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Effects of fertilization and concentrate feeding on water quality and growth performance of Nile tilapia (*Oreochromis niloticus*) grown in concrete tanks

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Abstract

An experiment was conducted to compare the effects of fertilizer application alone, concentrate feeding alone and combination of fertilization and feeding on water quality parameters and growth performance of sex-reversed Nile tilapia (*Oreochromis niloticus*). Three treatments (weekly fertilization with urea and Di-Ammonium Phosphate (DAP), concentrate feeding at 5% of fish body weight and weekly fertilization with urea and DAP plus concentrate feeding at 2.5% of fish body weight) were randomly allotted to nine concrete tanks. Three fingerlings per m^2 were stocked in the tanks and grown for 166 days. Results indicated that treatment had significant effect ($p \leq 0.001$) on water Dissolved Oxygen (DO), conductivity, total dissolved solids, nitrate and phosphorus but not on pH, salinity, temperature, ammonia and alkalinity. Fish cultured under the combination of feeding and fertilization had higher ($p \leq 0.0001$) weight gain (257.37 ± 5.71 g), growth rate (1.50 ± 0.04 g/day), yield (13,128.35 kg/ha/year) and lower Feed Conversion Ratio (FCR) (1.89 ± 0.03) than those reared under feeding alone and fertilization alone. It is concluded that the combination of weekly fertilization and concentrate feeding at 2.5% of fish body weight is better than either weekly fertilization alone or feeding alone at 5% of fish body weight.

Keywords: *Feed conversion efficiency, Growth rate, Yield, Nile tilapia, Water quality parameters*

1. Introduction

Feed costs in aquaculture production account for approximately 50% of total operational costs (Rana *et al.*, 2009) and is considered to be the major constraint for both small-scale fish farmers and commercial fish

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farmers. Reducing the amount of feed provided to fish in a pond is a means of lowering costs and increasing profit margin. One way of reducing cost is fertilizer application. When ponds are fertilized, nutrients in the fertilizer stimulate the growth of phytoplankton. Phytoplankton is food for other organisms (zoo-plankton and larger animals) that are eaten by fish. Weekly fertilization of fish pond has been shown to increase fish yield by increasing primary productivity through released inorganic nutrients, or by providing organic carbon through heterotrophic pathways (Knud-Hansen *et al*., 1991). Availability of natural food in pond water reduces fish requirement for artificial feeds, leading to low production costs and increased farm income. However, the natural food produced in the pond following the application of fertilizer of any type and form cannot suffice the nutritional requirements of fish for reasonable growth (Abbas *et al*., 2014), hence, supplementation of artificial feed is inevitable for optimum fish growth and obtaining higher yields.

Water quality in fish ponds is a major factor determining the growth performance of fish (Egna and Boyd, 1997). Maintaining proper water quality parameters is very important for survival, growth, and reproduction of aquatic organisms, hence, they need to be monitored. This is because fertilization of pond with excessive amount of fertilizer can cause severe environmental issues due to high concentration of algae that lead to algal bloom. Algal bloom hinders light penetration in the water, and this leads to decrease in photosynthesis rate and consequently decrease in the amount of Dissolved Oxygen (DO) in fish ponds. Furthermore, excessive pond fertilization results into excess nitrogen input that causes high concentration of unionized ammonia, which may reduce fish growth or cause mortality. On the other hand, provision of feeds in excess of what can be taken by the fish leads to wastage of diet and diet wastes means deteriorated water quality and economical losses (Ali *et al*., 2010). This situation often causes mass mortality of tilapia and consequently the farmers get a loss and abandon fish farming.

