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Growth response of Nile Tilapia (*Oreochromis niloticus*) stocked at different densities in the LAKE-Kalassane basin in northwestern Senegal

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ABSTRACT

Nile Tilapia (*Oreochromis niloticus*) were reared at three different densities in concrete circular tanks to evaluate the effects of stocking density on growth, survival rate and food conversion ratio. Fish (mean weight, 12.13 ± 9.3 g; N: 970) were stocked in three densities as: low (T1 = 0.9 kg/m^3), medium (T2 = 1.17 kg/m^3) and high (T3 = 1.37 kg/m^3) with three replicates. The growth trial lasted for 150 days. Bulk and individual weights of fish in each tank were recorded monthly. The final mean weights of the fish stocked at densities of T1, T2 and T3 reached 79.66 ± 4.06; 55.80 ± 3.12 and 44.81 ± 6.21 g respectively. The average survival rates at the end of the experiment were 92.9 ±1.1%; 80.88 ±1.92% and 97 ± 0.02% for treatments T1, T2 and T3 respectively. Calculated food conversion rates ranged from 0.98 in low density fish (T1), 0.85 in medium density fish (T2), and 0.83 in high density fish (T3). The condition factor is equal to 1.76 in low density stocked fish (T1), followed by 1.77 in the medium density fish (T2) and finally 1.82 in high density fish (T3). The regression coefficients a and b and the results of the weight-length analysis are deduced from the graphical representation of the weight-length relationship. The growth of *O. niloticus* is of negative allometric type. Indeed, the regression coefficients (b-values) of the weight-length relationship of the individuals of the three treatments are lower than 3. This indicates that *O. niloticus* individuals reared in the different treatments tend to grow more in height than in weight. The results revealed that the stocking densities in this study had no significant effect on growth and survival of *O. niloticus*.

Keywords: Feeding, growth, survival, *Oreochromis niloticus.*

INTRODUCTION

The contribution of aquaculture to seafood production has increased continuously over the past two decades, reaching 46% in 2016–2018, up from 25.7% in 2000, with an annual growth rate of 5.3% from 2001 to 2018, surpassing that of any other major food to increasing world population and higher demand for seafood protein (FAO, 2020). The Nile tilapia, *Oreochromis niloticus* is considered as one of the most important species of fish in tropical and sub-tropical aquaculture (FAO, 2012). It serves as an important source of animal protein and income throughout the world (Sosa et al., 2005). Tilapia can grow and reproduce facing a wide range of environmental conditions and tolerate stress induced by handling (Siddik et al., 2014).

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Tilapia farming is booming around the world in both developed and developing countries as this group of fish can be cultured under very basic conditions and is therefore ideal for subsistence farming, but is prone to more sophisticated, market-oriented cultural programs. Tilapia is an important species throughout global, but knowledge of its appropriate stock density which can immensely affect production and efficiency of tilapia has been inadequate.

Fish pond density describes the number of fish that are initially stocked per unit area. It is one of the most important factors determining the production of a fish farm. Stocking density is one of the keys to success in aquaculture management as it directly affects survival, growth, behavior, health, water quality, feed consumption and production. The choice of stocking densities of fish depends in part on economic factors and market demands. Therefore, studying the ideal stocking density is one of the main factors in increasing production. Several studies have been carried out on the growth efficiency of fish at different densities, most results show reduced final weight when stocking density increased (Rahman et al., 2016; Sachin et al., 2020).

Fish farming in ponds in not known in the Niaye Area, despite the development of horticulture in the area with a lot of water usage in different form of irrigation.

Fish culture in Senegal is therefore still in its infancy, although there is a long history of aquaculture in it, the lack of trained personnel and inadequate planning has been major impediments to its development.

Numerous studies have been conducted in Senegal mainly on the feed and feeding of Nile tilapia (Badiane et al., 2021; Fall et al., 2020; Loum et al., 2013; Sagne et al., 2013), on temperature (Ly et al., 2021), on sex-ration (Ly et al., 2021) and biosecurity practices (Faye et al., 2020).

