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Pond water fertilization effects on the performance of Oreochromis niloticus in different culture systems in Meru County

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Abstract
Background: Information on pond water fertilization is important as it gives among others, productivity of various types of culture systems. Different pond water fertilization rates and physicochemical parameters were investigated in liner, earthen and concrete ponds in Meru County Kenya over a period of 3 months, August to November 2015. The aim of the study was to find out the effects of different rates of pond water fertilization on the production of O. niloticus in different culture systems.
***Materials and Methods**: Twelve fish ponds of size $2m^2$ were constructed in a randomized design, 4 of each and stocked with 8 niloticus monosex fingerlings each weighing 20gm sourced randomly from a hatchery in the county. Weight gain and total production was measured every 30 days for 90 days. ANOVA was used to analyze the data.*
***Results**: Results revealed that, concrete culture system produced the highest mean weight gain of 11.21 ± 3.27 gms, earthen 7.67 ± 1.36 gms and liner 6.41 ± 4.88 gms with 4 gms DAP, showing a significance difference in mean weight gain (F = 20.07, df = 2, P = 0.002).*
***Conclusion:**The study concludes that, different pond water fertilization rates strongly influences the growth performance of O.niloticus in different culture systems.*
***Key Word**: Fertilization, culture system, weight gain, monosex, O. niloticus.*

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I. Introduction

Globally, fish provides more than one billion people with a cheap source of daily animal protein [27]. More than 250 million people globally depend directly on fisheries and aquaculture for their livelihoods and millions are employed in the sector in roles such as processing or marketing. Fish is the primary source of nutrition being an affordable animal source of protein in some of the poorest countries, creating growing demand for this staple. However, fish supplies are failing to meet demand and there are major shortages in some developing countries where they are needed most [11, 27]

Generally, fish is food, controls diseases, is a source of income and employment [13]. Fish is an important source of essential nutrients and micro - nutrients, omega - 3s fatty acids, cognitive to physical and mental health development in human beings [18, 11]. According to [27], fish consumption is associated with a lower risk of fatal and coronary heart diseases, reduces risk of Alzheimer's brain disease, decreases symptoms of depression, improves quality of brain , vision and eye health among others . Fish is usually high in unsaturated fats, rich in vitamin D and provides health benefits in protection against cardiovascular diseases [27]. In addition fish is very rich in iodine and selenium minerals which are very essential for proper functioning of thyroid gland and thyroid hormone biosynthesis and metabolism. The two minerals are at times difficult to obtain in sufficient quantities from other foods (National Centre for Biotechnology Information, U.S. National Library of Medicine). Additionally, fish has more than twelve by - products which among them include leather, fish oil, fish meal, fish manure, fish glue, isinglass, gunny powder and surgical threads among others [20]. Larvivorous fish, Panchax, Gambusia,Trichogaster and Haplochitus which consume mosquito larva, assist in controlling diseases in the environment like yellow fever, malaria and other dangerous diseases that are spread by mosquitoes [13].

The amount of fish being captured in the wild globally leveled out from the 1990s and the State of World Fisheries and Aquaculture reports that 90.9 million tonnes of fish was captured globally in the wild in

2016 — a reduction of 2 million tonnes from the year before. In Africa, aquaculture production has stagnated at about 430,000 tonnes same period [15]

Oreochromis niloticus has for many decades been responsible for the global tilapia production from freshwater aquaculture and it accounts for about 83 % of total tilapia produced worldwide [13]. It is the most preferred strain of tilapia due to its high feed conversion ratio (FCR), superior taste, big size for filleting, high demand and therefore is the widely grown farmed fish [6], compared to other species. However, aquaculture's growth has slowed leveling out to 5.8 percent annual growth between 2010 and 2016, down from 10 percent in the 1980s and 1990s [13].