Pond culture is the most common method of raising Nile tilapia in Tanzania. Among the primary factors limiting the production capacity of a pond is the quantity of available nutrients, which form basic materials for structure and growth of living organisms. Proper pond fertilization and supplementary feeding techniques are used to supply these nutrients in optimal quantities, thereby overcoming natural deficiencies. Although inorganic and organic fertilizers can be used in fishponds, inorganic fertilizers have some advantages compared to organic fertilizers. Inorganic fertilizers are applied at low application rates, dilute easily in water, have a well-defined composition and high nitrogen contents. A study done in Bangladesh (Wahab *et al*., 2014) indicated that proper pond fertilization with inorganic fertilizer combined with supplementary feeding at 50% satiation level results in higher fish yield and benefit-cost ratio for polyculture of tilapia and Silver carp than culturing on fertilizer application or 100% feeding alone. Another study done in Cambodia (Phanna *et al*., 2014) showed that pond fertilization plus supplementary feeding (50% satiation) is the most effective feeding for optimization of production, Feed Conversion Ratio (FCR), and growth performance of tilapia cultured under semi-intensive system or small-scale aquaculture. In Tanzania information on the combined effects of fertilization and supplementary feeding on water quality parameters in ponds and growth performance of fish is lacking. It is not known which pond management system can be used by small-scale farmers in order to reduce cost and increase production and profit. Therefore, the overall purpose of this study was to identify the best management practice that can be used by small-scale fish farmers for improving fish production in Tanzania. Specifically, the study aimed at evaluating the effects of pond fertilization alone, feeding alone and combination of pond fertilization with supplementary feeding on water quality parameters, growth performance, yield and profit margin of Nile tilapia.

2. Materials and methods

2.1. Study location

The experiment was conducted at fish farm of the Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Sokoine University of Agriculture is located at latitude 6-7 °S and longitude 37-38 °E at an altitude of about 500- 600 m above sea level. The area receives an average annual rainfall of between 600 and 1,000 mm. The climate is characterized by bimodal rainfall patterns, with short rains starting in November and ending in December and long rains starting in March and ending in May. The temperature ranges from 25 to 30 °C.

2.2. Experimental procedure and fish management

The experiment was conducted using nine concrete tanks, each having a surface area of 3.36 m^2. The treatments were weekly fertilizer application alone with urea and Di-Ammonium Phosphate (DAP) (T_1), concentrate feeding alone at 5% of fish body weight (T_2) and weekly fertilization with urea and DAP plus concentrate feeding at 2.5% of fish body weight (T_3). The three treatments were assigned randomly to the concrete tanks and each treatment was replicated three times. The concentrate feed comprised of fish meal (25%), cotton seed cake (10%), sunflower seed cake (10%), maize meal (4%), wheat bran (50%) and mineral premix (1%) and had a crude protein content of 30% CP. Prior to the start of the experiment, all tanks were drained, cleaned, dried for five days and then refilled with water and fertilized with urea and DAP at a rate of 3 g / m^2 and 2 g / m^2, respectively (except those under T_2), and left for 14 days before being stocked with fingerlings. The tanks were stocked with sex-reversed Nile tilapia with average weight of 1.1 g at a stocking density of three fingerlings per m^2. Fingerlings cultured in the tanks under T_2 and T_3 were fed concentrate diet at the feeding levels of 10 and 5% of their body weights, respectively, for the first two months and thereafter the amount of feed was reduced to 5 and 2.5% for T_2 and T_3, respectively. The fish were provided with feed twice per day at 10:00 h and 16:00 h. The experiment took 166 days.

Water samples were collected from each tank at three depths (i.e., at the top, middle and just off the bottom of the tank) of the water column, then mixed and put into 500 mL vials for determination of water quality parameters. The water quality parameters (i.e., pH, DO, conductivity, total dissolved solids, salinity, temperature, alkalinity, total phosphorus, ammonia and nitrate) were measured weekly between 09:00 h and 10:00 h. Pond water pH, DO, conductivity, total dissolved solids (TDS), salinity and temperature were measured in each tank using multiparameter (HI 98198 PH / EC / DO Multiparameter HANNA instrument).The water samples were preserved at $^-18\,^oC$ for laboratory analysis of Nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N) and phosphate-phosphorus (PO_4-P). NO_3-N and NH_3-N were determined using Kjeldahl method while PO_4-P was determined by spectrophotometry method.

All fish in each tank were taken for measurement of body weight and length fortnightly. Fish body weights and lengths were measured at the beginning of the experiment and then after every two weeks. Weight of individual fish was measured using a digital weighing scale while body length was measured using a ruler. At the end of each experiment, the following parameters were computed as shown below:

(i) Growth rate (g / day) = (final weight (g) – initial weight (g)) / experimental period in days.

(ii) Specific growth rate (% per day) = $[\ln W_2 - \ln W_1 / T] \times 100$, where W_1 = initial body weight (g), W_2 = final body weight (g) and T = experimental period in days.

(iii) Condition factor (K) = $100W / L^3$, where W = body weight and L = body length.

(iv) Feed Conversion Ratio (FCR) = Feed provided (g) / body weight gain (g).

(v) Survival rate (%) = [(number of fish stocked – number of fish died) / number of fish stocked] × 100.