The objective of this study was to examine the effect of the optimal stocking densities of Nile tilapia fingerlings in ponds and their impact on growth efficiency. The weight-length relationship for Nile tilapia was also studied.

MATERIALS AND METHODS

Presentation of the study area

The study area is the LAKE Kalassane basin (Figure 1), located in the municipality of Ndiébène Gandiol in the district of Rao, department of Saint-Louis. It has an area of 14 hectares and consists of 36 parcels of land. This basin is an integral part of Gandiol and is located between 16°28'30" and 16°24'05" west longitude and 15°50'20" and 15°56'10" north latitude (Sy, 2020). The climate is sub-Saharan with a cold dry season from November to February, a hot dry season from March to June and a rainy season from July to October. Average annual temperatures range from 23.7°C to 25°C. The highest average monthly temperatures are between 35°C and 37°C (harmattan) and occur during the rainy season. From November to February, minimum and maximum temperatures are below 18°C and 28°C, respectively (ANACIM, 2016). The Niayes area has no permanent surface water. Water resources in the area are essentially groundwater. The main water reserve is a good quality surface aquifer that extends over the entire area. This aquifer plays a primary role in supplying water for all needs (Touré et al., 2005).

Fish and system

Oreochromis niloticus fingerlings were obtained at the National Aquaculture Agency

Hatchery unit of Richard-Toll in the North of SENEGAL.

Nine hundred and seventy (970) fingerlings with an average initial weight of 12.13 ± 9.3 g were transported in transparent plastic bags filled with 1/3 water and the rest with oxygen to the LAC-Kalassane farm. After one week acclimatization to the new environmental conditions, *Oreochromis niloticus* fingerlings were separated into three densities: low (T1 = 0.9 kg/m^3), medium (T2 = 1.17 kg/m^3) and high (T3= 1.37 kg/m^3) with three replicates and fed with imported feed (Le GOUESSANT). These fingerlings from the same batch were randomly distributed in each pond. The ponds used in this study were circular with a volume of 3 m^3 and a diameter of 2.5 m with a height of 1.20 m. Each pond was covered with a protective net against avian predation.

Ground water was pumped in a borehole to fill the ponds. One-third of water volume was changed twice a week and the whole water volume was renewed every month to clean the pond walls and remove the attached algae. Water quality parameters such as temperature and pH were measured twice a day, in the morning (9:00 am) and afternoon (3:00 pm). Samples of water were taken from each pond for determination of temperature and pH using a multi-parameter instrument, model WTW. Multi 3110 SET. Ponds in the different treatments were subjected to the same environmental conditions (lighting).

Fish in each tank were fed twice daily, at 9:00 am and 3:00 pm, with an imported feed (Le GOUESSANT, containing 38% crude protein).

The amount of feed distributed was approximately equivalent to 5% of their biomass weight. To quantify the exact feed intake for the feed conversion ratio computations, the left-over of feed was siphoned out immediately, dried, and weighed.

All the fish of each tank were counted and weighed every 2 weeks and the feed amount was adjusted accordingly. A Toprime digital Gram SCALE (precision: 0.01g) was used during the different weighing (feed distributed and fish weight) during the control fisheries.

Total length and standard length of juveniles were performed every two weeks using an graduated ichthyometer to the pre cm size of the fish.

Dead individuals were removed and counted daily and the feed was adjusted after each weighing.

Growths performances

To estimate the growth of fish during this study and characterize the efficiency of feed use, the following different zootechnical parameters were calculated using Excel software.

- ***Survival rate (SR)***:

The survival rate was calculated from the total number of fish at the end of the experiment and the number of fish at the beginning of the rearing, according to the equation: final number of fish / initial number of fish) x 100.

- ***Feed conversion rate (FCR):***

It is an index of feed transformation that measures the efficiency of the conversion of feed into fish flesh, represents the ratio between the total amount of feed distributed to fish and the gain obtained in biomass. It was determined by the equation: quantity of dry feed distributed / gain in fresh weight.

- ***Condition factor K***

The weight-length relationship is a parameter that verifies the growth of the fish population. It was established using the formula Pt= a Ltb, where Pt and Lt represent the total weight (g) and total length (cm) of the fish, respectively. The constants a and b are deduced after linearization of the relationship by logarithmic transformation as: Log (Pt)= log(a) x b*log (Lt).

