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Emma A Komba
(1). Mwalimu Julius K. Nyerere University of Agriculture and Technology, P O Box 976 Musoma, Tanzania
(2). Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA), P.O Box 3004, Morogoro, Tanzania

Renalda N Munubi
Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA), P.O Box 3004, Morogoro, Tanzania

Sebastian W Chenyambuga
Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA), P.O Box 3004, Morogoro, Tanzania

Corresponding Author:
Emma A Komba
(1). Mwalimu Julius K. Nyerere University of Agriculture and Technology, P O Box 976 Musoma, Tanzania
(2). Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA), P.O Box 3004, Morogoro, Tanzania

Comparative evaluation of water quality parameters and growth performance of sex-reversed Nile tilapia (*Oreochromis niloticus*) raised in two different climatic conditions in Tanzania

Emma A Komba, Renalda N Munubi and Sebastian W Chenyambuga

Abstract
A study was done to compare water quality parameters, growth and production performance of Sex-reversed Nile tilapia (*Oreochromis niloticus)* cultured in two districts of Tanzania, which experience different climatic conditions (cold and moderately warm). Fingerlings (1.00 g average weight) were stocked in earthen ponds (2 fish/m^3), then raised for six months. Fish were fed twice daily and ponds were inorganically fertilized fortnightly. Measurements of water quality parameters and fish growth parameters (weight, length and width) were done biweekly. The results revealed significant differences on various water quality parameters; including temperature, salinity, conductivity and alkalinity between the two districts ($p \leq 0.05$). Mean growth rate, specific growth rate, mean final weight, estimated annual yield and Food Conversion Ratio were significant better for fish grown in warm than those in cold climate ($p \leq 0.05$). It is concluded that, fish growth and water quality parameters are better in warm than cold condition.

Keywords: Annual yield, growth rate, physico-chemical water quality parameters, specific growth rate, survival rate

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is one of the most cultured and popular species in aquaculture production in Tanzania and worldwide [1, 2]. In many developing countries, it is mainly cultured in earthen ponds or cages under mixed-sex culture system [3]. High growth rate, tolerance to wide range of environmental conditions, high food utilization efficiency, good fecundity and good flesh quality are among the many good farming qualities which make tilapia to be the species of choice for aquaculture in many areas [4, 5].

Despite its ability to survive in a wide range of environmental conditions, production performance of Nile tilapia vary considerably from place to place or time to time due to changes in quality of environmental conditions (biological, chemical and physical environments) in which they are cultured [6, 7]. For proper survival and growth of Nile tilapia, water quality parameters must be maintained within the tolerable limits. Good water quality is characterised by proper levels of dissolved oxygen, pH, temperature, salinity, transparency, limited levels of metabolites and other environmental factors affecting fish growth [8]. Changes beyond the tolerable limits may add stress to the fish and affect productivity.

Climatic conditions of the area play important role in influencing water quality parameters such as temperature, salinity, pH, evaporation and dissolved oxygen, which in turn, influence the growth and survival of cultured fish [9]. In Tanzania, like other many countries, different places around the country differ climatically. These differences in climatological factors influence water quality parameters, hence aquatic life. This study intended to compare pond water quality parameters and the performance (growth rate, feed conversion efficiency, survival rate and production yield) of Nile tilapia cultured in two districts experiencing different climatic conditions in Tanzania i.e. low temperature and moderately high temperature.

2. Materials and Methods

2.1 Experimental location

The study was conducted in Mufindi and Mbarali districts which are located in Iringa and Mbeya regions of Tanzania, respectively. Mufindi district lies between latitude 8^0 00' – 9^0 15' S and longitude 34^0 35' – 35^0 55' E. The mean annual rainfall ranges between 950 and 1600 mm. The mean maximum temperature is 18.4 ^{0}C (between November and February) and the minimum is 13.1 ^{0}C (July). The altitude ranges from 1700 to 2200 meters above sea level [10]. Mbarali district is located between latitude 7^0 and 9^0 S and between longitude 33.8^0 and 35^0 E. The altitude ranges from 1000 to 1800 meters above the sea level. Average temperature ranges between 25 and 30 ^{0}C. The annual rainfall is about 450 to 650 mm [11].

