algae production as algae are rapidly removing carbon dioxide from water in the organic fertilizer treatments for use in photosynthesis and oxygen production.

It is recommended also that alkalinity in the medium and high organic fertilizer treatments (330 and 355.5 mg/L, respectively) was higher than those of chemical fertilizer treatments (306.9-294.2mg/L). Higher carbonate alkalinity in the medium and high organic fertilizer treatments were associated with high water PH (8.64-8.53), while lower carbonate alkalinity in chemical fertilizer treatments which were associated with lower PH values (8.25-8.22).

Early morning pH

Higher early morning PH values were detected in the organic fertilizer treatments which reflected higher algal production and increased photosynthetic activities that resulted in higher algal concentration and abundances. Also these higher values were detected in organic fertilizer treatments (8.53-8.64) compared to those of chemical fertilizer treatments (8.22-8.72). This could be explained by the higher algae production in the organic fertilizer treatments. PH of water increases when plants are rapidly removing carbon dioxide from water for use in photosynthesis (Boyd, 1990). The control treatment had an intermediate value (8.43) compared to those of fertilizer treatments. There are interrelationships among various forms of CO_2, photosynthesis, and PH. The importance of photosynthesis is obvious here, for plants can successively absorb CO_2, and eliminate bicarbonates, precipitate carbonates, and form hydroxyl ions, all these events account for rises in PH. Removal of the CO_2 and Photosynthesis will result in a rise of PH (Cole, 1979).

Total phosphorus and orthophosphate

Total Phosphorus concentrations had intermediate values in all treatments (0.214- 0.276 mg – P/L) except for that of the high organic fertilizer treatment (0.513 mg – P/L) which was significantly higher ($P < 0.05$) compared to all treatments. Total phosphorus is considered as an index for phytoplankton abundance in water since it includes organic sestonic phosphorus and soluble reactive phosphate phosphorus. Seston concentration is associated with phytoplankton abundance in water (Hutchinson, 1975).

Nutrient assessment in pond water can be based on total nitrogen and total phosphorus measurements, and plankton abundance can be followed using secchi disk visibility measurements. Since the average secchi disk readings in the high organic fertilizer treatment (28.95 cm) was nearly similar to those the majority of other treatments (approximately 24.8 – 39.5 cm), the higher total phosphorus concentration in the high organic fertilizer treatment may be associated with the increase in both of soluble organic phosphorus and soluble reactive phosphorus produced during the decomposition of the heavy organic fertilizer dose ($4g/m^2/d$) applied in that treatment. Aerobic bacteria work on organic fertilizer releasing both soluble organic phosphorus and orthophosphate during the process of organic fertilizer decomposition under aerobic conditions (Wudtisn and Boyd, 2005).

Soluble reactive phosphorus concentrations were similar among all treatments (0.061 – 0.093 mg-p/L) except for that of the high organic fertilizer treatment which had significantly higher orthophosphate concentration (0.256 mg-P/L) compared to other treatments ($P<0.05$). This could be attributed to the high bacterial decomposition on the heavy organic fertilizer dose applied in that treatment. Both soluble organic phosphorus and soluble reactive phosphorus (orthophosphate) are the main end-products of bacterial activity on organic fertilizer under aerobic conditions.

In a study of Boyd (1982); it was found that orthophosphate concentration represents a small fraction (usually <10%) of total phosphorus concentration. Also, The difference between total phosphorus and filterable orthophosphate concentrations may be used as an index of the Phosphorus contained in plankton and detritus In addition, The ratio of total phosphorus: soluble reactive phosphorus ranged between 2.7:1 and 3.5:1 for all treatments except for the high organic fertilizer treatment which had TP: PO_4 ratio of 2:1. The difference in concentration of total phosphorus and soluble reactive phosphorus represents the concentration of phosphorus present in phytoplankton and other particulate matter. Consequently, the difference between TP and PO_4 concentrations in pond water could be considered as an index of the phytoplankton abundance in water. The TP- PO_4 difference among different treatments ranged 0.18-0.25 for the organic fertilizer treatments and 0.15-0.18 for the chemical fertilizer treatments, indicating similar phytoplankton abundances among treatments.

