TOPIC AREA

PRODUCTION SYSTEM DESIGN AND BEST MANAGEMENT ALTERNATIVES

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EXPERIMENTAL POND UNIT ASSESSMENT IN TANZANIA

Production System Design and Best Management Alternatives/Experiment/16BMA01PU

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ABSTRACT

An experiment was carried out to compare the effects of pond fertilization alone, concentrate feeding alone at 5% of fish biomass and a combination of fertilization and feeding at 2.5% of fish biomass on water quality parameters and growth performance and yield of Nile tilapia. The experiment was conducted using nine earthen ponds with average size of 188.67 m^2 at Tindiga Village, Kilosa District, Tanzania. The treatments were weekly fertilization alone with urea and Di-Ammonium Phosphate (DAP) at a rate of 3 g/m^2 and 2 g/m^2, respectively (T_1), concentrate feeding alone at 5% of fish biomass (T_2) and weekly fertilization with urea and DAP plus concentrate feeding at 2.5% of fish biomass (T_3). The concentrate diet contained 30% crude protein. The ponds were stocked with sex-reversed Nile tilapia at a stocking density of 3 fingerlings per m^2. A random sample of 30 fish per pond was measured for body weight and length every two weeks. Dawn pond water pH, dissolved oxygen (DO), conductivity, total dissolved solids, salinity and temperature were measured weekly while diel measurements were taken nine times in 24 hours at an interval of 3 hours (i.e. at 0600 h, 0900 h, 1200 h, 1500 h, 1800 h, 2100 h, 2400 h, 0300 h and 0600 h) at the beginning, mid and end of the experiment. The experiment took 166 days. A second experiment was conducted using nine concrete tanks, each with a surface area of 3.36 m^2. The treatments used in this experiment were the same as those used in the first experiment. The sex-reversed Nile tilapia were stocked at the same stocking rate (3 fingerlings/m^2) and fed the same feed and the same feeding levels and frequency used in the first experiment. The purpose of this experiment was to complement the pond experiment.

Results indicate that in both culture system (earthen ponds and concrete tanks) treatment had significant effect ($p \leq 0.001$) on water pH, DO, conductivity, TDS and salinity but not on temperature and turbidity. Ponds under fertilization alone (T_1) (pH = 8.23 ± 0.02, DO = 4.03 ± 0.11 mg/L) and fertilization plus feeding (T_3) (pH = 8.20 ± 0.02, DO = 4.43 ± 0.11 mg/L) had higher ($p \leq 0.001$) water pH than those under the treatment of concentrate feeding alone (T_2) (pH = 8.08 ± 0.02, DO = 3.88 ± 0.09 mg/L). Results for diel measurements show that DO, pH and temperature values were lowest at 0600 hours, started to increase at 0900 hours and reached the peak at 1500 hours and then started to decrease and reached the lowest values at 0300 hours. In both earthen ponds and concrete tanks, treatment had significant effects on final body weight, weight gain, growth rate, specific growth rate and feed conversion ratio (FCR), but did not significantly affect survival rate. Fish cultured in ponds under T_1 had significantly lower weight gain (65.4 ± 1.1 g), growth rate (0.4 g/day) and specific growth rate (2.5%) than those cultured under T_2 and T_3. The weight gain (193.8 ± 4.5 g), growth rate (1.2 g/day) and specific growth rate (3.3%) of fish reared in ponds under T_3 were

significantly higher than of those on T_2. Treatment influenced significantly labour and feed costs, fish yield, revenue and gross margin. Fish reared in ponds under T_3 resulted into significantly higher yield (13,065 ± 458 kg/ha/year) and profit (TZS 25,600,813 ± 3,007,007) than those cultured under T_2 and T_1. It is concluded that the combination of weekly fertilization of ponds and concentre 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.

INTRODUCTION

In Tanzania aquaculture sector contributes to national food security and economic development, especially of rural poor farmers. Although it accounts only for a small proportion of total fish produced at the national level, aquaculture production provides vital animal protein to the people residing in areas which are located far away from the major fishery resources or where transport of fish is either difficult or too expensive. In some parts of the country where protein intake per capita is low and where protein malnutrition prevails, the socio-economic benefit of aquaculture is high. It provides employment and is a source of income for resource poor farmers. In recent years, there has been a growth in interest on aquaculture, mainly because of decline in capture fisheries. Aquaculture production is practiced by small-scale farmers in the country, mostly in the regions of Arusha, Mbeya, Iringa, Morogoro, Kilimanjaro, Ruvuma, Tanga, Coast, Dar es Salaam, Lindi, and Mtwara. Currently, it is estimated that there are about 21,300 grow-out earthen ponds in operation (MLFD, 2015) and over 95% of the farmers culture Nile tilapia (Oreochromis niloticus) under mixed-sex culture (Kaliba et al., 2006).

The emphasis of the national fisheries policy (URT, 1997) is on a semi-intensive integrated mode of fish culture, focusing on Nile tilapia. (Oreochromis niloticus). Pond culture of Nile tilapia is now viewed as a possible source of livelihoods for farmers residing in proximity to the urban markets of cities and towns. Nile tilapia is given first priority due to its desirable aquaculture characteristics, including fast growth, short food chain, efficient conversion of food, high fecundity (which provides opportunity for distribution of fingerlings from farmer to farmer), tolerance to a wide range of environmental parameters, and good product quality (Hussain et al., 2000; Neves et al., 2008). The aquaculture sub-sector has a great potential for expansion due to the fact that Tanzania is endowed with ample water resources all over the country. Despite the available potentials for fish production, low production is experienced in many small-scale ponds due to low productivity of the commonly cultured species coupled with poor management. Management practices for pond-cultured tilapia in Tanzania involve only pond fertilization and feeding. Small-scale fish farmers fertilize their ponds using farm yard manure before stocking and apply manure once per month during grow-out (Chenyambuga et al., 2014). Some farmers put manure in cribs in order to fertilize the ponds slowly. Cattle, sheep, goat, and chicken manure are commonly used to fertilize fish ponds. Feeding of pond cultured Nile tilapia depends on natural food and concentrate feeds. Farmers in rural areas provide maize bran, kitchen leftovers, and vegetables/weeds as supplementary feeds to their fish twice per day. The amount provided varies from farmer to farmer. The irregular fertilization and supplementation of low quality feeds results into low production.