Despite the government of Kenya promoting aquaculture (fish farming) especially from 2009 to 2013 through the introduction of the famous Economic Stimulus Fish Farming Enterprise Programme, fish production still remains low in the country [21]. Fish catch from Lake Victoria has been declining over time due to overfishing, ineffective management practices, hyacinth invasion, industrial and agricultural pollution [13]. In the lake, annual fish catch landed in 2006 was 143,900 tonnes declining to less than 108,000 tonnes in 2016 and the decline has been going on over time [13]. Kenyan Indian Ocean fisheries isunderexploited landing less than 9,000 tonnes annually [12]. The very poor often rely on fishing as a primary source of income. These small-scale fishers are particularly vulnerable as fish stocks diminish. Increased productivity from sustainable aquaculture can be a driver for rural development by mitigating risks to livelihoods and contributing to income generation and employment. Demand for fish and fisheries products has been increasing with increase in population, hence the government's effort to increase fish production through aquaculture [21].

A sustainable approach to aquaculture will help to protect our natural resources and ensure that fish stocks are available for future generations. Currently Aquaculture, in particular, has tremendous potential to enhance food security and be environmentally sustainable. Small-scale aquaculture is especially important for meeting the world’s growing demand for fish. As fish require a smaller environmental footprint than other animal source food, aquaculture is a more environmentally sustainable option for meeting the world’s food needs than other animal source foods [13].

According to [14], in Kenya tilapia farming was promoted as a family subsistence activity but this did not create sufficient incentives for fish farmers to commercialize their aquaculture activities. Tilapia farming in Kenya ranges from a rural subsistence extensive, low input practice, non-commercial and household consumption to largely limited semi- commercial production [17]. Many fish farmers have continued to raise fish in different culture systems utilizing various inputs; commercial fish pellets, Diammonium phosphate and lime whose information on their effects in fish production in different culture systems is limited. The current study therefore aims to address the gaps in low tilapia production by examining the effects of pond water fertilization on the performance of Oreochromis niloticus in different culture systems in Meru County, Kenya.

II. Material And Methods

2.1 Experimental design

The study was carried out in Meru County, Kenya (Meru fisheries office compound) which is in the eastern side of Mt Kenya, straddling the equator within 0^o 6’ North and about 0^o 1’ South, and latitudes 37^o West and 38^o East.

A randomized block experimental design was set up. Twelve (12) outdoor fish ponds, each 2 square metres with a depth of 1 metre, were constructed at the study site (4 earthen, 4 liner and 4 concrete). The first set of 3 ponds were filled with water and treated with 2 gms DAP, 2^{nd} set 4 gms DAP and the final set 6 gms DAP (earthen, liner and concrete) and a control for each treatment. The 12 ponds were then given two weeks reaction time before stocking. Each pond was stocked with 8 O.niloticus fingerlings (a stocking density of 4 fish per square metre) each weighing about 20 gms, all male (hand sexed) from a hatchery in the county. The first set of fish was fed at 1 % body weight (2 gms) for each type of culture system, the second 2 % (4 gms) and the third 3 % (6 gms) daily at 1000 and 1600 hours with a commercial fish feed 26 % crude protein. Weight of fish was measured every 30 days and total production at the end of the 90 day period.

2.2 Water quality monitoring

Water temperature in every pond was measured using a temperature sensor of the pH probe (Type SenTix 41 – 3) of a multiline meter (WTW, Weilheim-Germany). The probe was immersed in water to a depth of 30 cm allowed to stabilize and the readings made and recorded in degrees Celsius (^oC).

Water pH readings were taken (three times a week) during the study period. They were taken in all the ponds. Dissolved oxygen level was measured using an oxygen probe (Type Cello X 325) WTW, Germany. The probe was immersed in water and water was stirred with the probe, the readings were allowed to stabilize at (24 ^0C, 10 mgl^{-1}) and the readings recorded. The reading was taken at a depth of 30 cm while stirring.

2.3 Fish sampling

After every 30 days, fish were removed from each pond using a sein net, placed in a bucket of water and each fish weighed individually using an electrical weighing balance (two decimal places). The fish were returned to their respective ponds after measurements. Growth performance of fish was evaluated using weight gain (W_t) of fish during the 90 days period of the experiment, (W_0) was weight of fish at stocking. W_{t1} = weight gain of fish after 30 days, W_{t2} 60 days and W_{t3} 90 days. There was no mortality witnessed in the experiment.