Higher growth rate of fish is corresponded with the increase in planktonic life which showed their maximum densities at high phosphate concentration in the water (Sin, 1987).

Secchi disk visibility

Secchi disk visibility in the organic fertilizer treatments (range 24.8-39.5cm) was almost similar to those of the chemical fertilizer treatments (26-35.2cm), with no significant differences among treatments ($P>0.05$). Phytoplankton abundances were within favorable conditions for fish growth in all treatments with an overall range of 24.8-39.5cm among treatments. The abundance of algal stocks (biological turbidity of water)was less in the control treatment due to the lower dissolved nitrogen and phosphorus salts being affected by the absence of fertilizer input in that treatment.

In fish ponds, secchi disk transparency provides a rough estimate of plankton abundance. Water transparency showed an inverse correlation plankton abundance (Padmavathi and Prasad, 2007)

Semi-intensive aquaculture ponds often develop dense phytoplankton population (chlorophyll A>250µg/L, secchi disk visibility<20cm) in response to a high rate of nutrient input (Hargreaves, 1998). Ponds used for intensive fish culture are normally turbid with algae which grows in response to addition of fertilizer or fish feed (Boyd, 1990). In addition, ponds which received application of fish feed also had abundant phytoplankton growth because roughly 75 percent of the nutrients in feed are excretory products during the process of metabolism (Boyd, 1979)

Water quality variables were the best explanatory variables for natural food availability, which in turn explained natural food ingestion best (Rahman et al, 2008). The results of the present study indicated that chemical and organic fertilizer treatments were approximately similar in terms of algal abundances although they were dissimilar in terms of rates of algal production as indicated by higher PH values and carbonate concentrations in the organic fertilizer treatments.

1-2-Growth performances and condition factor

It is well known that Nile tilapia could obtain more than 50% of its nutritional requirements from feeding on algae and zooplankton, especially during the juvenile stage of growth. Consequently, using low cost fertilization programs can highly reduce nutritional requirements for dietary ration. The dry algal material contains 45-50% crude protein which is highly digestible (digestibility coefficient =65%).Consequently, algal matter is highly nutritious (Boyd, 1990) and is of parallel value to protein content of oil meals.

In the water quality experiment, growth rates of Nile tilapia were higher in organic fertilizer treatments (0.54-.62 gm/fish/day) compared to those of the chemical fertilizer treatments (0.47-0.51 gm/fish/day). This could be attributed to the effect of organic fertilizer which enhanced the production of zooplankton in rearing tanks. Zooplankton is considered a good nutritional material (animal protein source) for fish since it contains 70% crude protein Moreover, bacterial activities on manure help the release of soluble nitrogen and phosphorus salts from the decay of organic matter in manure, and thus increasing primary productivity of algae.

In the organic fertilizer treatments, Nile tilapia feed on supplementary diet, zooplankton, algae and bacterial films contained in organic manure. While in the chemical fertilizer treatments, Nile tilapia would feed mostly on supplementary diet and algae since zooplankton and bacterial abundance would be less available.

Chemical fertilizers stimulate the natural productivity of water through photosynthesis, whereas animal manures provide, upon decomposition, nutrients for both autotrophs and heterotrophs. The chicken manure treatments produced better growth due to its ability to stimulate the development of heterotrophs (bacteria), autotrophs (algae) and zooplankton organisms and to increase fish production in ponds (Nguenga et al, 1997).

Green et al. (1989) compared yields of tilapia (Oreochromis niloticus) in sets of ponds receiving chicken litter, cow manure or nitrogen and phosphorus inorganic chemical fertilizer. The added nitrogen was equal in all treatments. Chemical fertilization and cow manure supported similar fish yields (8.0and 8.6 kg per hectare per day, respectively). The yield with chicken manure was 11.7 kg per hectare per day.Diana et al. (1991) reported that net fish yield was higher in organically than inorganically fertilized ponds inspite of similar primary production and chlorophyll "a" concentration.