2.2 Pond Preparation, Stocking and Management

Eight earthen ponds (650 m^2 average size) were used; four ponds in each district. Prior stocking, all ponds were drained, cleaned, dried and then refilled with water. Initial fertilization was done seven days prior to stocking, using urea and Diamonium Phosphate (DAP) at rate of 3 g/m^2 and 2 g/m^2, respectively. All through the experiment, fertilization were done fortnightly using same fertilizers and same application rates. Sex reversed male Nile tilapia fingerlings (1.00 g average weight) were stocked (2 fish/m^3) and reared for six (6) months. Fish were fed 10% of their body weight during the first month, followed by 5% of body weight for the remaining experimental period. The supplemented diet contained 25% Crude protein (CP). Feeding was done twice daily (10.00 and 16.00 h).

2.3 Sampling, Data collection and Analysis

Body weight, total length (TL) and width were measured fortnightly throughout the experimental period alongside with measurement of physico-chemical water quality parameters. Random samples of fifty fish from each pond were collected using a seine net of 10 mm mesh size and measured. Body weights were measured using a digital weighing balance (0.01 g) while the TL and width (0.1 cm) was measured using measuring ruler. At the end of the experiment, fish were harvested counted and measured. Generated data were subjected to the following formulae to calculate different growth indices and survival rates [12, 13, 14, 15, 16].

$$\text{Daily Weight Gain (DWG)} = \frac{\text{Final weight (g)} - \text{initial weight (g)]}}{\text{Time (days)}} \quad (1)$$

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

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Amount of feed consumed (g DM)}}{\text{Weight gain (g)}} \quad (3)$$

$$\text{Survival Rate (SR)} = \frac{\text{Total number stocked} - \text{total number died}}{\text{Total number stocked}} \text{ X 100} \quad (4)$$

$$\text{Fish yield (kg/ha/year)} = \frac{\text{Weight of fish harvested (kg/ha)}}{\text{Experimental period (days)}} \text{x 365 days} \quad (5)$$

Water quality parameters i.e. temperature in ^{0}C, dissolved oxygen (DO) in mg L^{-1}, pH, conductivity in μScm^{-1} and salinity were measured in situ, using DO meter (HI 98198 PH/EC/DO Multiparameter HANNA instruments) at three depths; top, middle and bottom of the pond water, then the average values of the three depths were computed. Water samples from the three depths were collected using plastic containers (500 ml), mixed and preserved at $^-18$ ^{0}C for laboratory analysis of Nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N) and phosphate-phosphorus (PO_4-P). NO_3-N and NH_3-N were determined using Kjeldahl method while PO_4-P was determined spectrophotometry following standard procedures [17].

2.4 Data analysis

Results were expressed as mean ± Standard error. Analysis of variance (ANOVA) was used to test the effect of location (climate) on growth performance and water quality parameters. The influence of each water quality parameter on fish growth was assessed using multiple regression analyses. All statistical analyses were made by the General Linear Model (GLM) procedure using Statistical Analysis System software (SAS) for windows version 8. The mean values were compared by Duncan's New Multiple Range test at 5% significance.