Weight gain = $W_t - W_0$

Total production = $W_{0} + W_{t1} + W_{t2} + W_{t3}$

Net yield = Total weight of fish after 90 days – Total weight of the fish at stocking

2.4 Data analysis

Data was analyzed using descriptive and inferential statistics using GENSTAT statistical package. Analysis of variance (ANOVA) was used to find out the significant differences in the mean weight gain of fish among the culture systems under the various treatments. Means were separated using Turkey's HSD multiple range statistical method. Significance level was tested at $P \leq 0.05$

III. Results

Growth performance of O. niloticus on varied quantities of inorganic fertilizer (DAP)

Growth performance of fish on fertilizing water with 2 gms DAP

Growth performance of Oreochromis niloticus in the three different culture systems when fed on different amounts of pellets and pond water fertilized with 2 gms DAP showed variations during the study period (Table 1). In liner culture system, the mean weight gained varied form 4.84 gms (30th day) to 6.13 gms (90th day). The total weight gain was 19.29 gms while the mean weight gain was 6.43 ± 1.74. In earthen pond, weight gain varied from 4.50 gms (30th day) to 7.24 gms (90th day). Total weight gain was 18.99 gms while mean weight gain was 6.33 ± 1.58. In concrete pond, weight gain varied from 7.55 gms (30th day) to 7.75 gms, total weight gain was 22.85 gms and mean weight gain was 7.62 ± 0.12. Highest total weight gain was 22.85 gms in concrete ponds and the lowest was in earthen culture system 18.99 gms (Figure 1). In concrete pond, flattening of the graph started at day 30, in earthen it flattened at day 60. While in liner, the graph declined drastically after the 60th day. Using one-way Analysis of Variance, the results showed that fish weight gain was not significantly different between the culture systems, ($F = 0.83$, df = 2, $P = 0.479$).

Table no.1: Fish weight gain in (gms) in different cultured ponds on fertilizing pond water with different amounts of DAP

Treatment (DAP gms)	culture system	30 days	60 days	90 days	Total weight	Mean weight (MW) gain ±SD
2gms	Liner	4.85	8.29	6.15	19.29	6.43 ± 1.74^{a}
	Earthen	4.50	7.25	7.24	18.99	6.33 ± 1.58^{a}
	Concrete	7.55	7.75	7.55	22.85	7.62 ± 0.12^{a}
						p = 0.479
4gms	Liner	1.00	1.75	1.80	4.55	1.52 ± 0.45^{a}
	Earthen	6.58	8.17	8.16	22.91	7.64 ± 0.92^{b}
	Concrete	11.67	18.70	11.67	42.04	14.01 ± 4.06^{c}
						p = 0.002
6gms	Liner	7.10	13.40	13.33	33.83	11.28 ± 3.61^{c}
	Earthen	7.83	9.67	9.66	27.16	9.05 ± 1.06^{c}
	Concrete	12.00	12.03	12.00	36.03	12.01 ± 0.02^{c}
						p = 0.296

Values are expressed as mean ± SE. Values in the same column having different superscript letters are significantly different ($p < 0.05$). Wg = Weight gain, Tw = Total weight gain and Mw = Mean weight gain ±SD.