Averages of condition factor of Nile tilapia at harvest in the organic fertilizer treatments (2.0-2.21) were significantly higher than those of the chemical fertilizer treatments (1.7-2.0). The addition of organic manure in the rearing tanks had a positive effect on condition factor of Nile tilapia. This could be explained by the increase in natural food quality (zooplankton abundances) in the organic fertilizer treatments compared to those of the chemical fertilizer treatments. The condition factor of Nile tilapia fed the control diet (1.98) did not differ significantly from those of Nile tilapia in the chicken manure treatments. This indicated that Nile tilapia produced by the control and chicken manure treatments were of good quality and better shape compared to those produced in the chemical fertilizer treatments .Nile tilapia harvested from the organic fertilizer treatments were more round (better thickness) than those harvested from the chemical fertilizer treatments, indicating better quality of fish and better nourishment in the organic fertilizer treatments.

Green et al. (1989) found that the mean net fish production was the greatest in the chicken litter treatment (1759 Kg per 150 per days), and production was different when dairy cow manure (1295 Kg per 150 per days) or chemical fertilizer (1194 Kg per 145 per days) were the nutrient sources. The greater fish production by chicken litter treatments, probably results from increased bacterial production or direct consumption of manure by fish (Popma,1982).Green et al (1989) reported that the final weight of fish was significantly greater for chicken litter (203.9±16.1 g)than for the chemical fertilizer(150.4±17.9 g) treatments.

2-Fish production experiment

2-1- Growth performances

Mean individual weights of fish at harvest after 90 days rearing were significantly higher in the medium organic fertilizer, medium chemical fertilizer and control treatments (218.1, 206.8 and207.4 gm/fish, respectively). Nile tilapia reared in high chemical and high organic fertilizer treatments attained lower harvest size(179.4 and 189.9 gm/fish, respectively). The medium dose of either chemical or organic fertilizer treatments along with supplementary feeding produced heavier fish compared to those of the high chemical or high organic fertilizer treatments.

The highest specific growth rate for Nile tilapia juveniles (0.53 % per day) was observed in the medium organic fertilizer treatment, followed by those of the medium chemical fertilizer and control treatments (0.49 and 0.48 %, respectively) the lowest growth performances were observed in the high chemical and the high organic fertilizer treatments(0.28 and0.36%, respectively).

In the high manure and high chemical fertilizer treatments, water supported greater over-abundance of algae compared to other treatments. High chemical and high manure doses in those treatments significantly increased water quality deterioration, especially in terms of dissolved oxygen. High algal blooms in the high chemical fertilizer and high manuring treatments reduced seechi disk to less than 10 cm by the end of the experiment. Dense algal blooms in those treatments resulted in low dissolved oxygen during nighttime over the duration of the experiment, lowering diet intake by fish during day-time.

Large quantity of manure would rapidly deteriorate the water quality and result in a high mortality of fish, as observed in tank experiments (Kumar et al,2002). Pond fertilization using high amount of manure can lead to water quality deterioration, including the serve depletion of dissolved oxygen, high biological and chemical oxygen demand, and high ammonia levels (Boyd, 1982). High organic manuring also lead to severe depletion of dissolved oxygen, leading to stress in cultured fish and loss of appetite (Parker, 1986).

The gradual accumulation of organic matter in water body leads to the subsequent dominance of biodegradation and decomposition processes and causes an oxygen deficit (Pechar ,2000). Although it has been established that high fish yield in culture systems can be achieved by higher abundance of plankton through organic manuring, practical alternatives to pond manuring are needed because heavy manuring may reduce water quality (Prithwiraj et al., 2008).