3. Results

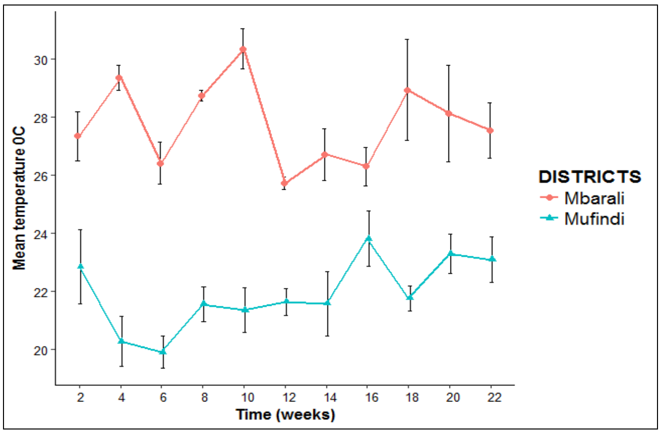
3.1 Pond water quality parameters

Results are presented as mean ± Standard error (LSM ± SE). The results show that, the pond water in Mbarali had significantly higher ($p\leq0.05$) temperature, salinity, conductivity and alkalinity compared to that in Mufindi (Table 1). The values for DO, pH, nitrate, ammonia, water transparency and phosphorus did not differ between the two locations ($p>0.05$). In contrast to pH and DO, the trends of pond water temperatures between the two districts were significantly different throughout the experimental period (Figure1).

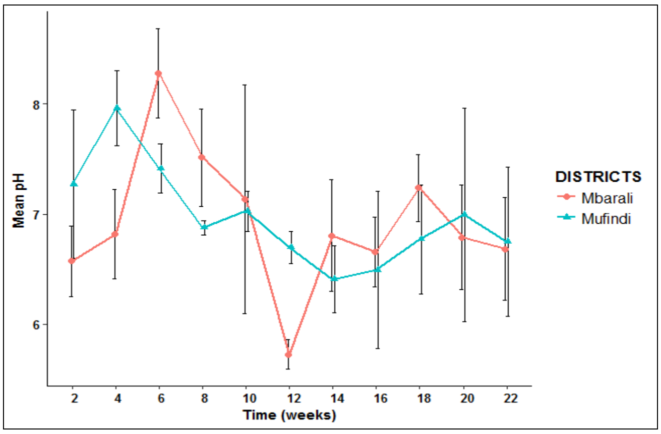
Table 1: Comparison of water quality parameters (LSM ± SE) in ponds located in Mbarali and Mufindi districts

	Locations		
Variables	**Mbarali**	**Mufindi**	**p Value**
Temperature ^{0}C	27.72 ± 0.25^a	21.93 ± 0.25^b	<.0001
pH	6.91 ± 0.15^a	6.96 ± 0.15^a	0.8081
Dissolved oxygen (mgL^{-1})	6.17 ± 0.27^a	6.09 ± 0.27^a	0.8284
Salinity (mgL^{-1})	57.35 ± 1.86^a	13.18 ± 1.86^b	<.0001
Conductivity (μScm^{-1})	121.62 ± 3.27^a	31.81 ± 3.27^b	<.0001
Transparency (cm)	15.73 ± 0.56^a	17.25 ± 0.56^a	0.0597
Ammonia (mgL^{-1})	0.08 ± 0.19^a	0.07 ± 0.19^a	0.0625
Nitrate (mgL^{-1})	7.72 ± 0.25^a	7.71 ± 0.24^a	0.9629
Phosphorus (mgL^{-1})	1.33 ± 0.17^a	0.98 ± 0.17^a	0.1444
Alkalinity ($mgCaCO3^-L$)	105.30 ± 4.27^a	82.39 ± 4.27^b	0.0003

*ab= Means with same superscript letter in the same row do not differ significantly (p>0.05)



(a)



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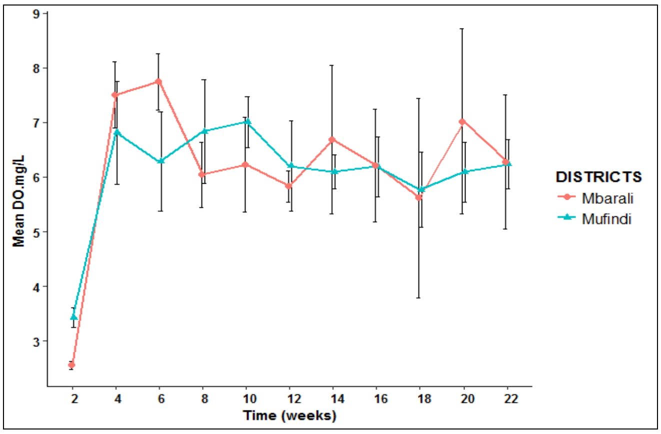