The value of b gives information about the type of growth of the fish. Growth is said to be isometric if $b = 3$ and allometric if $b \neq 3$ (positive if $b > 3$ and negative if $b < 3$). This value of b is between 2.5 and 3.5 and provides information about the dimensions of growth or an interpretation of the well-being of individuals (Thabet, 2017). The constant a is a characteristic factor of the environment (Ouédraogo, 2000).

Statistical analysis

The data were expressed as means plus or minus the standard deviation ($n = 3$). They were entered into Excel and then imported into R. The effects of density were tested with one way analysis of variance (ANOVA), followed by Tukey's test. Differences were considered significant at $p < 0.05$. R software was used for all statistical analyses.

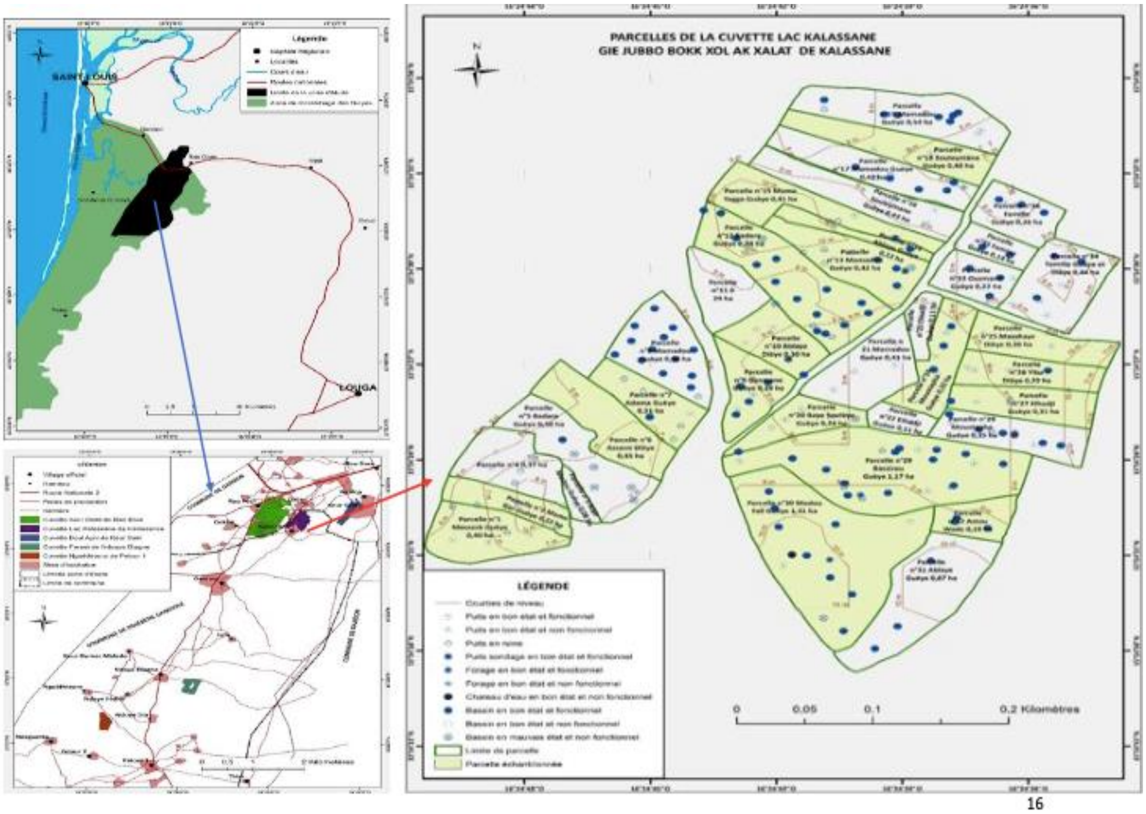

Figure 1: Mapping of the study area.

RESULTS

Water quality parameters

Overall, temperatures ranged from 27°C to 31.8°C for all treatments. The lowest temperature values were recorded in the morning. Temperatures increased as the experiment progressed.