Growth rate in terms of daily weight gain, was generally higher in Nile tilapia raised in the medium organic fertilizer treatment (0.92 gm/fish/day), followed by those of the medium chemical fertilizer and control treatments(0.83 and 0.82 gm/fish/day, respectively). The higher daily weight gain observed in the medium organic and medium chemical fertilizer treatments were due to the higher availability of natural food along with better water quality.

These results were parallel with those achieved by Dhawan and Kaur (2002) who reported that the higher availability of natural food resulted in higher growth of carps in natural ponds.In addition, animal wastes lead to increased biological productivity of pond through various path-way, which result in increase in fish production (Orhibhabor and Ansa, 2006).

In the control one, fish were fed at 7 grams diet/m^2/day. This high feeding rate resulted in the increase in concentrations of metabolic wastes by fish such as organic matter, nitrogen and phosphorus salts in the water column which increased algae growth and production in rearing tanks. These results are in accordance with Massout (1999) who reported that metabolic wastes such as phosphorus, ammonia, and nitrate serve as plant nutrients and stimulate phytoplankton growth in aquaculture ponds.

The lowest daily weight gains were observed in the high chemical and high organic fertilizer treatments (0.46 and 0.58 gm/fish/day, respectively).which could be explained by the deterioration in oxygen concentration in water due to the high algal blooms.

2-2- Feed performances

The best feed conversion ratio was observed in the medium organic fertilizer treatments (2.1:1), followed by those of medium chemical fertilizer and control treatment (2.26 and 2.4:1, respectively). Better feed conversion ratios were obtained in the medium organic and medium chemical fertilizers and control treatments due to the high of availability of natural food along with better water quality in those treatments.

Feed accounts for 40-60% of the production costs in aquaculture, with protein sources accounting for a significant proportion of this cost (Fotedar, 2004). Nile tilapia are commonly grown in semi-intensive culture using fertilization to increase primary production that is used by tilapia for food (Diana *et al.,* 1991). Fertilizers can be used to reduce the quantity and expense of supplemental feeds. An increase in natural food has a much greater effect on tilapia production (Bahnasawy, 2009).

The high chemical and high organic fertilizer treatments produced the poorest feed conversion ratios (4.3 and 3.26:1, respectively) compared to all treatments, with significant differences among treatments (p>0.05). This could be explained by the loss of appetite to feed intake under water quality deterioration (i.e. oxygen deficit) caused by the high fertilizer doses applied in those treatments. Environmental deterioration in those treatments reduced growth performances of fish through the loss of fish appetite especially under low oxygen concentration stress.

Semi-intensive production in ponds using fertilizers and supplementary feeding is a mean of producing low-cost fish in developing countries. It can provide an opportunity to balance the use of supplementary feeding in correlation with the natural food availability and hence reduce the production cost (Suman and Samir,2009).Resource-poor farmers prefer semi-intensive carp polyculture because the capital needed to buy (expensive) artificial feeds is minimized, while the exploitation of natural foods in ponds is optimized. Nevertheless, there is a tendency by richer farmers to further increase production through the application of artificial feeds (Rahman, 2006).

The protein efficiency ratio (PER) ranged 1.32-2.64 among treatments during the experimental period, with significant differences (P>0.05) among means. The best PER value was obtained in the medium organic fertilizer treatment (2.64), followed by that of the medium chemical fertilizer treatment (2.39). The high organic and chemical fertilizer treatments had lower protein efficiency ratios (1.68 and 1.32, respectively) compared to those of the medium organic and medium chemical fertilizer treatments (P>0.05). The control treatment produced a low PER value (1.4) in spite of employing a high quality feed (30 % crude protein) in this dietary treatment. All fertilizer treatments used a low quality feed (18% crude protein) at the same feeding rate (7gm/m^2/day).However, the low quality feed (supplementary feed, 18% crude protein) employed in the fertilizer treatments produced better feed conversion ratios, high protein efficiency ratios and high economic returns compared to the control treatment which employed complete high quality feed (30% crude protein). This was due to the direct effect of fertilizers on plankton production and fish nutrition.