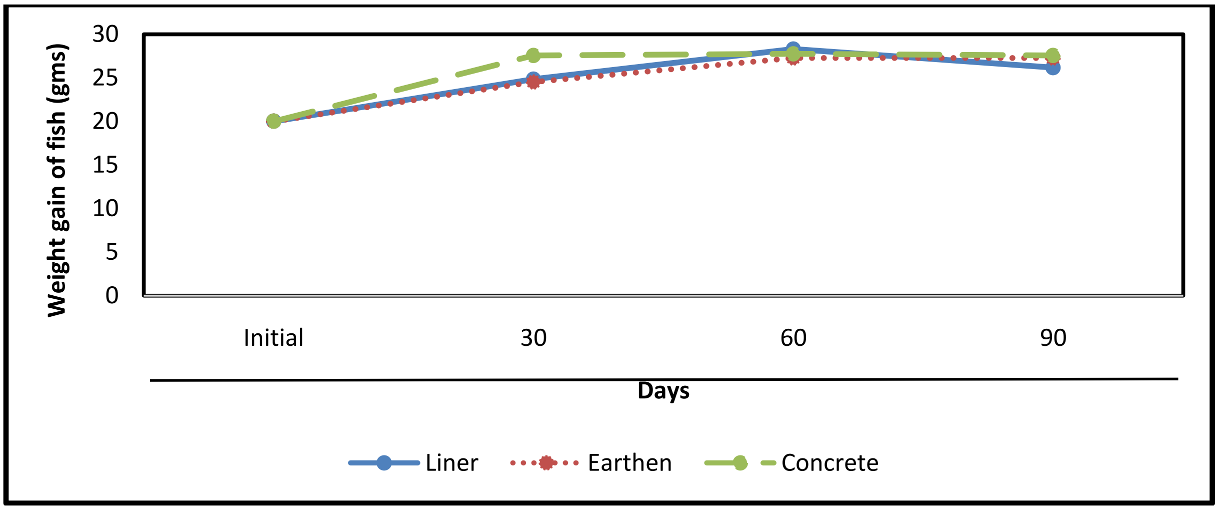

Figure no.1: Fish mean weight gain in grams when pond water was fertilized with 2 gms DAP in the three culture systems during the study period (August 2015 to November 2015).

Performance of fish on fertilizing pond water with 4 gms DAP

The study showed that on fertilizing pond water with 4 gms DAP and feeding the fish with 4 gms pellets, growth performance of fish in the different ponds varied. In liner culture system weight gain varied from 1.00 gms (30th day) to 1.80 gms (90th day). Total weight gain was 4.55 gms while the mean weight gain was 1.52 ± 0.45 gms (Table 1,Figure 2). In earthen pond weight gain varied from 6.58 gms (30th day) to 8.16 gms (90th day). Total weight gain was 22.91 gms while mean weight gain was 7.64 ± 0.92. In concrete pond, weight gain varied from 11.67 gms (30th day) to 18.70 gms, total weight gain was 42.04 gms and mean weight gain was 14.01 ± 4.06 (Table 1). Highest weight gain 14.01 ± 4.06 g was in concrete ponds and the lowest weight gain 1.52 ± 0.45 g was in liner culture system (Figure 2).

Growth performance of fish in concrete ponds increased steadily to day 65 after which, there was a sharp decline. In earthen ponds there was steady increase in growth performance of fish upto day 30 then gradual increase to the end of the experiment. In liner ponds, there was a low gradual growth performance of fish upto the end of the experiment (Figure 2).Using Analysis of Variance, the results revealed that there was significant difference in the growth performance between the culture systems (F = 20.07, df = 2, p = 0.002) (Table 1). Turkey's test revealed that fish growth performance in concrete culture system was significantly higher than in earthen and liner culture systems, and that the best time to harvest fish in the same system was day 60 (F = 5.844, p = 0.039, appendix 8). In liner system, the best time to harvest was on day 90 (F = 13.147, p = 0.006) where growth performance was at its peak.

