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Growth Performance and Yield of Nile Tilapia (*Oreochromis niloticus* (Linnaeus, 1758)) under Different Stocking Densities and Fertilization Scenarios in Earthen Pond Culture

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Abstract

This experiment was conducted to explore the effects of chemical and organic fertilizers at different levels of stocking density on the growth performance and yield of Nile Tilapia (*Oreochromis niloticus* (Linnaeus, 1758)) in earthen pond culture in southwestern Ethiopian highland located at an altitude of 1700 m above sea level. The ponds were divided into control and treatment with diammonium phosphate (DAP) and poultry manure application at three levels of stocking densities as 1, 2 and 3 fish m^{-2} in a completely randomized design. All the experimental ponds had two replicates. The fertilizers were applied to the treatment ponds at a rate of 2 g m^{-2} per week for 150 days. Juveniles with mean initial weight of 20.9 ± 0.19 g and mean initial length of 11.51 ± 0.16 cm were stocked.

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The results showed that the growth performance parameters (viz. weight gain, daily growth rate and specific growth rate) and yield of Nile Tilapia were dependent on both the stocking density and fertilizer type. The fishes stocked in the ponds treated with DAP at 1 fish m^{-2} attained the highest mean values on all the growth parameters followed by the fishes stocked in the poultry manure treated ponds at the same rate of density. In contrast, total weight gain and yield increased with an increase in stocking densities, and they were greater in the treatments with DAP than in the treatments with poultry manure at the same loading rate. Therefore, it can be concluded, from this experiment, that the most effective stocking density for Nile Tilapia earthen pond culture is at 1 fish m^{-2} for larger size fish demand while 3 fish m^{-2} gives higher gross production or yield with DAP treatment. Survival rate remained fairly similar for all levels of stocking density and fertilizer types.

Keywords: Chemical fertilizer; Diammonium phosphate (DAP); Earthen ponds; Growth performance; Nile Tilapia; Poultry manure; Yield.

1. Introduction

Aquaculture is a practice of cultivating any beneficial aquatic organisms including finfish under human controlled setting. Modern concept of aquaculture was introduced from Europe into Africa during the colonial periods [1]. The total aquaculture output of Africa is still very low compared to production from the capture fisheries. This is due to a lack of regular planning and exercises for aquaculture development in most African countries. Most of the Ethiopian fresh water capture fisheries come from the lakes, and its aquaculture sector is virtually undeveloped. Aquaculture in Ethiopia remains more potential than actual practice despite the fact that the country's physical and socio-economic conditions appear to support its development [2]. The high central plateau above 2 500 m (11 % of total area) could be appropriate for all year round farming of cold water species in the country. These areas present temperature characteristics favorable for the breeding of a large number of species, from cold water to warm water fishes. In addition, their temperature conditions are remarkably stable as compared to European so-called "temperate climates" and give a great scope for cultivating a large range of species in very good conditions. The lowlands (33 % of total area) offer ideal temperature conditions for warm water species such as tilapine, but are unfortunately water-deficient zones, with a long dry season susceptible to drought. Soils are also generally sandy and not appropriate for pond construction. However, water storage microdams could be employed for fish breeding [3]. According to [4], in Ethiopia future demand for fish would reach 117 586 tons in 2025. Positive factors which trigger the projected demands by as much as 15-20 % include the relatively low price of fish or the increasing price of its substitutes, a rise in income, and an improvement and expansion of fish distribution or supply networks and improvement in fish product quality. Those factors that retard effective demand for fish need to be addressed through education, fish consumption promotion and product development. In view of this, the present water bodies or fish supply sources are unable to meet the demand. This calls for an increased focus on stocking and enhancement of artificially made water bodies and development of aquaculture. According to [5], based on water availability, temperature, topography, soil texture, land use and cover, and economic factors, Ethiopia has an estimated 15 158 km^2 of land are highly suitable for aquaculture in earthen ponds. The popular candidate species for aquaculture in the country are Nile Tilapia (*Oreochromis niloticus* (Linnaeus, 1758)) and the African catfish (*Clarias gariepinus* (Bruchell, 1822)).