Weekly fertilization of fish pond has been shown to increase fish yields by increasing primary productivity through released inorganic nutrients, or by providing organic carbon through heterotrophic pathways (Knud-Hansen et al., 1991). When ponds are fertilized, nutrients stimulate the growth of phytoplankton. Phytoplankton is food for other organisms (zoo-plankton and larger animals) that are eaten by fish. However, pond fertilization with excessive amount of fertilizer can cause severe environmental issues due to high concentration of algae that lead to algal blooms and hypoxic waters. Excess nitrogen input can cause high unionized ammonia concentrations, which may reduce fish growth or cause mortality. Moreover, provision of feeds in excess of what can be taken by the fish leads to wastage of diet and diet waste means deteriorated water quality and economical losses (Ali et al., 2010). This situation often causes mass mortality of tilapia and consequently the farmers abandon fish farming. Sustainable production of tilapia largely depends on quality of water. In the broadest sense, the term water quality includes all physical, chemical, and biological characteristic of water. Pond water characteristics, physical, chemical and biological factors, interact in pond ecosystem as well as the organisms being cultured (Egna and Boyd, 1997). Maintaining proper water quality parameters is very important for survival, growth, and reproduction of aquatic organisms. Water quality in fish ponds is a major factor determining the production of fish (Egna and Boyd, 1997) and needs to be monitored.

Sustainable fish farming depends on the maintenance of healthy pond water environment and the production of sufficient fish food organisms. 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, in order to obtain maximum possible fish yield from a water body. A study done in Bangladesh (Wahab et al., 2014) indicated that proper pond fertilization 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 fertilizers 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, 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. This study was carried out to compare the effects of pond fertilization alone, concentrate feeding alone at 5% of fish biomass and a combination of fertilization and feeding at 2.5% of fish biomass on water quality parameters and growth performance and yield of Nile tilapia.

METHODOLOGY

Study location and Sampling procedure

A study was conducted at Tindiga Village, Kilosa district, Tanzania. Kilosa district is one of the seven districts of Morogoro region and it is located approximately 300 km inland from Dar es Salaam. The district has an area of 14,245 km^2 and lies between latitude 5°55' S and 7°53' S and longitude 36°30’E and 37°30'E. The district comprises mostly flat lowland and experiences an average of eight months of rainfall (October–May), with the highest levels received between March and April. The rainfall distribution is bimodal, with short rains (November – January), followed by long rains (mid-February –May). Mean annual rainfall ranges between 800 and 1,600 mm. Kilosa district is located at 2200 m above sea level and has mean annual temperature of about 25°C. The district has a total of 164 villages. Tindiga village, which is located 13 km away from Kilosa, town was purposely selected because of existence of project fish farmers. The farmers were trained by the project supported by AquaFish Innovation Lab in 2013 and following the training the farmers constructed fish ponds and started culturing Nile tilapia.

To complement the results obtained from farmer's earthen ponds, another experiment was conducted at Magadu fish farm, Sokoine University of Agriculture (SUA), Morogoro using nine concrete tanks. Sokoine University of Agriculture is located between latitude 6 - 7^{o}S and longitude 37 - 38^{o}E at an altitude of about 500 - 600 m above sea level. The area receives an average annual rainfall of between 600 and 1000 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 25^0 to 30^{0}C.

Data collection procedure

Two experiments were conducted. The first experiment was conducted using nine earthen ponds at Tindiga Village, Kilosa District, Tanzania. The size of ponds ranged from 160 to 242 m^2 with average pond size of 188.67 m^2. The treatments were three and included weekly fertilization alone with urea and Di-Ammonium Phosphate (DAP) at a rate of 3 g/m^2 and 2 g/m^2, respectively (T_1), concentrate feeding alone at 5% of fish biomass (T_2), and weekly fertilization with urea and DAP plus concentrate feeding at 2.5% of fish biomass (T_3). The treatments were assigned randomly to the fish ponds 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 ponds were drained, cleaned to remove decomposed matters, inlets and outlets were rehabilitated, 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 ponds were stocked on 14th August, 2017 with sex-reversed Nile tilapia with average weight of 1.1 g at a stocking density of 3 fingerlings per m^2. Fingerlings cultured in ponds under T_2 and T_3 were fed 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 fed twice per day at 10.00 am and 4.00 pm and the experiment took 166 days.