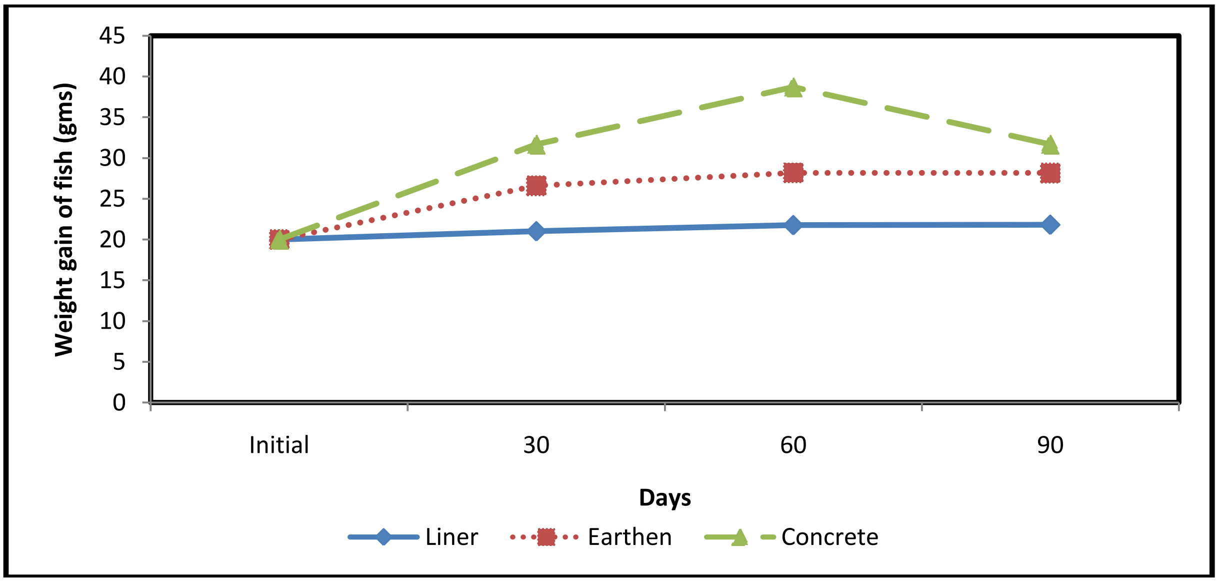

Figure no.2: Fish mean weight gain in grams when pond water was fertilized with 4 gms DAP in the three culture systems during the study period (August 2015 to November 2015).

Weight of fish on fertilizing water with 6 g DAP

The growth performance of Oreochromis niloticus when pond water was fertilized with 6 g DAP and fish fed on 6 gms of fish pellets in three different culture systems showed variations (Figure 3). In liner culture system, the mean weight gained varied form 7.10 gms (30th day) to 13.33 gms (90th day). The total weight obtained was 33.83 gms while the mean weight gain was 11.28 ± 3.61 gms (Table 1, Figure 3). In earthen pond, weight gain varied from 7.83 gms (30th day) to 9.66 gms (90th day). Total weight was 27.16 gms while mean weight gain was 9.05 ± 1.06 gms (Table 1). In concrete pond, weight gain varied from 12.00 gms (30th day) to 12.03 gms with total weight of 36.03 gms while the mean weight gain was 12.01 ± 0.02 gms (Table 1). Highest weight gain of 12.01 ± 0.02 gms was in concrete ponds and the lowest (9.05 ± 1.06) was in earthen culture system (Figure 3, Table 1). In concrete and earthen ponds, growth performance of fish increased slowly upto day 30 then flattened out. Increase in growth performance in liner ponds grew steadily from start and after day 60, the growth performance in liner was not affected, it overtook that in other culture systems. Using one way Analysis of Variance, the results showed that fish weight gain were not significantly different between the ponds, ($F = 1.50$, $df = 2$, $p = 0.300$) when pond water was treated with 6 gms DAP.