These results are parallel with those reported by Sumitra et al (1981) who detected a significant increase in fish yield due to the effect of organic fertilizer on the planktonic productivity of a commercial pond and those of Aziz et al. (2002) who studied the growth performance of major carps in fertilized ponds supplemented with feed calculated the contribution of primary productivity towards increase in fish yield to be 57.40%.On the other hand, Akiyama (1993) demonstrated that the use of sub-optimal quality feeds resulted in good, acceptable yields, comparable to those that are obtained with use of high-quality feeds.

Based on analyses of stomach content, Lim (1989) reported that up to half the food intake of tilapia in intensively fed ponds was natural food, which indicated its substantial contribution to tilapia growth. As Nile tilapia derives most of their nutrition from phytoplankton (Colman and Edwards, 1987),a strong correlation between algae production and net fish yield was expected(Knud-Hansen and Batterson,1994).

High expected harvests were observed in the medium organic, medium chemical fertilizer and control treatments (610,579 and 580 grams fish/ m^2, respectively). These harvest rates are equivalent to 2.56, 2.43 and 2.43 tons fish/acre/single harvest).As a result of low growth performances of fish and poor feed conversion ratios in the high chemical and high organic fertilizer treatment, expected harvests in those treatments were significantly lower than other treatments (2.11-2.23 tons fish/acre/single harvest)

It can be concluded that the use of low-quality feeds (18% crude protein) was superior to that of high-quality feeds (30% crude protein) in terms of producing good acceptable yield per acre and better economical returns. The use of low-quality feeds should be supported by the use of medium doses of either chemical or organic fertilizers in order to produce higher availability of natural food along with maintaining better water quality in rearing ponds.

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Table (1): Water quality indices and growth performances during the first trial:

Parameter / Treatment	Organic fertilizer			Chemical fertilizer			Control
	Low	Medium	High	Low	Medium	High	
Water temperature (C^o)	26.6± 2.75	26.9± 2.59	27.4± 2.24	27.5± 1.90	25.6± 2.71	26.8± 2.47	27.3± 1.95
Dissolved oxygen (mg/l)	10.71± 2.37	10.09± 1.1	10.03± 1.01	10.23± 2.78	11.51± 3.56	12.38± 1.45	11.99± 2.24
Total alkalinity (mg $CaCO_3$/l)	321.5± 40.2	330.0± 81.2	355.5± 91.9	292.2± 35.3	306.9± 46.8	294.2± 36.1	333.1± 53.8
Bicarbonate alkalinity (mg $CaCO_3$/l)	278.1± 36.9	286.7± 94.5	301.61± 66.3	244.0± 28.1	294.01± 13.5	264.7± 19.1	294.01± 54.6
Carbonate alkalinity (mg $CaCO_3$/l)	42.0± 13.1 ^{ab}	45.0± 19.5 ^{ab}	53.8± 31.0 ^{a}	51.2± 20.3 ^{a}	31.9± 14.1 ^{b}	35.1± 20.4 ^{b}	40.0± 16.5 ^{ab}
pH	8.55± 0.33	8.64± 0.53	8.53± 0.57	8.72± 0.56	8.25± 0.36	8.22± 0.26	8.43± 0.40
Total phosphorus (mg p/l)	.214± 0.15 ^{b}	.276± 0.14 ^{b}	.513± 0.19 ^{a}	.178± 0.18^{b}	.236± 0.2 ^{b}	.227± 0.19 ^{b}	.215± 0.14 ^{b}
Orthophosphate (mg p/l)	0.077± 0.063 ^{b}	0.093± 0.073 ^{b}	0.256± 0.16 ^{a}	0.061± 0.07 ^{b}	0.086± 0.08 ^{b}	0.089± 0.08 ^{b}	0.073± 0.06 ^{b}
Secchi disc visibility (cm)	39.5± 18.3	24.8± 4.4	28.95± 7.1	31.7± 9.3	35.2± 19.6	26.0± 9.1	35.24± 12.0
Initial weight (gm/ fish)	50.74± 6.6 ^{a}	51.33± 6.79 ^{a}	51.24± 7.09 ^{a}	50.22± 5.29 ^{a}	51.33± 6.86 ^{a}	50.22± 4.09 ^{a}	54.83± 4.09 ^{a}
Daily weight gain (gm/fish/day)	0.54± .081 ^{b}	0.54± .092 ^{b}	0.62± .011 ^{a}	0.47± .049 ^{b}	0.49± .063 ^{b}	0.51± .058 ^{b}	0.51± .058 ^{b}
Condition factor	2.21± 0.2 ^{a}	2.13± 0.18 ^{ab}	2.02± 0.14 ^{b}	1.83± 0.21 ^{c}	1.70± 0.11 ^{c}	2.02± 0.15 ^{b}	1.98± 0.14 ^{b}