Fish body weights and lengths were measured at the beginning of the experiment and then after every two weeks. A random sample of 30 fish per pond, 5% of total fish in each pond, was taken for measurement of body weight and length. Weights of individual fish were measured using digital weighing scale, while body length was measured by using a ruler. Pond water pH, dissolved oxygen (DO), conductivity, total dissolved solids, salinity, and temperature were measured in each pond using Multiparameter (HI 98198 PH/EC/DO Multiparameter HANNA instrument). The water samples for measurements for these variables were collected at three depths through the water column (i.e., at the surface (10 cm from the top), middle of the water column, and just off the pond bottom). Dawn measurements were done weekly between 0600 and 0700 hours, while diel measurements were taken three times during the experimental period (i.e., at the beginning, middle, and end of the experiment). Diel measurements were taken nine times in 24 hours at an interval of 3 hours (i.e., at 0600 h, 0900 h, 1200 h, 1500 h, 1800 h, 2100 h, 2400 h, 0300 h and 0600 h). Water samples were collected in 400 ml vials for determination of nitrite (NO_2), nitrate (NO_3), ammonia (NH_3), alkalinity, and total nitrogen. In addition, more water samples were collected in 100 ml vials for determination of chlorophyll a and phosphorus. The water samples were taken weekly from five points in each pond at a depth of 15 cm from the top and mixed together to get composite samples. They were collected between 0900 and 1100 h, put in a cool box and transported to the laboratory at Sokoine University of Agriculture (SUA), where they were stored in the deep freezer until analysis at the end of the experiment. For determination of algae biomass and species composition, two nets, each with a size of 25 cm x 50 cm (1250 cm^2) and mesh size of 20 µm were installed in each pond. Algae samples were collected from each net and put in 400 ml and 5 ml vials. The vials were put in a cool box and transported to the laboratory at SUA, where they were stored in the deep freezer until analysis at the end of the experiment. Water depths were monitored daily by installing in each pond a wooden bar graduated in cm. Water depth was read from the wooden bar daily. Water evaporation rate was measured with an evaporation pan. Water turbidity was determined weekly with a secchi disc with a diameter of 20 cm.

The second experiment was conducted at SUA using nine concrete tanks, each having a surface area of 3.36 m^2. The treatments used in this experiment were the same as those used in the first experiment. The sex-reversed Nile tilapia were stocked at the same stocking rate (3 fingerlings/m^2)

and fed the same feed at the same feeding levels and frequency used in the first experiment. All fish in each tank were individually measured for body weight and length before the start of the experiment and then every two weeks thereafter. Measurement of water quality parameters followed the same protocol as that used in the first experiment.

At the end of each experiment, the following parameters were computed as shown below:
(i) Growth rate (GR)

$$GR = \frac{\text{Final weight (g)} - \text{initial weight (g)}}{\text{Time in days}} \quad (1)$$

(ii) Specific growth rate (SGR)

$$SGR = \frac{[\text{In(Final weight (g)} - \text{In(initial weight (g)]}}{\text{Time in days}} X\,100 \quad (2)$$

(iii) Feed convertion ratio (FCR)

$$FCR = \frac{\text{Total weight of food consumed(g)}}{\text{Total weight gain by fish(g)}} \quad (3)$$

(iv) Survival rate (SR)

$$SR = \frac{\text{Total number stocked-total number died}}{\text{Total number stocked}} x\,100 \quad (4)$$

(v) Annual Yield (AY)

$$AY = \frac{\text{Total weight of fish harvested x 365}}{\text{Experimental period in days}} \quad (5)$$

(vi) Gross margin
Gross margin (GM) analysis was used to determine profitability of fish culture in each treatment and was calculated as

$$GM = \text{Total revenue from fish sold fish} - \text{Total variable costs} \quad (6)$$

Statistical analysis
Data generated on growth performance parameters (GR, SGR, FCR and yield) and water quality parameters (pH, Temperature, DO, Total Dissolved Solids (TDS), Salinity, turbidity) were analyzed using R Studio software version 3.4.4. Analysis of variance was done in a completely randomized design and the effect of treatment was tested using the F test. Tukey's test was used to determine the significance of the differences between a pair of treatment means.

RESULTS

Water quality parameters in earthen ponds and concrete tanks subject to three treatments
Table 1 shows mean ± se of water quality parameters (pH, DO, temperature, conductivity, TDS, salinity and turbidity (secchi disk reading)) in earthen ponds while Table 2 shows the mean ± se for the same water parameters in concrete tanks used in the experiment. In both culture system (earthen ponds and concrete tanks) treatment had significant effect on water pH, DO, conductivity, TDS and salinity but not on temperature and turbidity. Ponds under fertilization alone (T_1) and fertilization plus feeding (T_3) had higher ($p \leq 0.001$) water pH than those under the treatment of concentrate feeding alone (T_2). Ponds under T_1 had higher ($p \leq 0.001$) DO values than those under T_2 and T_3, but there was no significant difference between the DO values in ponds under T_2 and T_3. On the other hand ponds subjected T_2 had higher ($p \leq 0.001$) conductivity, TDS and salinity than those under T_1 and T_2. For concrete tank system, tanks under T_1 had significantly higher pH and DO than those under T_2 and T_3. Moreover, tanks under T_3 had significantly higher pH and DO compared to those on T_2. For

conductivity and TDS, the values obtained in tanks under T_1 and T_2 did not differ significantly but were significantly different from the values obtained in tanks under T_3. Salinity and temperature values did not differ significantly among the treatments.

Table 3 shows mean (± se) of diel water quality parameters in pond water under the three treatments. The results show that treatment had significant effects on water pH, DO and conductivity. Water pH in ponds under fertilization alone (T_1) differed significantly from that obtained in ponds under feeding alone (T_2), but was not significantly different from that obtained in ponds under a combination of fertilization and feeding (T_3). Similarly, the pH values in ponds under T_2 were not significantly different from that in ponds under T_3. The DO values differed significantly among the treatments. Ponds under T_1 showed the highest while those on T_2 had the lowest DO values. Water in ponds under T_2 showed higher conductivity values than that in ponds under T_3, which, in turn, had higher conductivity values than that in ponds under T_1. The mean values for water salinity, TDS and temperature did not differ among the treatments.

The diel measurements for water quality parameters in concrete tanks are shown in Table 4. The results show that treatment significantly affected water pH, DO, conductivity and TDS but not salinity, and temperature. Water in tanks under T_1 had higher pH values than that in tanks under T_2 and T_3, but water pH values in T_2 and T_3 were not significantly different. The water DO value in tanks under T_1 was significantly higher than that in tanks under T_3, which in turn was higher than that in tanks under T_2.