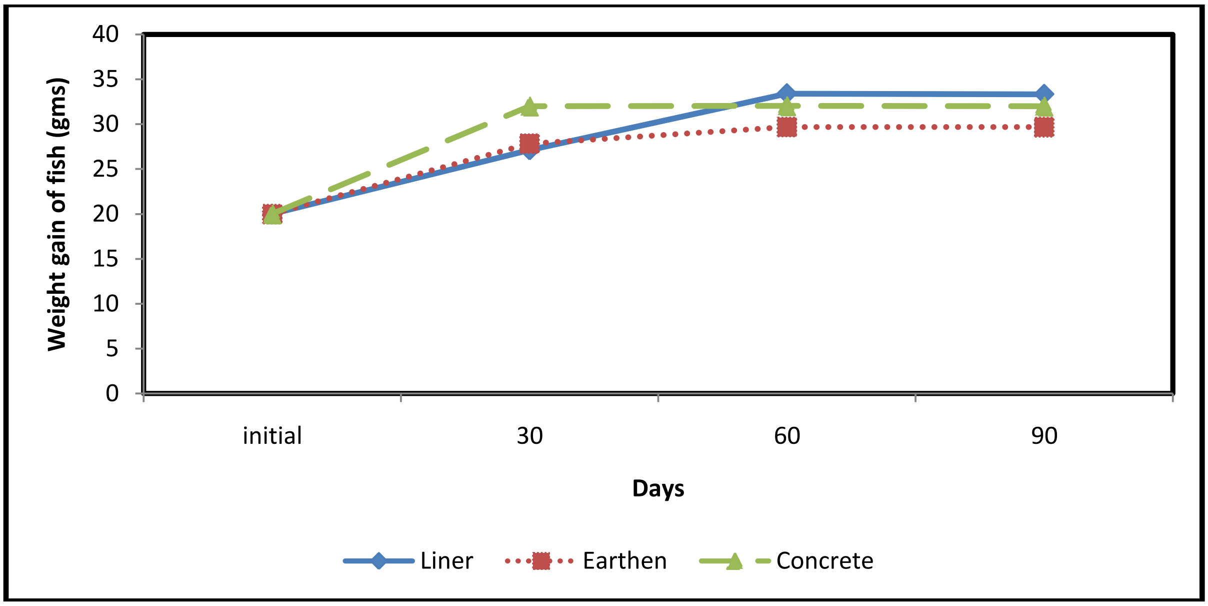

Figure no.3: Fish mean weight gain in grams when pond water was fertilized with 6 gms DAP in the three culture systems during the study period (August 2015 to November 2015).

IV. Discussion

Variations in growth performance of fish in fertilized water is brought about by increase in phytoplanktons and zooplanktons in a culture system which increase available live feed for fish in the pond leading to more fish production [8] and [24]. Live water organisms comprise of three main categories phytoplankton, nekton and benthic organisms with phytoplankton being the most important to fisheries [2]. According to [19], phytoplanktons are very vital in Pond productivity in terms of fish yields. It is the lowest trophic level in aquatic food chain in most types of water systems and therefore is utilized as food by aquatic organisms both directly and indirectly [2].

According to [1], raising the level of fertilization of culture systems increased the growth performance of GIFT (Genetically Improved Farmed Tilapia) by over 10 % and also nutrient composition in the body of the tilapia. Variations in feeding practices and frequency led to increase in fish production in Thailand, [5].

The high weight gain in concrete culture system could be attributed to good conducive conditions, higher pH, alkalinity and dissolved oxygen in concrete ponds and fertilization of the pond water. This could be attributed to the fact that concrete system had no particulate matter and food was available to the fish. After food was exhausted, weight remained stagnant. This possibly also happened in liner and earthen ponds. The weight gain in earthen pond increased steadily up to 60 days and this could be attributed to the fertilization of the pond which brought about live feeds, which increased weight and became flat after day 60 may be due to exhaustion of live feed.

However, after day 60, growth performance graph of earthen pond overtook that of liner. This couldbe attributed to the more stable natural conditions in the earthen ponds since the water is in contact with soil. In liner system, there was a steady increase of growth performance up to day 60 then a decline. The growth increase in liner could be attributed to higher temperature since the black lining is a good absorber of heat. The higher temperature in liner could have increased primary productivity resulting in increase in weight of fish. The noted decline in mean fish weight gain after day 60 in liner ponds could be attributed to the fact that, the fish possibly had stopped feeding after the artificial feeds got exhausted. Photosynthetic process could also have slowed down causing the decline. Algae previously in the liner pond water could also have been exhausted leading to the decline. In the absence of live feeds in the water, there was no continuous weight gain. This point is the best for harvesting and selling fish to avoid wastage of inputs or further weight loss of fish. Compared to other studies, mean weight of 217 grams in earthen ponds in Egypt [20] is higher than that recorded in earthen ponds of 18.99 g in the study area when Oreochromis niloticus was fed the same and ponds fertilized with 2 grams DAP. Also 134.80 g recorded in concrete ponds in Kenya [25] is higher than that recorded in concrete ponds of 22.85 g in the study area, even when ponds were treated the same and fish fed with similar feed.