(vi) Gross margin = Total revenue obtained from fish harvested – total variable costs.

3. Statistical analysis

Data generated on growth performance parameters (growth rate, specific growth rate, weight gain, FCR and yield) and water quality parameters (pH, DO, conductivity, TDS, salinity, temperature, alkalinity, total phosphorus, ammonia and nitrate) were analyzed using SAS software version 9 (SAS, 2003). Analysis of variance was done in a completely randomized design and the effect of treatment was tested using the F-test at $p = 0.05$. Duncan's Multiple Range test was used to determine the significance of the differences between a pair of treatment means.

4. Results and discussion

4.1. Water quality parameters

Results on water quality parameters are shown in Table 1. The results indicate that treatment had significant effect on DO. The concrete tanks subjected to the treatment of fertilization alone (T_1) (9.97 ± 0.21 mg / L) and fertilization plus feeding (T_3) (7.84 ± 0.20 mg / L) had higher ($p \leq 0.0001$) DO values than those under concentrate feeding alone (T_2) (6.51 ± 0.20 mg / L). This is due to the fact that fertilizer application in T_1 and T_3 increased the production of phytoplankton. These phytoplankton produce most oxygen in water through photosynthesis, the process in which green plants use solar energy to convert water and carbon dioxide to oxygen and carbohydrates (Knud-Hansen, 1998). On the other hand, the lower DO level in T_2 was caused by oxygen depletion as a result of decomposition of uneaten feeds. Aerobic bacteria use oxygen to decompose feed materials, and this contributes to low oxygen levels in pond water. The results of this study agree with the findings by Ibrahim and Nagdi (2006) who reported that pond fertilization with chemical fertilizers helps to maintain high DO and moderate pH values.

The results in Table 1 show that the concrete tanks under T_1 had higher ($p \leq 0.05$) water conductivity, TDS and salinity compared to those under T_2 and T_3 while those under T_3 had the lowest values. The concentration of nitrate and phosphorus differed significantly among the treatments. The concrete tanks subjected to T_1 had the highest nitrate concentration in water, followed by those under T_2 while those under T_3 had the lowest concentration. The concentration of phosphorus was higher ($p \leq 0.0001$) in concrete tanks under T_3 than in those under T_1 which, in turn, had higher ($p \leq 0.0001$) phosphorus content than the concrete tanks under T_2. The higher total phosphorus concentration in the fertilized concrete tanks (T_1 and T_3) may be due to the increase in both soluble organic phosphorus and soluble reactive phosphorus produced during the decomposition of the fertilizer applied in the concrete tanks. The concentration of ammonia in tank water did not differ ($p > 0.05$) among the treatments. However, the water in the concrete tanks under T_1 and T_3 had slightly higher ammonia content than those under T_2. The higher content of ammonia in water of the fertilized tanks (T_1 and T_3) was mainly due to higher algal biomass. This agrees with Elnady *et al*. (2010) who reported that higher concentration of total ammonia in the chemical fertilizer is positively correlated with higher algal abundances. The decomposition of dead algal by bacterial activity and the mineralization of algal protein into ammonia by fish and other aquatic animals resulted into higher ammonia content in water.

The average pH values were not different ($p > 0.05$) among the concrete tanks under T_1, T_2 and T_3 and were within the range recommended for tilapia. According to Stickney (1994), pH values of 7.7-8.7, measured at 09:00-10:00 h, are considered safe for fish, since the ponds are relatively well buffered. Water salinity, temperature and alkalinity were not affected ($p > 0.05$) by treatment. Average salinity ranged from 0.03 to 0.04 mg/L in concrete tanks under T_3 and T_1, respectively. Mean water temperatures in the concrete tanks during the experimental period were almost similar in the three treatments and ranged from 27.53 ± 0.11 to 27.82 ± 0.10 °C in concrete tanks under T_1 and T_3, respectively. Average alkalinity values were slightly higher in T_2 (78.21 ± 5.10 mg/L) and T_1 (74.20 ± 5.18 mg/L) compared to T_3 (71.76 ± 3.52 mg/L). Similar results on water quality parameters have been obtained by El Naggar *et al*. (2008) in Egypt. The water quality parameters important for fish growth are DO, temperature, pH, salinity and ammonia. Generally, the values of water pH, DO, salinity and temperature in the current study were within the normal range for Nile tilapia growth. According to Popma and Lovshin (1995) the ideal water temperature, pH, DO and salinity for Nile tilapia growth range from 25 °C to 30 °C, 6 to 9, 3 to 6 mg/L and 5 to 10 ppt, respectively. These values make the fish thrive well in pond water and grow fast.