Depending on the extent of stocking density and nutrient source, aquaculture can be practiced as extensive, semi-intensive and intensive. Extensive culture practice occurs where naturally occurring microflora and fauna supply all nutritional requirements. Semi-intensive culture occurs when ponds are intentionally fertilized with chemical or organic fertilizers to stimulate natural food production, or when supplemental feed is added. Fertilization of the ponds enhances the growth of plankton as a natural feed for fish growth in the earthen pond culture. Intensive culture occurs when the entire nutritional requirement is derived from the external sources, such as complete moist pelleted feeds [6]. To get a good crop of marketable fish, it is also necessary to stock the ponds with the right number of juveniles. Stocking density could range from 0.5-3 fish m^{-2} or 5 000-30 000 fish ha^{-1} in semi-intensive culture ponds, depending on the availability of resources such as fertilizers and feeds [7]. Thus, this study was aimed at assessing the effects of applications of chemical and organic fertilizers at different levels of stocking density for best growth performance and yield of Nile Tilapia, one of the most suitable candidate species in Ethiopia, in earthen pond culture.

2. Materials and methods

2.1. Description of the experimental ponds

The study was conducted at Jimma located 350 km southwest of Ethiopian highland at an altitude of 1700 m above sea level. The experimental ponds had an area of 15 m^2 and a mean depth of 75 cm. The ponds were fitted with inlet and outlet pipes of 10-cm diameter. A screen of 2-mm mesh wire was fixed to each of the water inlet and overflow pipes to prevent the entrance of wild fish and escape of experimental fish. The pond sites were fenced with mesh and barbed wires to keep out predators (Fig. 1).

2.2. Experimental design

The experimental ponds were filled with fresh water from a nearby river, Awetu River, after being drained of their old waters. The ponds were regularly topped-up for the water lost through seepage and evaporation. Among a total of 18 ponds, six ponds that received no fertilizer served as control (T_0), and the remaining 12 ponds served as treatments. The diammonium phosphate (DAP), a chemical fertilizer, was added into the first six treatment ponds (T_1) at a rate of 2 g m^{-2} $week^{-1}$ [8]. The fertilizer was dissolved in the water from the ponds and disseminated over the same ponds. Similarly, poultry manure was added into the remaining six treatment ponds (T_2) at the same rate as for the DAP. The manure was kept in pieces of sacks and suspended in the ponds waters to prevent direct feeding by the fishes. While the nitrogen and phosphorus concentrations of DAP were referred from the manufacturer’s product description, the concentrations of these elements in the poultry manure used in the present study were determined according to the proximate method of analysis [9, 10]. The ponds were divided randomly into three stocking density groups of 1, 2 and 3 fish m^{-2}, each in two replicates. At these rates, a total of 90, 180 and 270 juvenile fishes were randomly stocked into both the treatment and control ponds in a completely randomized design. The experimental lasted for 150 days between September, 2012 and January, 2013.

2.3. Data collection

Sixty per cent of fish in each treatment was sampled randomly by using a 0.6-mm stretched mesh seine net. The total length (TL) of the fish samples was measured using a measuring board while the fish weight (W) was measured with a beam balance (Ohaus, USA) to the nearest 1 cm and 1 g, respectively. Plankton sampling was undertaken from both the control and treatment ponds monthly. The water samples were collected using a 1-liter bottle and preserved in Lugol's iodine solution for phytoplankton and in 4 % formalin solution for zooplankton. These were identified microscopically to the genus or species level following relevant keys [11, 12, 13]. Water temperature, pH and dissolved oxygen were measured in-situ using HQ40d multi-parameter digital meter (HACH, USA).

Figure 1: Some views of the study ponds

2.4. Computations of growth performance and survival rate

Growth performance and survival parameters were computed as follows [14]:

- Weight gain (W_g) (kg) = Mean final weight (kg)-Mean initial weight (kg)
- Daily growth rate (DGR) (g day^{-1}):

DGR = Weight gain (g)/Duration of the experiment (days)

- Specific growth rate (SGR) (% day^{-1}):

SGR = ((Ln Mean final weight- Ln Mean initial weight)/Duration of the experiment (days))*100, where, Ln = natural logarithm

- Total weight gain (TW_g) (kg):

$TW_g = \sum_{i=1}^{n} \text{Weight gain during the duration of the experiment} * \text{Total number of fish}$

- Yield (Y) (kg $year^{-1}$):

Y = (Weight gain during the duration of the experiment /Duration of the experiment (days))*365 days

- Survival rate (SR)%:

SR = (Number of fish stocked / Number of fish harvested)*100

2.5. Statistical analyses

Significant differences in the interaction effects between fertilization and stocking density were tested using two-way analysis of variance (ANOVA) in SPSS (version 16). Variations in the physico-chemical parameters of the pond water during the study period were tested using one-way ANOVA. All statistical tests were considered at 5 % significance level.