Figure 1 and Figure 2 show the mean DO values for a period of 24 hours in pond water and concrete tank water, respectively. In both ponds and concrete tanks, the highest DO values were observed under T_1 while the lowest values were found under T_2. Also in both systems, the highest DO values were obtained at 1500 hours while the lowest values were observed between midnight and 0600 hours. With regard to temperature, the highest values were obtained at 1500 hours while the lowest values were observed from 0300 hours to 0600 hours (Figure 3 and Figure 4). Figure 5 and Figure 6 show the mean pH values for a period of 24 hours in both earthen ponds and concrete tanks. In both systems, like for ponds, the highest DO values were observed under T_1 while the lowest values were found under T_2. Similarly, peak pH values were observed at 1500 hours while the lowest values were observed from 0300 to 0600 hours. It seems that DO, pH and temperature values followed the same pattern, i.e. they were lowest at 0600 hours, start to increase at 0900 hours and reached the peak at 1500 hours and then started to decrease and reached the lowest values at 0300 hours.

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

	Treatment			
Water variable	**Fertilization alone**	**Feeding alone**	**Fertilization and feeding**	***p*-Value**
pH	$8.23{\pm}0.02^{a}$	$8.08{\pm}0.02^{b}$	$8.20{\pm}0.02^{a}$	4.909e-07
DO(mg/L)	$4.43{\pm}0.11^{a}$	$3.88{\pm}0.09^{b}$	$4.03{\pm}0.11d^{b}$	0.0007
Conductivity(µS/cm)	$1324{\pm}9^{b}$	$1363{\pm}8^{a}$	$1343{\pm}9^{ab}$	0.0051
TDS	$662{\pm}4^{b}$	$681{\pm}4^{a}$	$672{\pm}4^{ab}$	0.0052
Salinity(PSU)	$0.66{\pm}0.0^{c}$	$0.68{\pm}0.0^{a}$	$0.67{\pm}0.0^{b}$	0.0072
Temp (^{O}C)	$25.20{\pm}0.09^{a}$	$25.24{\pm}0.09^{a}$	$25.30{\pm}0.08^{a}$	0.6918
Water depth(cm)	$31.5{\pm}0.2^{c}$	$34.8{\pm}0.3^{a}$	$33.5{\pm}0.2^{b}$	2.2e-16
Secchi disk (cm)	$25.7{\pm}0.7^{a}$	$25.7{\pm}0.7^{a}$	$24.3{\pm}0.7^{a}$	0.2848

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.001$.

Table 2: Comparison of water quality parameters in concrete tanks subjected to three different treatments

Water variable	Treatment T1	Treatment T2	Treatment T3	p-Value
pH	8.35±0.05[a]	7.54±0.06[c]	7.76±0.05[b]	2.2e-16
DO(mg/L)	9.97±0.21[a]	6.51±0.20[c]	7.84±0.20[b]	2.2e-16
Conductivity(µS/cm)	81±1[a]	79±1[a]	76±1[b]	0.0001
TDS	41±0[a]	40±1[a]	38±1[b]	1.949e-05
Salinity(PSU)	0.04±0.0[a]	0.04±0.0[a]	0.03±0.0[b]	0.0004
Temp (^{O}C)	27.53±0.11[b]	27.61±0.10[ab]	27.82±1.10[a]	0.1037

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.001$.

Table 3: Diel water quality parameters of pond water under three different treatments

Water variable	Treatment T1	Treatment T2	Treatment T3	*p*-Value
pH	8.82±0.08[a]	8.54±0.04[b]	8.68±0.06[ab]	0.0075
DO(mg/L)	6.77±0.22[a]	5.14±0.18[c]	6.05±0.23[b]	6.785e-07
Conductivity(µS/cm)	1323±7[c]	1409±4[a]	1350±7[b]	2.2e-16
TDS	662±4[a]	704±2[a]	713±36[a]	0.1867
Salinity (PSU)	0.65±0.0[a]	0.70±0.0[a]	0.71±0.0.04[a]	0.2376
Temp(^{O}C)	30.17±0.31[a]	30.22±0.27[a]	29.99±0.25[a]	0.8191

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.001$.

Table 4: Diel water quality parameters in concrete tanks under three different treatments

Water variable	Treatment T1	Treatment T2	Treatment T3	p-Value
pH	9.61±0.06[a]	8.30±0.05[b]	8.38±.06[b]	2.2e-16
DO(mg/L)	8.37±0.12[a]	4.87±0.15[c]	5.39±0.18[b]	2.2e-16
Conductivity(µS/cm)	53±1[c]	70±1[a]	64±1[b]	2.2e-16
TDS	26±0[c]	35±1[a]	33±1[b]	2.2e-16
Salinity (PSU)	0.02±0.0[b]	0.03±0.0[a]	0.03±0.0[a]	5.736e-06
Temp(^{O}C)	26.72±0.11[b]	27.06±0.11[a]	27.08±0.11[a]	0.0263

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.001$.