According to [13] and [19] fertilizing a pond with inorganic fertilizers or manurestimulates and expands the plankton and phytoplankton population thereby increasing productivity of a pond per unit area. Report by [25] indicated a significant weight gain of fish in fertilized concrete ponds in Kenya as compared to ponds which had not been fertilized.

According to [21], fish which were reared in fertilized earthen ponds with 4 g DAP and fish fed with a commercial feed in Columbia, the fish attained a growth performance of 3,120 kg ha^{-1} ($P < 0.05$)in four months compared to a growth performance of 2,470 kg ha^{-1} in earthen ponds which were not fertilized. In Pakistan, earthen ponds which were fertilized and fish fed in a similar way, a growth performance of fish of 373.56 kg/acre/year was recorded, while in those which were not fertilized, fish attained a growth performance of 286.40 kg/acre/year [3].

The high weight gain in concrete culture system as compared to the other systems could be attributed to the fact that, since there were no suspended particles in the concrete ponds which could have hidden the food, all the food was available to the fish increasing fish growth performance. Addition of phosphorous and nitrates possibly improved mineral content of pond water contributing to good water quality leading to more multiplication of micro-organisms producing additional food for the fish hence more productivity compared to the other culture systems. There could also have been faster growth of algae in the concrete system. However after day 65, growth performance of fish in concrete pond started declining possibly due to the fact that, DAP fertilization and fish feeds had gottenfinished resulting in limited food hence dismal growth performance of fish.

Growth performance of fish in the earthen system increased moderately though less than in the concrete culture system to day 30, 60 and 90 after which the growth performance flattened out (Figure 2). Earthen system is moderately stable compared to the other systems and that's why there were no drastic changes in the system. Water in earthen pond is in direct contact with the soil, decomposition and respiration processes could have released carbon dioxide which is very vital for photosynthetic primary productivity process. Hence the slight rise in the graph of growth performance of fish in earthen pond after day 30. The leveling out points represent the best time to harvest the fish to avoid wastage of inputs. Excessively high temperatures in liner ponds could have inhibited microbial activity and fish feeding behavior causing the constantly low growth performance of fish in the system. Probably decomposition and respiration depleted dissolved oxygen in liner ponds decreasing feeding behavior of fish in the system. In liner system, growth of addition food from primary productivity is poor. Due to limited food in the liner pond, growth performance of fish was low upto the end of the experiment.

Comparing growth performance of fish at 2 gms and 4 gms DAP, earthen and concrete culture systems performed better at 4 gms DAP than at 2 gms DAP. This could be attributed to the fact that, with application of more DAP, there were more minerals (phosphates and nitrates) for increased natural productivity hence additional food for the fish. Limiting factor for good fish growth could have been phosphates. Availability of more phosphates after addition of DAP removes the limiting factor of fish growth by increasing multiplication of micro-organisms in water.Fish in liner culture system were however performing better with 2 gms of DAP (temperature was 26.07 degrees Celsius Appendix 1) than 4 gms of DAP (temperature was 27.24 degrees Celsius. The very warm temperatures in liner ponds 25.72 degrees Celsius could have made the fish inactive leading to less feeding behavior. Maina et al., (2012) recommend an optimal temperature of about 24.90 degrees Celsius for optimal fish growth.

According to [23] a growth performance of 24.93 g was recorded in fertilized earthen ponds in Sweden with 4 g DAP. The results compare well but are slightly higher than those of the current study of 22.91 in earthen ponds with 4 g fertilization rate. In concrete ponds of same size in Pakistan, a growth performance of 96.03 g was recorded when the ponds were fertilized with 4 g DAP and fish fed on a commercial diet. Their findings are higher than the production of 42.04 gms in the current study.