3. Results

3.1. Weight gain (W_g)

The mean initial weight (W) and total length (TL) ranged from 19.3±0.17 to 22.50±0.21 g and 11.25±0.13 to 11.76±0.18 cm respectively (Table 1). Statistically, there was no significant difference in the mean initial fish size among the stocking density groups for each category of the fertilization scenario ($p > 0.05$). However, the interaction effects of fertilization treatments and stocking density levels were statistically significant on the fish growth performance ($p < 0.005$). Fishes stocked in the DAP ponds (T1) at the rate of (1 fish m^{-2}) attained the highest mean final weight (66.72±1.32 g) followed by those stocked in the poultry manure ponds (T_2) (mean final weight = 51.33±1.32 g) at the same rate of stocking density. Fishes stocked at the rate of 3 fish m^{-2} generally gained the least weight while those stocked at 2 fish m^{-2} ranked between the two stocking density levels. In all cases, ponds with DAP treatment demonstrated the highest growth performance (Table 1; Fig. 2). SD = Stocking density (fish m^{-2}), T = Treatment group, TL_i = Mean initial total length (cm), TL_f = Mean final total length (cm), W_i = Mean initial weight (g), W_f = Mean final weight (g), TW_g = Total weight gain (kg), Y = Yield (kg $year^{-1}$), n(%) = mean number and percentage of fishes finally harvested per pond

Table 1: Parameters of length, weight and yield of Nile Tilapia in the control (T_0) and treatment (T_1 and T_2) ponds at the three stocking density levels during the experimental period

SD	T	TL_i ± SE	TL_f ± SE	W_i ±SE	W_f ± SE	TW_g	Y	n(%)
1	T_0	11.7±0.18	12.22±0.18	19.3±0.29	27.5±1.32	0.095	0.231	14(93.33)
	T_1	11.66±0.18	13.89±0.18	20.6±0.29	66.72±1.32	0.558	1.359	13(86.67)
	T_2	11.76±0.18	12.72±0.18	20.6±0.29	51.33±1.32	0.4096	0.997	14(93.33)
2	T_0	11.25±0.13	12.03±0.13	22.5±0.21	26.83±0.93	0.103	0.251	29(96.67)
	T_1	11.68±0.13	12.69±0.13	20.08±0.21	44.25±0.93	0.592	1.441	27(90.00)
	T_2	11.65±0.13	12.81±0.13	20.08±0.21	41.80±0.93	0.568	1.382	28(93.33)
3	T_0	11.61±0.10	12.00±0.10	19.3±0.17	25.91±0.93	0.246	0.598	43(95.56)
	T_1	11.68±0.10	12.02±0.10	20.07±0.17	36.33±0.93	0.623	1.515	42(93.33)
	T_2	11.68±0.10	12.02±0.10	20.07±0.17	35.46±0.93	0.621	1.512	43(95.56)

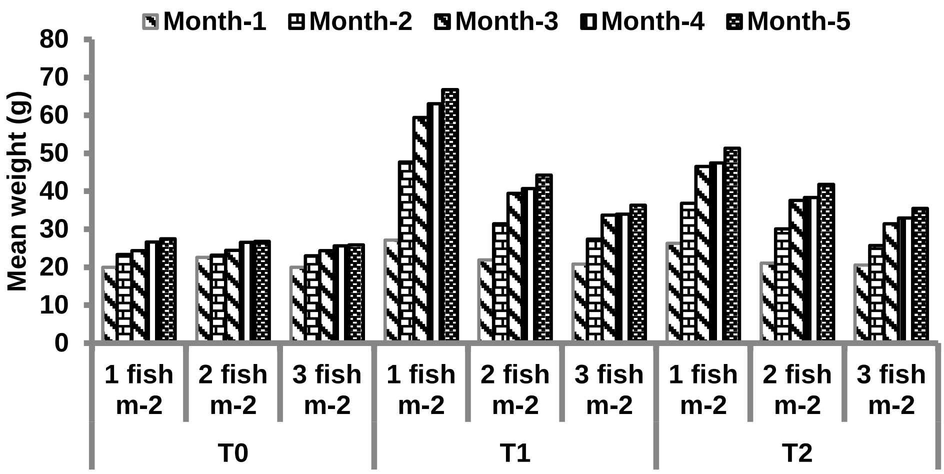

Figure 2: The change in the weight of Nile Tilapia in the control (T_0) and treatment (T_1 and T_2) ponds at the three stocking density levels during the experimental period