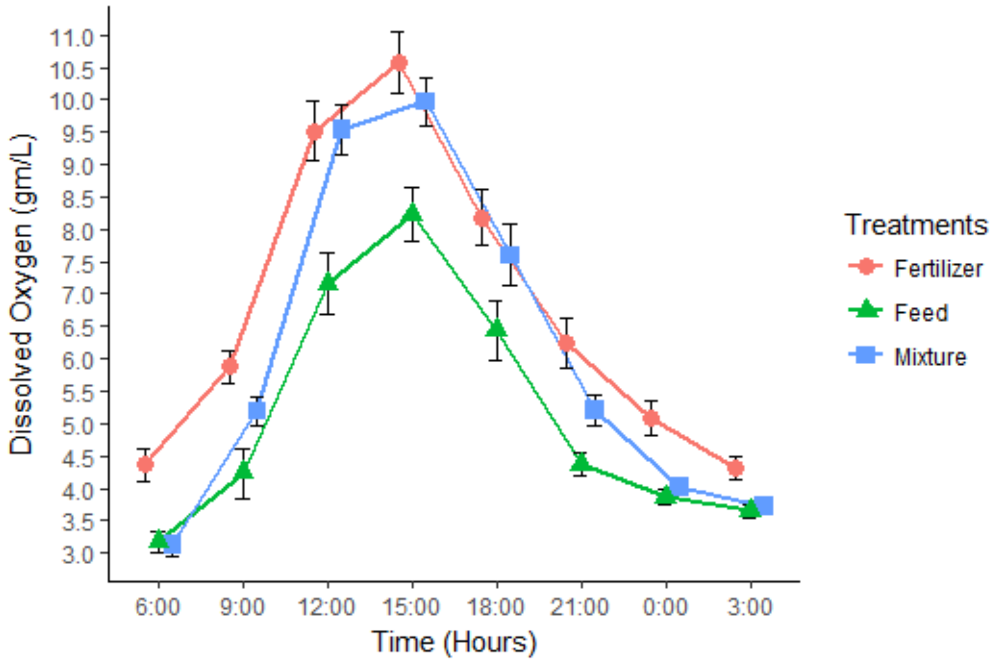

Figure 1: Diel mean DO values in pond water under the three different treatments

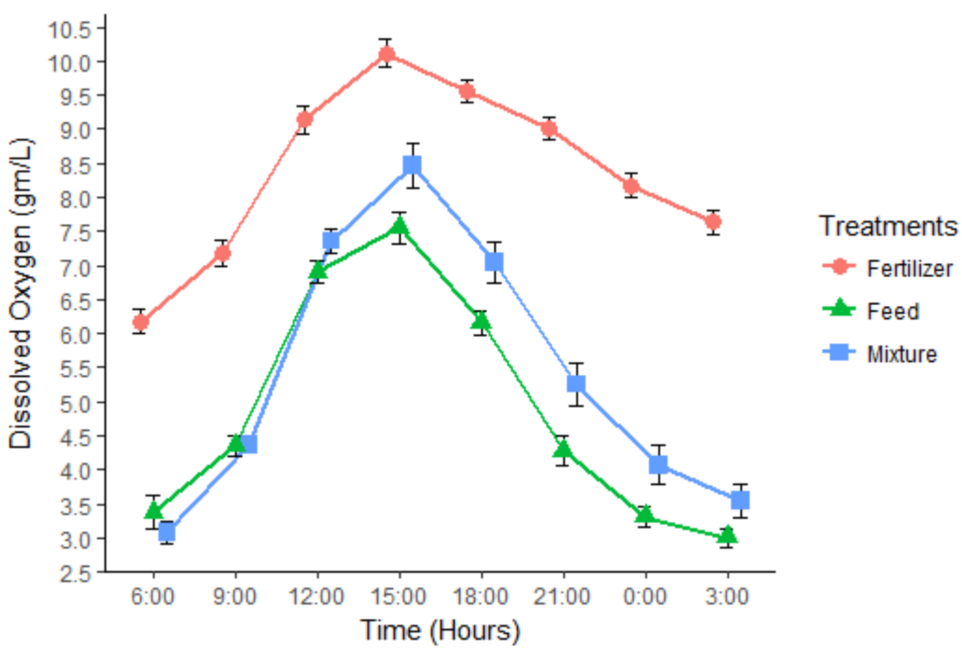

Figure 2: Diel mean DO values in concrete tanks under the three different treatments