The use of inorganic and organic fertilizers in extensive, semi-intensive and intensive production systems greatly influences growth performance of aquatic organisms especially fish, but considerable differences exist in the type of fertilizers used, their availability, cost, and application rates [24]. According to [10], tilapia farmers in Egypt generally use a single application of sometimes DAP and urea at rates of 35 and 25 kg/ha, respectively) mostly in earthen ponds beforefish stocking. In addition, many farmers start feeding their fish about one month after stocking.

According to [7], pond fertilization increases concentrations of nitrogen, phosphorus and other plant nutrients, stimulate phytoplankton photosynthesis that is the base of the food web culminating in increased fish production. Fertilization results in two to fivefold increase in aquaculture production of all species of fish. This is due to, high phytoplankton abundance and zooplankton diversity which is achieved with fertilization [22]. According to [18] fertilized earthen ponds in Kirinyaga Kenya had a higher growth performance of fish than ponds which had not been fertilized. In Ghana, liner and concrete ponds which had been fertilized and limed recorded higher weigh gain of Oreochromis niloticus than those which had not been fertilized [9].

Pond fertilization can increase growth performance of fish by stimulating the growth of algae which are eaten by zooplanktons and insects which serve as food for fish [4]. Algae also make the water turn green, which helps to shade the pond bottom, preventing growth of troublesome rooted weeds and filamentous algae (moss or pond weeds) especially in earthen ponds [4].

The high weight gain in concrete culture system could be attributed to more productivity due to favourable alkaline conditions. The walls and bottom of the concrete pond are made of limestone which increases hardness of water leading to good water quality. The increase in nitrogen and phosphorus in the pond coupled with good water quality might have increased algae in the pond raising aquatic biomass productivity of the pond due to increased nutrient content of the system. The clearness of water in concrete pondscould also have contributed to more light penetration enhancing primary productivity process in the concrete ponds. Fish growth performance in the liner pond overtook that of concrete and earthen (Figure 3) just before day 60 and then leveled out after day 60. Possibly the limiting factor (temperature) responsible for low weight gain in fish in liner ponds previously is not present in this treatment. Presence of more nitrates, phosphorous and favourable alkalinity could have contributed to additional food for the fish hence good growth performance of fish. Absence of suspended particles in liner pond could have made all food more visible and available to the fish hence increased growth performance in the liner.

The low production in earthen ponds could be attributed to the low pH in the earthen ponds leading to less micro-organic activity hence limited food for the fish leading to low productivity in the earthen culture system. Low dissolved oxygen also might have led to less feeding activity of the fish. The leveling out of the mean weight gain after day 30 in concrete culture system could be attributed to the fact that the fertilization effect was declining faster in concrete ponds compared to the other systems.

The final mean weight of 24.82 g in earthen ponds in Kenya when fed commercial fish pellets of 26 % crude protein and pond fertilized with 6 g DAP [17] is slightly lower than the final weight (27.16 g) in the study when treated similarly. Other studies done in concrete ponds fertilized with 6 g DAP in Malawi {14] and fish fed with 26 % commercial feed, the final mean weight of 28.10 g was lower than the 36.03 g found in concrete ponds in the study when the ponds were fertilized with 6 g DAP and fish fed with similar diet

V. Conclusion

Fertilizing pond water using varying amounts of inorganic fertilizer varied. The growth performance of fish was best in concrete ponds when 4 gms of DAP was used. The mean weight gain was 14.01 gms, and total weight gain of 42.04 gms. The lowest weight gain of fish was in liner ponds with a mean weight gain of 1.52 gms and mean total weight gain of 4.55 gms. Best harvest time was after 60 days. Fertilization of pond water thus improves growth performance of fish tremendously. Fish farmers will therefore improve fish production in their culture systems by fertilizing the pond water before stocking.

Depending on the culture system and technologies being employed for aquaculture activities in a given locality, fish farmers thus have a wide range of choice of inputs and culture systems depending on their costs, to increase fish production hence incomes and improved livelihoods.

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