3.2. Daily and Specific growth rates

The mean daily growth rates (DGR) and specific growth rates (SGR) of the fishes were computed between the successive sampling months (Figs. 3 and 4). The variations in the mean DGR and mean SGR of the fishes followed similar pattern. The mean DGR and SGR of the fishes in the control ponds generally remained lower, ranging from 0.009 g day^{-1} and 0.038 % day^{-1} at 3 fish m^{-2} to 0.022 g day^{-1} and 0.103 % day^{-1} at 1 fish m^{-2}, than those grown in the fertilization treated ponds. The maximum mean DGR and SGR (0.149 g day^{-1} and 0.438 % day^{-1}) was attained in the 1 fish m^{-2} density with DAP treatment (T_1), followed by the fishes in the poultry manure treatment (0.102 g day^{-1} and 0.341 % day^{-1}) at the same rate of stocking density (T_2). These were in turn followed by the fishes stocked in the DAP treated ponds (T_1, 0.069 g day^{-1} and 0.246 % day^{-1}) and poultry manure treated ponds (T_2, 0.059 g day^{-1} and 0.216 % day^{-1}) at 2 fish m^{-2}. Fishes stocked in the treatment ponds at 3 fish m^{-2} density achieved the least DGR and SGR as compared to the fishes stocked at the lower rate. At this rate, the fishes achieved DGR and SGR of 0.045 g day^{-1} and 0.173 % day^{-1} in the DAP treated ponds (T_1) and 0.039 g day^{-1} and 0.153 % day^{-1} in the poultry manure treated ponds (T_2). On the whole, the DGR and SGR demonstrated an increasing trend with decreasing stocking density and in the ponds treated with DAP treatment.

3.3. Yield **(Y)**

In contrast to the mean weight gain, DGR and SGR per individual fish, the total weight gain and the net yield per year increased with increasing stocking densities (Table 1). Similar to these fish growth performance parameters, the total weight gain and net yield were greater in treatments with DAP (T_1) than in the treatments with poultry manure (T_2) and control (T_0). Thus, the trends in the total weight gain and yield were in contrast with the weight gain per individual fish across the stocking densities while they demonstrated similar trends across the fertilization types.