The pH values ranged between 6.8 and 7.7 for treatments 1 and 2 and between 6.8 and 7.5 for treatment 3. The highest values are also recorded at the beginning of the experiment. It should therefore be noted that these parameters were subject to environmental conditions.

Growths performances

Throughout the experiment, the fish showed no pathological signs and did not suffer high mortalities. The average survival rates at the end of the experiment, were 92.9 ± 1.1%; 80.88 ± 1.92% and 97 ± 0.02% for treatments 1, 2 and 3 respectively.

The statistical analysis shows that the difference between the survival rates of the different batches is not significant (P>0.05), which makes it possible to attribute the recorded mortalities rather to the manipulations during the biometric controls than to the treatment since they occurred the day after the growth controls.

The zootechnical parameters at the end of the experiment show that the final average weights of the fish vary between 79.66 ± 4.06 g for treatment 1 (low density); 55.8 ± 3.12 g for treatment 2 (medium density) and 44.81± 6.21 g for treatment 3 (high density).

Duncan's test shows that there is no significant difference (P>0.05) between the final mean weights of T2 and T3 diets, 55.8 g and 44.81 g, respectively, in contrast to T1 (79.66 g).

Calculated food conversion rates ranged from 0.98 in lowdensity fish (T1), 0.85 in medium density fish (T2) and 0.83 in high density fish (T3).

Results on the weight-length relationship

The condition factor is equal to 1.76 in low density stocked fish (T1), followed by 1.77 in the medium density fish (T2) and finally 1.82 in high density fish (T3).

The regression coefficients a and b and the results of the weight-length analysis are deduced from the graphical representation of the weight-length relationship (Figures 2; 3 and 4). The growth of *O. niloticus* is of negative allometric type. Indeed, the regression coefficients (b-values) of the weight-length relationship of the individuals of the three treatments are lower than 3. This indicates that *O. niloticus* individuals reared in the different treatments tend to grow more in height than in weight.

Table 1: Zootchnical performances of *O. niloticus* under different treatments.

Zootechnical parameters	Treatment 1	Treatment 2	Treatment 3
Initial stocking density (kg/m^3)	0.9	1.17	1.37
Final average weight (g)	79.66 ± 4.06	55.80 ± 3.12	44.81 ± 6.21
Survival rate (%)	92.90 ± 1.10	80.88 ± 1.92	97.00 ± 0.02
FCR	0.98 ± 0.12	0.85 ± 0.11	0.83 ± 0.23
CF	1.76 ± 0.22	1.82 ± 0.17	1.77 ± 0.09

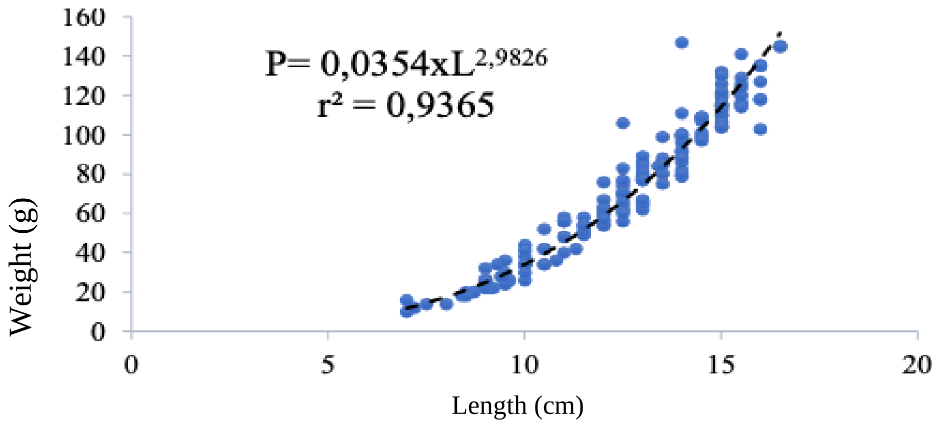

Figure 2: Weight-length relationship of *O. niloticus* individuals from treatment T1.