Table (2): Growth performances during the production experiment:

Parameter / Treatment	Medium chemical fertilizer	High chemical fertilizer	Medium organic fertilizer	High organic fertilizer	Control
Initial weight (grams/fish)	131.37 $\pm$ 3.2 ^{a}	137.7 $\pm$ 4.0 ^{a}	135.0 $\pm$ 12.1	136.67 $\pm$ 0.83 ^{a}	132.88 $\pm$ 0.66 ^{a}
Final weight (grams/fish)	206.85 $\pm$ 1.3 ^{ab}	179.45 $\pm$ 13.8 ^{c}	218.15 $\pm$ 0.15 ^{a}	189.9 $\pm$ 4.1 ^{bc}	207.4 $\pm$ 22.7 ^{ab}
SGR	0.49 $\pm$ 3.5 ^{ab}	0.28 $\pm$ 5.5 ^{c}	0.53 $\pm$ 0.1 ^{a}	0.36 $\pm$ 3.0 ^{bc}	0.48 $\pm$ 0.11 ^{ab}
DWG (g/fish/day)	0.83 $\pm$ 5.0 ^{ab}	0.46 $\pm$ 0.11 ^{c}	0.92 $\pm$ 0.14 ^{a}	0.58 $\pm$ 5.5 ^{bc}	0.82 $\pm$ 0.24 ^{ab}
Condition Factor	1.6 $\pm$ 0.0 ^{ab}	1.64 $\pm$ 7.8 ^{ab}	1.68 $\pm$ 8.0 ^{a}	1.56 $\pm$ 2.5 ^{b}	1.58 $\pm$ 3.5 ^{ab}
FCR	2.26 $\pm$ 0.15 ^{b}	4.3 $\pm$ 1.01 ^{a}	2.1 $\pm$ 0.3 ^{b}	3.26 $\pm$ 0.3 ^{ab}	2.46 $\pm$ 0.7 ^{b}

Table (3): Yield and feed performances during the production experiment:

Parameter / Treatment	Medium chemical	High chemical	Medium organic	High organic	Control
FCR	2.26 ± 0.15 [b]	4.3 ± 1.01 [a]	2.1 ± 0.30 [b]	3.26 ± 0.30 [ab]	2.4 ± 0.76 [b]
PER	2.39 ± 0.14 [a]	1.32 ± 0.31 [b]	2.64 ± 0.39 [a]	1.68 ± 1.55 [b]	1.4 ± 0.4 [b]
Yield/m^2	579.18 ± 3.7 [ab]	502.46 ± 38.7 [c]	610.82 ± 0.42 [a]	531.72 ± 11.4 [bc]	580.72 ± 63.5 [ab]
Expected Yield/ acre	2432 ± 16.0 [ab]	2110 ± 163.0 [c]	2565 ± 1.5 [a]	2233 ± 48.0 [bc]	2438 ± 266.5 [ab]

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