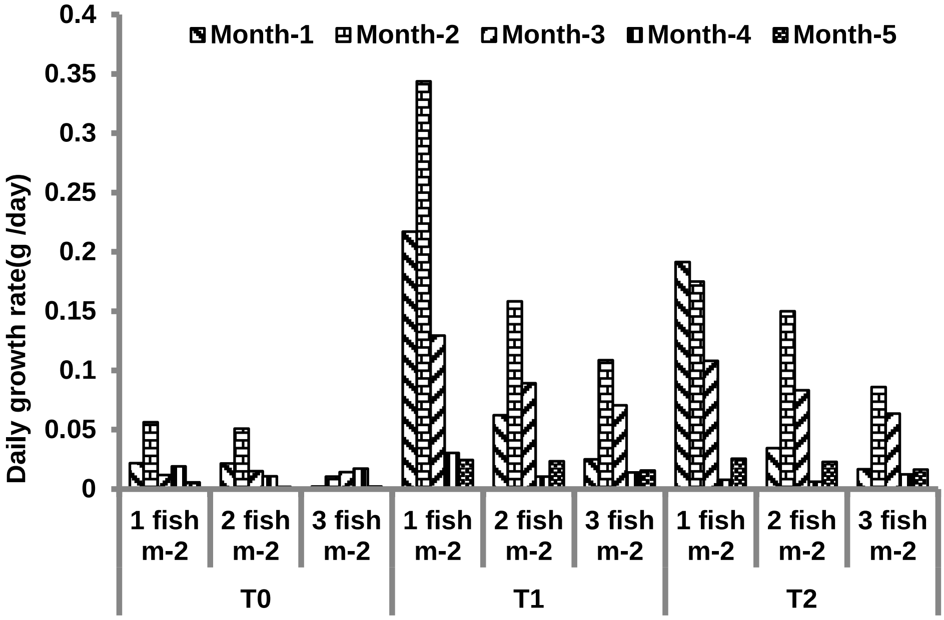

Figure 3: The mean daily growth rates (DGR) (g day^{-1}) comparison of Nile Tilapia in the control (T_0) and treatment (T_1 and T_2) ponds at the three stocking density levels during the experimental period

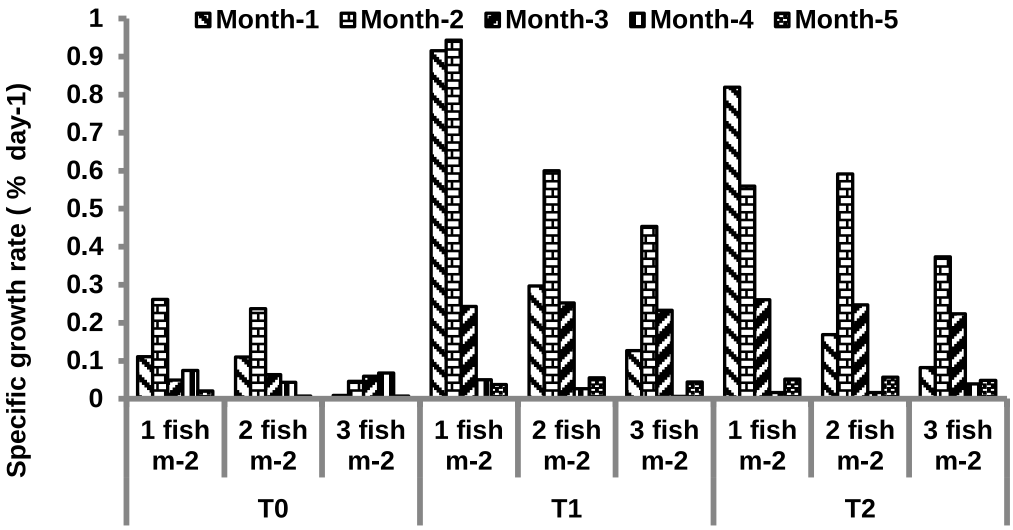

Figure 4: The specific growth rates (SGR) (% day^{-1}) of Nile Tilapia in the control (T_0) and treatment (T_1 and T_2) ponds at the three stocking density levels during the experimental period

3.4. Survival rate (SR%)

The survival rates of the fishes stocked in all stocking density and fertilization scenarios generally remained high ranging from 86.67 % to 96.67 %. The SR% did not vary with the stocking density levels and fertilization scenarios (Table 1).

3.5. Plankton

The genera or species of phytoplankton and zooplankton identified from the control and treatment ponds during the experimental period are summarized in Table 2 and Table 3, respectively.

Table 2: List of phytoplankton identified from the control (T_0) and treatment (T_1 and T_2) ponds during the experimental period

Major category	T_0	T_1	T_2
Chlorophyceae (Green algae)	Spirogyra sp.	Spirogyra sp. Chlamydomonas sp. Pediastrum simplex Closterium sp.	Spirogyra sp. Chlamydomonas sp. Pediastrum simplex
Characeae (Green algae)	Nitella tenuissima		
Bacillariophyceae (Diatoms)	Pediastrum simplex	Cyclotella sp.	Pleurosigma sp.
Euglenophyceae (Euglenids)		Euglena sp.	Euglena sp.
Chrysophyceae (Golden algae)		Synura uvella	
Cyanophyceae (Blue-green algae)		Anabaena sp.	

Table 3: List of zooplankton identified from the control (T_0) and treatment (T_1 and T_2) ponds during the experimental period

Major category	T_0	T_1	T_2
Cladocera	Bosmina sp.	Bosmina sp.	Bosmina sp.
Copepoda	Neocyclops salinarium	Paracyclops fimbriatus Megacyclops viridis	Megacyclops viridis
Rotifera		Euchlanis sp. Trichocerca sp. Asplanchna sp.	Euchlanis sp.