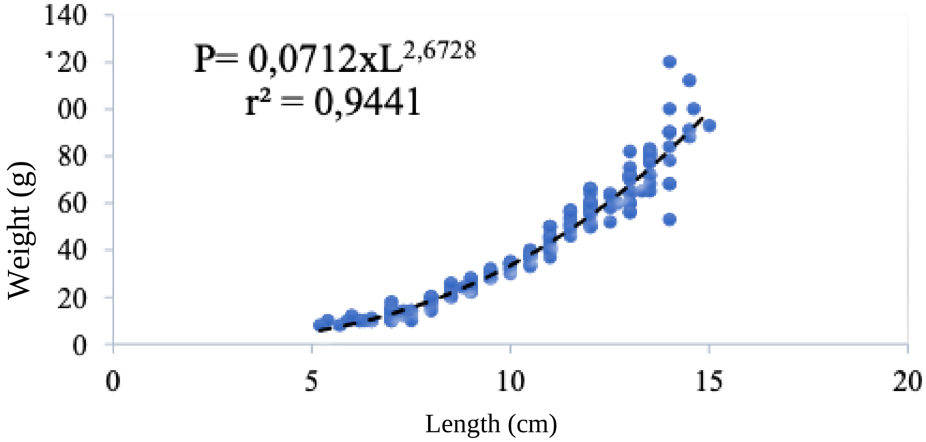

Figure 3: Weight-length relationship of *O. niloticus* individuals from treatment T2.

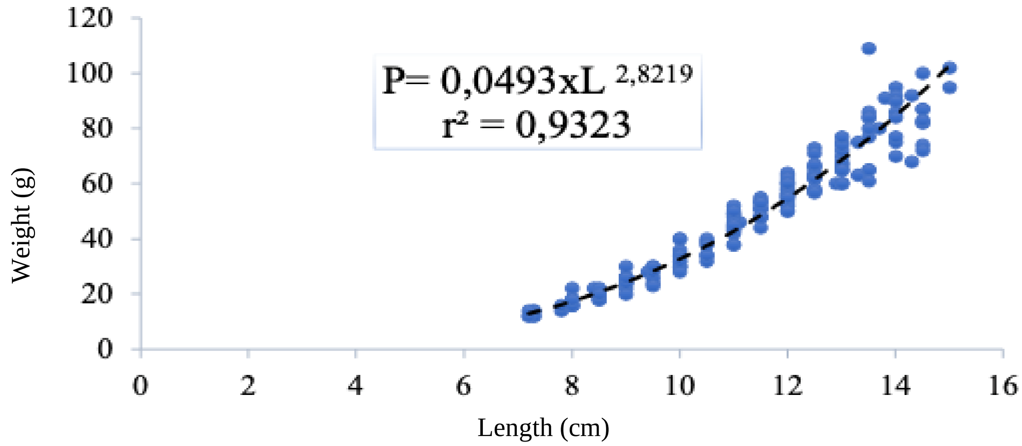

Figure 4: Weight-length relationship of *O. niloticus* individuals from treatment T3.

DISCUSSION

The average values of water quality parameters such as temperature and pH during the whole experimental period were within the acceptable levels required for normal growth and physiological activities of Nile tilapia (Amoni, 2020).

Water temperature and pH must be kept at an optimal level compatible with fish species.

Water temperature is the most crucial parameter for fish growth. If the water temperature is below the critical level, fish could stop feeding and would even die. The metabolic activity and physiological functions of aquatic animals (e.g., feed utilization, feed conversion, growth rates) can be affected by the water temperature (Kassaye, 2012).

According to Magblenou et al. (2020), the optimal temperature would be between 25 and 30°C. Similar results were observed, on a study on diversification of fish production systems: rearing *Oreochromis niloticus* in cage (Diallo, 2012). The latter informs that the thermal optimum for tilapia growth is between 27 and 32°C. However, in his thesis, Thabet

(2017) stated that in Tunisia, at the dam impoundment, the average temperature encountered during the growth of tilapia is between 9 and 28°C.