Table 1: Comparison of water quality parameters in concrete tanks under three different treatments

Water Quality Parameter	Treatment			*p*-Value
	T_1	T_2	T_3	
pH	8.53 ± 0.10^a	8.06 ± 0.41^a	7.90 ± 0.13^a	0.3181
DO (mg/L)	9.97 ± 0.21^a	6.51 ± 0.20^c	7.84 ± 0.20^b	0.0001
Temperature (°C)	27.53 ± 0.01^a	27.61 ± 0.10^a	27.82 ± 0.10^a	0.3100
Salinity (mg/L)	0.04 ± 0.00^a	0.04 ± 0.00^a	0.03 ± 0.00^a	0.1205
Alkalinity (mg/L)	74.20 ± 5.18^a	78.21 ± 5.10^a	71.76 ± 3.52^a	0.5013
Ammonia (mg/L)	5.32 ± 0.27^a	4.72 ± 0.19^a	4.77 ± 0.23^a	0.0980
Nitrate (mg/L)	6.54 ± 0.35^a	6.02 ± 0.19^{ab}	5.68 ± 0.28^b	0.0430
Phosphorus (mg/L)	0.47 ± 0.04^b	0.21 ± 0.04^c	0.69 ± 0.08^a	0.0001
Conductivity (µS/cm)	81.03 ± 0.85^a	79.06 ± 0.88^b	75.49 ± 1.02^c	0.0262
TDS (mg/L)	40.61 ± 0.44^a	39.58 ± 0.45^b	37.57 ± 0.50^c	0.0079

Note: ^{abc} Means with the same superscript letter in the same row do not differ ($p > 0.05$) while those with different superscript differ significantly at $p \leq 0.05$.

4.2. Growth performance, feed utilization efficiency and condition factor of Nile tilapia (O. niloticus) cultured in concrete tanks under three treatments

The growth performance of Nile tilapia cultured under three treatments (fertilization alone (T_1), feeding alone (T_2) and a combination of fertilization and feeding (T_3)) is shown in Figure 1. The fish cultured under T_3 showed the highest growth performance, followed by those under T_2 while those reared under T_1 had the lowest growth performance. Table 2 shows fish body weight gain, growth rate, specific growth rate, FCR,

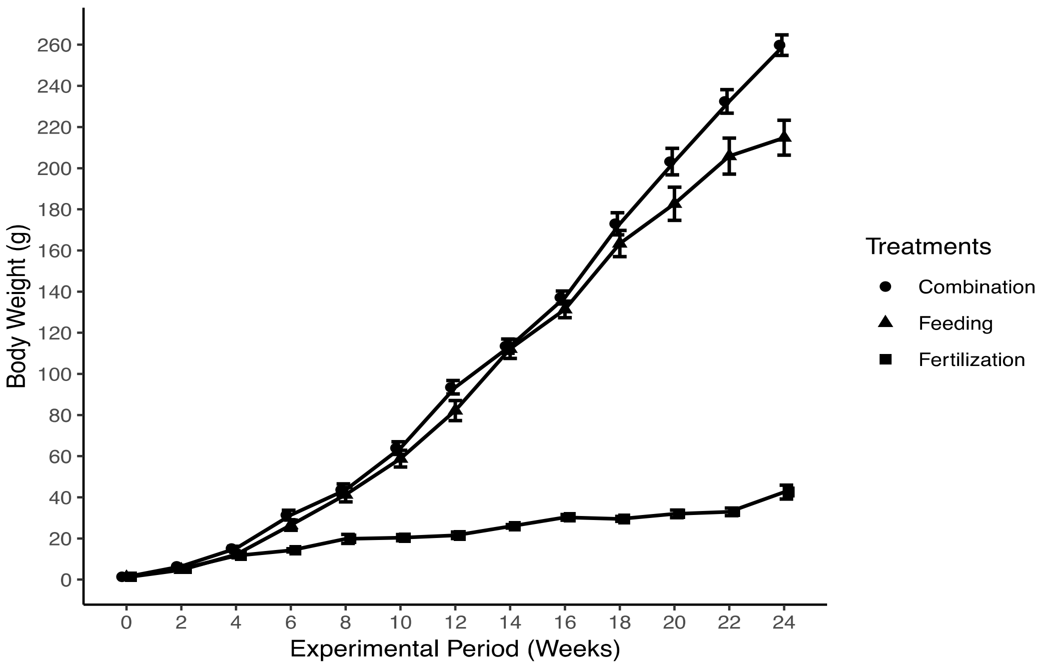

Figure 1: Comparison of growth performance of *O. niloticus* cultured in concrete tanks under three different treatments