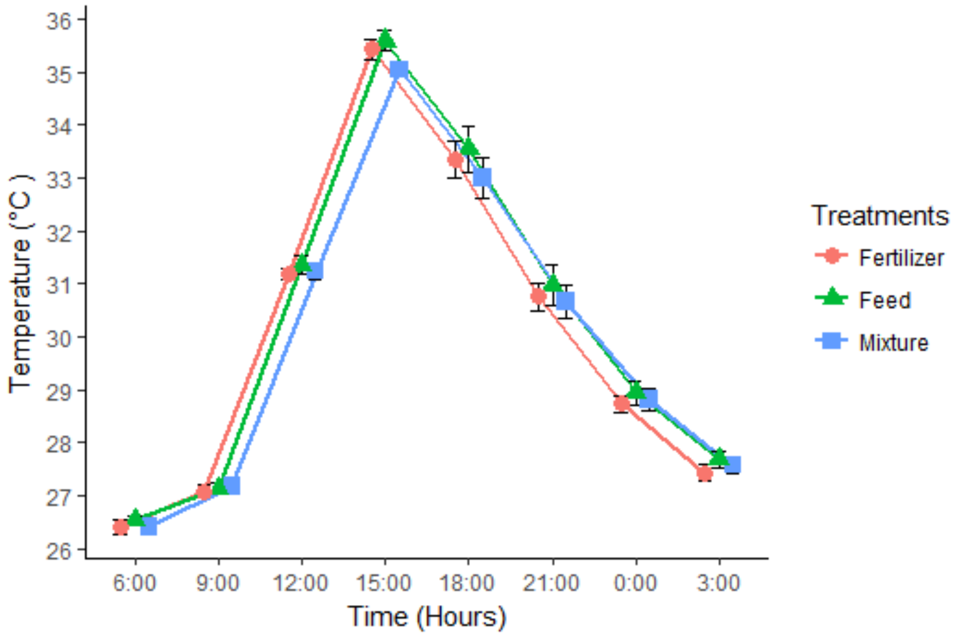

Figure 3: Diel mean water temperature in ponds under three different treatments

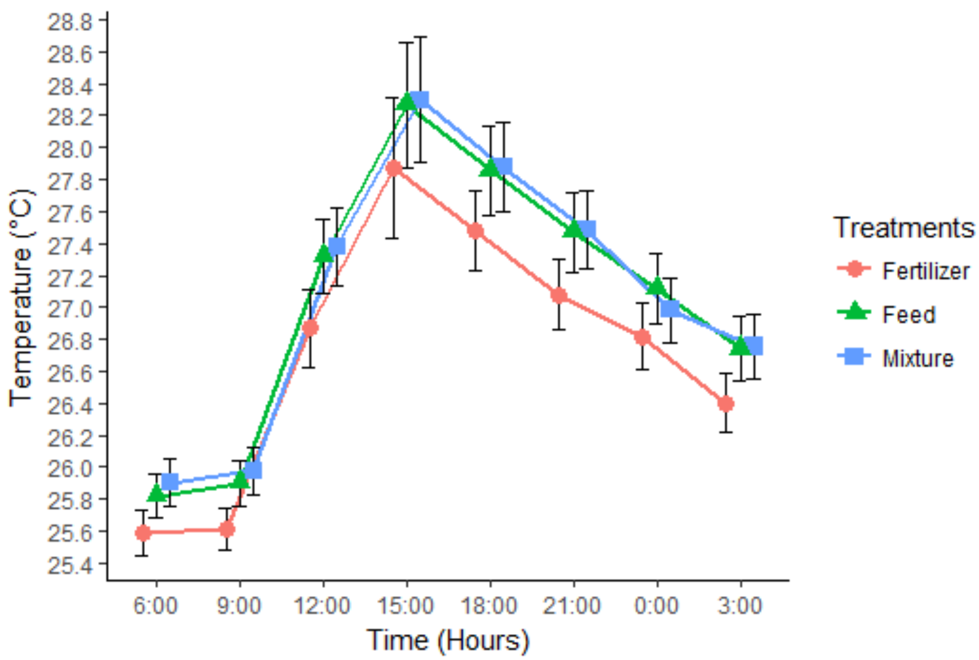

Figure 4: Diel mean water temperature in concrete tanks under three different treatments

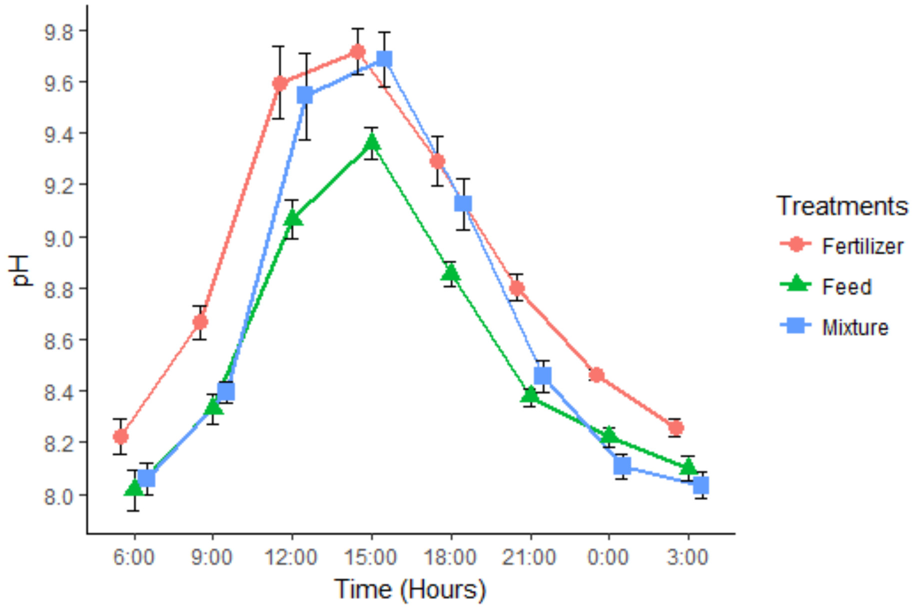

Figure 5: Diel mean water pH in ponds under three different treatments

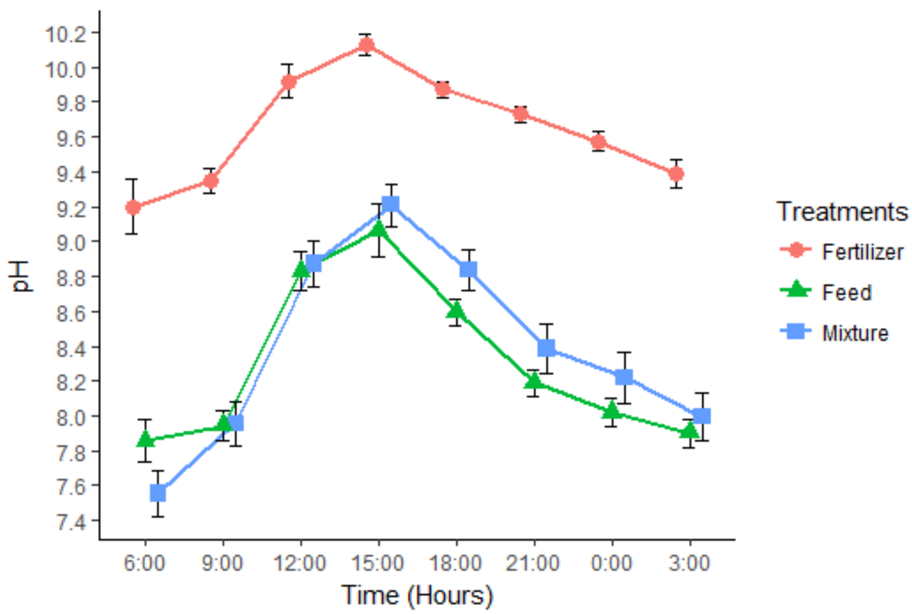

Figure 6: Diel mean water pH in concrete tanks under three different treatments

Growth performances of Nile tilapia (O. niloticus) cultured in earthen ponds and concrete tanks under three treatments