For Bouhania and Hammia (2020), these values would be within the tolerance of the species as close to neutrality. Toko et al. (2018) reported pH values between 6.9 ± 0.6 and 6.81 ± 0.13 in their study conducted in Batran and Songhaï reservoirs. Similarly Ouédraogo (2000), in a study on the reproductive biology of tilapia *Oreochromis niloticus* from the Comoé dam lake in Burkina Faso, reported pH values between 6.52 and 10.9.

During this study, no major problems were recorded concerning the survival of fish.

The observed mortalities could be related to the stress caused by the handling during the control fisheries, as the deaths always occur after the control fisheries. The survival rates observed are satisfactory (generally above 70%).

The zootechnical parameters at the end of the experiment show that the final average weights of the fish vary between 79.66 ± 4.06 g for treatment 1 (low density), 55.8 ± 3.12 g for treatment 2 (medium density) and 44.81± 6.21 g for treatment 3 (high density). No significant difference (P>0.05) were observed between the final mean weights of T2 and T3 diets, 55.8 g and 44.81 g, respectively, compared to T1 (79.66 g).

The lowest density achieved the best growth this is in accordance with the findings of

Osofero et al. (2009). Social interactions through competition for food and/or space can negatively affect fish growth, hence higher stocking densities leads to increased stress and that resulting increase in energy requirements causing a reduction in growth rates and food utilization. This explanation is in conformity with the study done by Aksungur et al. (2007) on the effects of stocking density on growth performance on *Psetta maxima*.

Calculated food conversion rates ranged from 0.98 in low density fish (T1), 0.83 in medium density fish (T2), and 0.85 in high density fish (T3). Food conversion ratio increased with increasing stocking density thus as stocking densities increased the juveniles became less efficient in utilizing the food for somatic growth. This is attributed increasing stress (aggressive behavior, dominance), which leads to higher energy requirements, causing a reduction in growth rate and feed efficiency (Kpogue and Fiogbe, 2012). Several studies report a negative effect as stocking density increases on the feed conversion rate of fish (Tran et al., 2019; Maucieiri et al., 2019). This is in agreement with the findings of Ronald et al., 2014, in their study on the effects of stocking density on the growth and survival of Nile Tilapia fry. In addition they indicated that high stoking density contribute in decreasing chronic stress, improve slow grower performance and hinder fast growing individuals due to dominance hierarchy reduction. On the contrary, Osofero et al. (2009) reported no effect of stocking density on food conversion rate which he attributed to using the same feed in the same environment.

A number of factors (e.g. sex, seasons, environmental conditions, stress, and availability of food) also affect the condition of fish. Stewart (1988) observed stress as a result of the reduction in the breeding and nursery ground of *O.niloticus* in lake Turkena, Kenya, as contributing to dramatically lower condition factors. Pollution was seen to affect the condition factors of *Orechromis niloticus* in lake Mariut, Egypt (Khallaf et al., 2003).

The condition factor is an important factor to determine the relative degree of robustness and nourishment in fish (Mortuza and Al-Misned, 2013). This factor might be influenced by sex, age, species type, maturity and environmental conditions (Anyanwu et al., 2007). Condition factor for all the experimental diets were >1.7 indicating that fish were above the average condition with good health during the entire period of the experiment. Higher value was observed in the T3, followed by T2 and T1.

This could be attributed to the accumulation of fat in the body (Laleye, 2000).

Lower value was observed in the T1 and that is a definite sign of allometric growth. The condition factor for mixed-sex tilapia was found to be 1.09 (Mortuza and Al-Misned, 2013), which was lower than all treatment of the present experiment.

Condition factor of *O. niloticus* fed with different levels of maltose varied from 1.68-1.86 (Ighwela et al., 2011) which was similar to the values obtained in the present experiment. In addition, in their study on Length-weight Relationship and Condition Factor of juvenile *Oreochromis niloticus* fed diets with *Pyropia spheroplasts* in closed recirculating system Shahabuddin et al. (2015) found condition factor varying from 1.2 to 1.7.

AUTHOR CONTRIBUTIONS:

SMS, MAL. and LD designed the experiment. FLD and ID carried out samples. Data analyses were done by MAL and LD. FLD prepared all the figures. LD participated in the correction of the manuscript. All authors have read and agreed to the published version of the manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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