3.6. Physico-chemical parameters

During the experimental period, water temperature (T) varied from 20.4-27.37 °C, the minimum being in September while the maximum water temperature was in December for all the ponds of the various fertilization scenarios. These variations in water temperature between the months during the study period were statistically significant ($p < 0.05$). The amount of dissolved oxygen (DO) measured in the DAP treated ponds (T_1) varied from 4.88 mg L^{-1} to 9.78 mg L^{-1} while that of poultry manure treated ponds (T_2) ranged from 5.13 to 7.38 mg L^{-1}. In the control ponds (T_0), DO varied from 5.48 to 6.10 mg L^{-1} during the study period. The pH for the pond water varied from 6.32 to 7.72. The variations in the amount of DO and pH values among the treatments and months were not statistically significant ($p > 0.05$).

4. Discussion

4.1. Growth performance

In the present study, a decrease in the growth performance of Nile Tilapia with increasing stocking density concurs with the findings of [15] who reported that a reduction of the stocking density by 50 % has resulted in improved growth performance of Nile Tilapia in fresh water ponds. Other studies [16, 17] also indicated that in Nile Tilapia culture the stocking density considerably affects the fish size and production as the fishes kept at high densities tend to have slower growth rate. Further studies [18, 19] reported that stocking density as high as 3 fish m^{-2} would cause density related declines in growth for fish in fertilized ponds. Studies on the effects of stocking density for the Nile Tilapia in cage culture systems found that the fish size and production are significantly affected by stocking density [2, 20, 21). Similar effects of stocking density were observed for other aquaculture fish species of cyprinid and catfish families as well. For instance, for Gilt-head bream (*Sparus aurata* Linnaeus, 1758) it was reported that fishes in the highest density group grew 25 % slower than the fishes in the lowest density group [22]. Similarly, a reduction in weight gain of fish at higher stocking density was observed in Rohu (*Labeo rohita (*Hamilton, 1822)) culture [23]. Conversely, higher growth performances at lower levels of stocking densities were reported for Silver carp and African catfish [24, 25]. The present finding augments [26] who stated stocking density as inhibitory factor for fish growth. Nile Tilapia is a territorial and aggressive fish so that the density effect on growth might be explainable by their competition for territories as well as the permanent stress caused by crowding [27, 28]. As stocking density increases in fertilized ponds, carrying capacity remains largely the same and density-dependent growth occurs [29]. In relation to the fertilization effect, we found that the fishes achieved better growth performance in the ponds with DAP treatment than in the ponds with the poultry manure. The likely factor that could explain the observed differences between these two forms of fertilizers relate to their relative concentrations of phosphorus and nitrogen. The concentrations of these elements in the poultry manure used in the present study were much lower (4.6 % total nitrogen and 2 % total phosphorus) than their concentrations in the DAP (18 % nitrogen and 20 % phosphorus). Therefore, at the same loading rates, equal effects of these fertilizers on the growth performance of fish cannot be expected [30, 31]. This finding, thus, suggests that relatively little amount of chemical fertilizer and large quantities of poultry manure should be used to fertilize fish ponds in Nile Tilapia culture for better growth parameters. Similar effects were observed for other fish species such as in Carp polyculture system whereby treatments with chemical fertilizers were found to present the highest yield than organic fertilizers [32]. In the present study, Nile tilapia grown in the control ponds at a specific stocking density had the least growth rates, weight gain and yield in contrast to those grown in the fertilizer treated ponds at the same rate of stocking densities. The lowest weight (25.91±0.93 g) was observed in the control ponds at a stocking density of 3 fish m^{-2}. Thus, our study, in agreement with the previous reports [19, 33, 34], demonstrated that ponds with fertilizer treatments increase Nile Tilapia growth and yield. However, the use of supplemental feeding in fertilized ponds could result in significantly higher growth rates and greater yields than employing fertilization alone [18, 35].