Table 2: Comparison of growth performance, FCR, condition factor, survival and yield of Nile tilapia (*O. niloticus*) cultured in concrete tanks under three different treatments

Growth Variable	Treatment			*p*-Value
	T_1	T_2	T_3	
Initial body weight (g)	1.39 ± 0.09[a]	1.07 ± 0.09[b]	1.43 ± 0.09[a]	0.0154
Final body weight (g)	42.41 ± 5.53[c]	215.41 ± 5.90[b]	258.67 ± 5.71[a]	0.0001
Weight gain (g)	41.11 ± 5.53[c]	214.11 ± 5.90[b]	257.37 ± 5.71[a]	0.0001
Growth rate (g/day)	0.24 ± 0.03[c]	1.25 ± 0.03[b]	1.50 ± 0.03[a]	0.0001
Specific growth rate (%)	2.03 ± 0.03[b]	3.00 ± 0.03[a]	3.12 ± 0.0[a]	0.0001
FCR	-	3.35 ± 0.09[a]	1.49 ± 0.08[b]	0.0001
K	1.59 ± 0.03[b]	1.95 ± 0.03[a]	1.89 ± 0.03[a]	0.0001
Survival rate (%)	90	87.7	90	0.4219
Yield (kg/ha/year)	2,220.04[c]	10,688.06[b]	13,128,35[a]	0.0005

Note: [abc] Means with the same superscript letter in the same row do not differ ($p > 0.05$) while those with different superscript differ significantly at $p \leq 0.001$.

condition factor (K), survival and estimated yield of Nile tilapia (*O. niloticus*) cultured under T_1, T_2 and T_3. The results indicate that fish cultured in concrete tanks under T_1 had significantly lower final body weight, weight gain, growth rate, specific growth rate and yield than those cultured in tanks under T_2 and T_3. Fish cultured in tanks under T_2 on average gained 173 g while those on T_3 gained 216.26 g more weight than those on T_1. The results of the present study concur with the findings of Abbas *et al*. (2014) who concluded that application of fertilizers of any type and form cannot suffice the nutritional requirements of fish for reasonable growth and thus, supplementation of artificial feed is inevitable for satisfactory fish growth and higher yields. This implies that natural food produced as the result of pond fertilization should not be used as the sole source of food for fish, but should be combined with concentrate supplementation in order to promote fast growth and produce high yield of farmed Nile tilapia.

When comparison is made between T_2 and T_3, it can be seen that fish reared in concrete tanks subjected to weekly fertilization and daily feeding at 2.5% of body weight (T_3) had significantly higher final body weight, weight gain, growth rate, specific growth rate and yield than those under daily feeding alone at 5% of body weight (T_2). The mean final body weight, growth rate and estimated yield per ha per year of fish reared in tanks under T_3 exceeded those of fish reared under T_2 by 43.26 g, 0.25 g / d and 2,440.29 kg, respectively. Moreover, the fish under T_3 had significantly lower FCR than those on T_2, mainly because they were given half the amount of feed provided to the fish under T_2, but they grew faster compared to those under T_2. This is because weekly fertilization of concrete tanks with urea and DAP fertilizers in T_3 increased the production of natural food organisms (phytoplankton and zooplankton) which were then eaten by the fish cultured in those tanks. According to Knud-Hansen (1998) pond fertilization increases natural food production by stimulating algal productivity. This, in turn, promotes higher fish growth due to increase in the available natural food (phytoplankton and zooplankton). Elnady *et al*. (2010) showed that the growth of fish is strongly correlated with increase in phytoplankton and zooplankton productivity as a result of fertilization.