Table 5 and Table 6 show the growth performance, feed conversion ratio and survival of Nile tilapia (*O. niloticus*) culture in ponds and concrete tanks, respectively, under three treatments (fertilization alone (T_1), feeding alone (T_2) and a combination of fertilization and feeding (T_3)). In both earthen ponds and concrete tanks, treatment had significant effects on final body weight, weight gain, growth rate, specific growth rate and feed conversion ratio (FCR), but did not significantly affect survival rate. The results shown in Table 5 indicate fish culture in earthen ponds under T_1 had significantly lower final body weight, weight gain, growth rate and specific growth rate than those cultured in ponds under T_2 and T_3. Fish culture in ponds under T_2 on average gained 95.4 g while those on T_3

gained 128.4 g more weight than those on T_1. On the other hand the mean final body weight, weight gain, growth rate and specific growth rate of fish on T_3 were significantly higher than of those on T_2. The body weight gain and growth rate of fish reared in ponds under T_3 exceeded those of fish reared in ponds under T_2 by 33 g and 0.2 g/day, 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. Survival rate of fish did not differ ($p > 0.05$) among the treatments and ranged from 89.6 to 90.0% in ponds under T_2 and T_1, respectively. Like under pond system, fish cultured in concrete tanks under T_1 had significantly lower final body weight gain, weight gain, growth rate and specific growth rate than those reared in concrete tanks under T_2 and T_3. Fish reared in concrete tanks under T_3 had higher final body weight gain, weight gain, growth rate and specific growth rate and lower feed conversion ratio than those under T_2. The growth performance of fish for the whole experimental period are shown in Figure 7 for earthen ponds and Figure 8 for concrete tanks. In both systems, fish culture under T_3 showed the highest performance, followed by those under T_2. The fish reared under T_1 had the lowest growth performance. When comparison is made between earthen ponds and concrete tanks, it can be seen that fish under T_1 gained more weight in ponds than in concrete tanks while those reared under T_2 and T_3 gained more weight in concrete tanks than in earthen ponds.

The results for economic analysis are shown in Table 7 for fish reared in earthen ponds under the three treatments. Among the variable costs, fingerling costs did not differ ($p > 0.05$) among the treatments while labour and feed costs differed significantly among the treatments. Ponds under T_3 had the highest labour costs, while those under T_1 had the lowest. The highest feed cost was observed under T_2. Feed cost accounted for 60.03% and 40.85% of total variable costs in treatment T_2 and T_3, respectively. Fertilizer cost did not differ ($p > 0.05$) between the ponds under T_1 and T_3, mainly because the same amount of fertilizer was used in the two treatments. Treatment influenced significantly the yield, revenue and gross margin. Fish reared in ponds under T_3 resulted into significantly higher yield, revenue, and profit than those cultured under T_2 and T_1. Fish reared under T_2 had higher yield and revenue than those under T_1. However, fish reared under T_1 resulted into profit while those under T_2 resulted into a loss mainly because of the higher feed cost.

Table 5: Comparison of growth performance of Nile tilapia (*O. niloticus*) cultured in ponds under three different treatments

	Treatment			
Growth variable	**T1**	**T2**	**T3**	***p*- Value**
Initial body weight (g)	1.3 ± 0.1^{a}	1.0 ± 0.1^{b}	0.9 ± 0.0^{b}	0.003
Final body weight (g)	66.7 ± 1.1^{c}	161.8 ± 3.6^{b}	194.8 ± 4.5^{a}	0.000
Weight gain (g)	65.4 ± 1.1^{e}	160.8 ± 3.6^{b}	193.8 ± 4.5^{a}	0.000
Growth rate (g/day)	0.4 ± 0.0^{e}	1.0 ± 0.0^{b}	1.2 ± 0.0^{a}	0.000
Specific growth rate (%)	2.5 ± 0.0^{c}	3.1 ± 0.0^{b}	3.3 ± 0.0^{a}	0.000
Survival (%)	90.0 ± 0.0^{a}	89.6 ± 0.2^{a}	89.7 ± 0.4^{a}	0.4672
FCR	-	4.1 ± 0.3^{a}	2.0 ± 0.1^{b}	0.0085

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.001$.

Table 6: Comparison of growth performance of Nile tilapia (*O. niloticus*) cultured in concrete tanks under three different treatments

	Treatment			
Growth variable	**T1**	**T2**	**T3**	***p*- Value**
Initial body weight (g)	1.5 ± 0.1^{a}	1.0 ± 0.1^{b}	1.4 ± 0.1^{a}	0.0011
Final body weight (g)	42.3 ± 2.8^{c}	230.0 ± 7.5^{b}	257.6 ± 4.5^{a}	0.000
Weight gain (g)	40.9 ± 2.8^{c}	229.0 ± 7.5^{b}	256.2 ± 4.5^{a}	0.000
Growth rate (g/day)	0.2 ± 0.0^{c}	1.4 ± 0.0^{b}	1.6 ± 0.0^{a}	0.000
Specific growth rate (%)	2.0 ± 0.1^{c}	3.3 ± 0.1^{a}	3.2 ± 0.1^{b}	0.000
Survival (%)	90 ± 0.0^{a}	87.7 ± 2.3^{a}	90 ± 0.0^{a}	0.4219
FCR		3.3 ± 0.2^{a}	1.5 ± 0.0^{b}	0.0016

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.001$.