In general, the higher results of weight gain, DGR and SGR at lower stocking density and in a chemical fertilizer treatment signify the effects of stocking density and the type of fertilizer on fish growth. In this regard, [36] stressed the importance of taking fish density into account when ranking families or progeny groups for growth performance where fish density is an important factor affecting growth and maturation of wild and laboratory fish, besides feed supply and its quality, genetics and environmental conditions. The DGR and SGR observed in this study are in agreement with the rates reported from other studies [2, 20, 21, 37, 38, 39] that indicated a decrease in the growth rates of Nile Tilapia with an increase in stocking density. On the other hand, [24] reported that higher values of SGR were obtained at lower stocking density of for other fish species (Silver carp) reared in earthen ponds.

In contrast to the weight gain and growth rates per individual fish, total weight gain or yield increased with increasing stocking density (Table 1). However, the effect of fertilization overall remained the same both on the growth performance per individual fish and total yield, which remained higher in the DAP treated ponds. Similar results were reported wherein densely populated ponds produced better yields than scarcely populated ones [2, 15, 20, 21, 40]. The positive relationship between stocking density and yield has been also described in culture based reservoirs fisheries [41]. Fertilized ponds are able to generate much more plankton as food for the fish than unfertilized ponds. In our study, much diverse phytoplankton and zooplankton species or genera were identified from the DAP fertilized ponds followed by the poultry manure treated ponds, and the least diverse plankton species were identified from the control ponds (Tables 2 and 3). More kilograms of fish can be sustained in the pond to the point where the fish start consuming the plankton produced at a rate faster than it can be regenerated. At this level, the amount of plankton that can be produced is usually the first limiting production factor. According to [42], fish production from fertilized ponds could reach 300-3 000 kg ha^{-1} which is equivalent to 0.45-4.5 kg per $15m^2$ pond, supporting the findings of the present study.

In our study, survival rate generally remained higher during the progress of the experiment except for the death of 17 (6.29 % mortality) fishes throughout the experimental period. The mean survival rates viz. 95.55 % in the control ponds (T_0), 94.44 % in the poultry manure ponds (T_2) and 91.11 % in the DAP treated ponds (T_1) were relatively higher than the 83.75 % reported for the same fish in earthen ponds [15]. These were also much higher than the 70 % [43] and 75 % [26] values reported for Nile Tilapia reared in cages. The higher survival rate observed in this study, thus, showed that survival was not much affected by the stocking density and the applied fertilizers. The overall mean survival rate i.e. 93.71 % was virtually similar to the 93.45 % value reported by [2], but it was lower than the 95.3 % reported by [21] for the same fish.

4.2. Physico-chemical parameters

The different physic-chemical parameters of the pond water were similar to each other and were within the safe limits for fish growth. No significant difference ($p > 0.05$) in DO and pH was detected for pond water of the treatments during the study period. The range of pH for pond water for all treatments varied from 6.32 to 7.72. This is in agreement with the report by [44] that the desirable range for pond pH is 6.5-9.5 and acceptable range is 5.5-10.0. Dissolved oxygen (DO) in pond water varied from 4.88 to 9.78 mg $liter^{-1}$ in all treatments during the experimental period. Water temperature ranged from 20.40-27.37 °C for all ponds during the experimental period. According to [45], the temperature range for the reproduction, normal growth and development of Nile Tilapia is about 20-35 °C and it can also tolerate a temperature as low as 7-10 °C. Other studies [46, 47] reported normal water temperature range for Nile Tilapia as 8-42 °C and optimal growing temperature being typically between 22 °C and 29 °C.

5. Conclusion

In this study, the best stocking density with regard to individual fish growth performance was 1fish m^{-2}. At this rate of stocking density, the chemical fertilizer (DAP) promoted better growth performance of Nile Tilapia compared with the poultry manure at the same weekly loading rate (2 g m^{-2}). However, gross production or yield increased with increasing stocking density. The fertilizers applied to the pond waters had positive effects on both the growth performance and fish yield, and hence the application of fertilizer had substantial contribution to the growth of the fish. However, inorganic fertilizers gave better growth performance and yield of fish than the poultry manure at the same application rate. Therefore, from this experiment, it can be concluded that the most effective stocking density for Nile Tilapia earthen pond cultured is at 1 fish m^{-2} for larger size fish demand while 3 fish m^{-2} gives higher gross production or yield with DAP treatment. Stocking density or fertilizer treatments had no significant effect on the survival of the fish. The authors recommend a scaling-up of the findings of the present study and its promotion among the local community depending on whichever fertilizer type is easily available and sustainable.

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