Condition factor (K) reflects the physiological state of a fish in relation to its welfare. Higher value of condition factor indicates better condition experienced by the fish (Anani and Nunoo, 2016). In the present study, the condition factors of the fish under T_2 and T_3 were significantly higher than that of the fish under T_1, implying that the environmental conditions in concrete tanks under T_2 and T_3 were more favorable for the growth and survival of Nile tilapia compared to that of the concrete tanks under T_1. On the other hand, the condition factor for the fish under T_2 was slightly higher than of those on T_3, though not significantly different. Similar results have been obtained by Abdel-Warith (2013) who obtained higher condition factor for the fish which received only artificial feed without any fertilization compared to those under weekly fertilization with either chicken manure or chemical fertilizer plus artificial feeding. In the present study survival rate of fish did not differ ($p > 0.05$) among the treatments and ranged from 87.7 to 90.0% in concrete tanks under T_1 and T_2, respectively.

4.3. Profitability of Nile tilapia (O. niloticus) cultured in concrete tanks under three different treatments

Results for gross margin analysis are shown in Table 3 for fish reared in concrete tanks subjected to the three treatments. Among the variable costs, fertilizer and fingerling costs did not differ ($p > 0.05$) among the treatments while labor and feed costs differed significantly among the treatments. Fertilizer cost did not differ ($p > 0.05$) between the treatments T_1 and T_3, mainly because the same amount of fertilizer was used in the two treatments. Concrete tanks under T_3 had the highest labor costs while those under T_1 had the lowest. The highest feed cost was observed under T_2. Feed cost accounted for 66.06 and 44.95% of total variable costs in treatment T_2 and T_3, respectively. Treatment influenced significantly the revenue and gross margin. Fish reared in concrete tanks under T_3 resulted into significantly higher revenue and gross margin than those cultured under T_2 and T_1. Fish reared under T_2 had higher revenue and gross margin than those under T_1. The fish reared under T_1 resulted into a loss mainly because of low yield as a result of significantly slow growth. The results in the present study concur with Waidbacher *et al*. (2006) who observed higher fish growth, yield, better feed utilization and profits for fish reared under pond fertilization and feeding concentrate diet at 6% of body weight compared to those which were subjected to either feeding alone or fertilization alone. According to Elnady *et al*. (2010) application of medium amount of chemical fertilizers (urea and TSP) as pond inputs can produce up to three- fold increase in fish yield. In this study it was observed that fish reared under T_3 produced the highest profit, followed by those reared under T_2 while those under T_1 resulted into a loss. These results indicate that pond fertilization combined with concentrate feeding at 2.5% of fish body weight reduced feed costs, and hence, increased the profit of Nile tilapia reared in concrete tanks under T_3 compared to those reared by only feeding at 5% of fish body weight without any fertilization. This agrees with Wahab *et al*. (2014) who reported that availability of natural food in pond water reduces fish requirement for artificial feeds, leading to reduced production costs and improved farm income. Artificial feed costs in aquaculture operations account for approximately 50-70% of total operational costs. Therefore, the application of inorganic fertilizers can be used as a means for reducing the need for supplementary feeds and, thus, can lower the production cost and increase the profit of fish farming enterprises.

Table 3: Comparison of variable costs, revenue and profit obtained from *O. niloticus* cultured in concrete tanks under three different treatments

Variable	Treatment			*p*-Value
	T_1 (TZS/ha/year)	T_2 (TZS/ha/year)	T_3 (TZS/ha/year)	
Fingerling cost	15,789,382.6	15,789,382.6	15,789,382.6	-
Labor cost	9,000,000.0^c	12,600,000.0^b	18,000,000.0^a	0.0001
Fertilizer cost	3,254,457.2	-	3,254,457.2	-
Feed cost	-	55,255,102.4^a	30,241,772.9^b	0.0001
Total variable cost	28,043,839.8^c	83,644,485.0^a	67,285,612.7^b	0.0001
Revenue	20,185,864.0^c	98,066,693.0^a	118,977,965.0^a	0.0001
Gross margin	–7,857,975.6^c	14,422,208.3^b	51,692,352.0^a	0.0001

Note: ^{abc} Means with the same superscript letter in the same row do not differ ($p > 0.05$) while those with different superscript differ significantly at $p \leq 0.001$.

5. Conclusion

This study has shown that that the combination of weekly fertilization and supplementary feeding is better than feeding alone or fertilization alone. Therefore, from the results of this study the following conclusions can be made.

i. Combination of weekly fertilization of concrete tanks and concentrate feeding at 2.5% of fish biomass promotes higher growth rate and results into higher profit than either weekly fertilization alone or feeding alone at 5% of fish biomass.

ii. Combination of weekly fertilization of concrete tanks and concentrate feeding at 2.5% of fish biomass does not affect water quality parameters beyond the range recommend for tilapia growth.

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