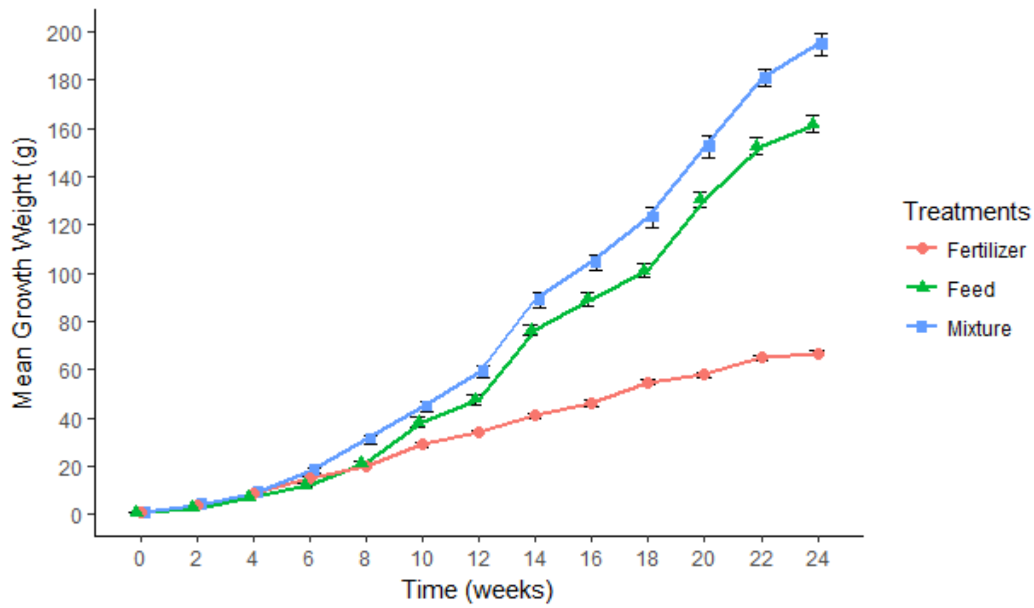

Figure 7: Comparison of growth performance of *O. niloticus* cultured in earthen ponds under three different treatments

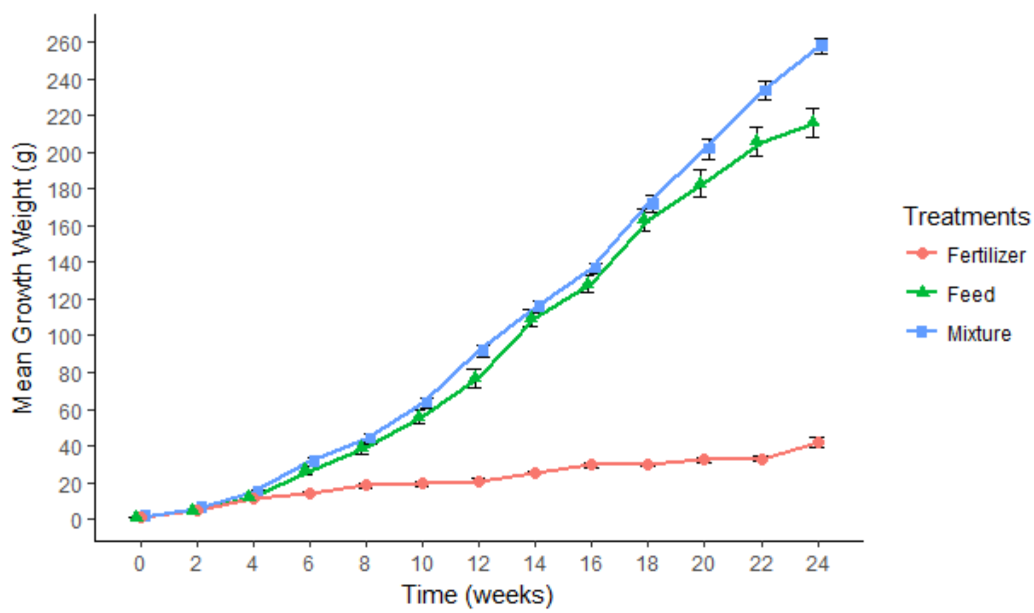

Figure 8: Comparison of growth performance of *O. niloticus* cultured in concrete tanks under three different treatments

Table 7: Comparison of variable costs, revenue and profit obtained from *O.niloticus* cultured in earthen ponds under three different treatments.

VARIABLE	**Treatment**			***p*-Value**
Variable costs (TZS /ha/Year)	**T1**	**T2**	**T3**	
Fingerling Cost	22,958,144±601,234[a]	22,198,993±1,009,160[a]	22,484,390±1,364,821[a]	0.8383
Labour cost	1,654,749±48,483[b]	14,279,749±6,009,183[ab]	23,992,930±143,720[a]	0.0337
Fertilizer cost	208,187±4,096[a]	-	202,498±4,554[a]	0.4319
Feed cost	-	54,796,586±5,683,682[a]	32,233,886±572,883[b]	0.0446
Total cost	24,821,080±560,314[b]	91,275,328±12,580,773[a]	78,913,704±652,772[b]	0.0046
Algae Dry matter(g)	34.6±0.8[a]	36.0±1.0[a]	36.0±1.1[a]	0.5028
Productivity				
Yield (kg/ha/year)	4,602±376[b]	10,720±962[a]	13,065±458[a]	0.0010
Total revenue(TZS/ha/year)	36,820,392±3,008,558[b]	85,763,684±7,696,247[a]	104,514,517±3,659,779[a]	0.0010
Gross margin	11,999,312±2,588,720[ab]	(5,511,645)±8,013,280[b]	25,600,813±3,007,007[a]	0.0373

Note: Means with the same superscript letter in the same row do not differ while those with different superscript differ significantly at $P \leq 0.05$.

CONCLUSION

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

i. Combination of weekly fertilization of ponds and concentre 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 ponds and concentre feeding at 2.5% of fish biomass does not affect water quality parameters beyond the range recommend for tilapia growth.
iii. Water quality parameters (pH, DO, salinity and temperature) in ponds are lowest at 0300 - 0600 hours and attain peak value at 1500 hours.

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