(c)

Fig 1: Comparison of water temperature (a), pH (b) and dissolved oxygen (c) from fish ponds located at Mbarali and Mufindi districts

3.2 Influence of water quality parameters on fish growth performance

The results for multiple regression analysis indicated that among the water quality parameters analysed, ammonia levels affected significantly the growth of fish in both districts. Water temperature, DO and conductivity had positive influences on the growth of fish in both districts. However, NH_4-N, NO_3-N and alkalinity had negative influence on fish growth in both districts. The influence of each water quality parameter on the growth of fish in each experimental location is summarized in Table 2.

Table 2: Regression on the influence of water quality parameters on fish growth

	Mbarali			Mufindi		
Parameter	**Estimate (b)**	**SE of the estimate**	**p-value**	**Estimate (b)**	**SE of the estimate**	**p-value**
Temperature ^{0}C	4.49	1.91	0.1773	3.25	1.54	0.0409
pH	9.18	13.94	0.5140	-3.67	2.94	0.2181
Dissolved O_2(mgL^{-1})	16.85	6.12	0.0087	0.29	2.00	0.8844
Ammonia (mgL^{-1})	-30.19	10.89	0.0083	-7.06	2.13	0.0019
Nitrate (mgL^{-1})	-15.92	7.61	0.0524	-1.97	1.07	0.0471
Alkalinity (mgL^{-1})	-0.56	0.4	0.1672	-0.34	0.1	0.0622
Phosphorus (mgL^{-1})	-5.02	1.46	0.6632	0.36	0.18	0.9094
Conductivity(µScm)	0.51	0.33	0.1314	1.13	0.28	0.0002
Transparency (cm)	8.49	1.51	<.0001	-2.09	0.88	0.0221

3.3 Production Performance and Survival Rate of Nile tilapia

The analysis of variances showed that, location influenced significantly the growth performance of the fish throughout the study period (p<0.05). The mean final body weight (FnBW), weight gain (WG), daily growth rate (DGR), specific growth rate (SGR), survival rate (SR), estimated annual yield, final body length (FnBL) and final body width (FnBWd) were higher for the Nile tilapia raised at Mbarali than for those raised at Mufindi (p≤0.05). The results also showed significantly better feed conversion ratio (FCR) for the fish raised at Mbarali (1.49 ± 0.06) than those raised at Mufindi district (2.16 ± 0.06), (Table 3). Generally, it was clear that fish reared at Mbarali increased in body weight over time at a faster rate compared to those reared at Mufindi district (Fig. 2).

Table 3: Comparison of Growth performance (LSM ± SE) of tilapias grown in ponds located in warm and cold climate (Mbarali and Mufindi districts)

	Locations		
Variables	**Mbarali**	**Mufindi**	**p Value**
InBW (g)	1.16 ± 0.03 [a]	0.83 ± 0.03 [b]	<.0001
FnBW(g)	228.68 ± 4.99 [a]	86.68 ± 4.99 [b]	<.0001
WG (g)	227.70 ± 4.79 [a]	85.71 ± 4.79 [b]	<.0001
DWG(g/d)	1.26 ± 0.03 [a]	0.48 ± 0.03 [b]	<.0001
SGR (%)	3.12 ± 0.02 [a]	2.52 ± 0.02 [b]	<.0001
Yield (kg/ha/year)	6828.43 ± 407.95 [a]	4465.29 ± 407.95 [b]	0.0352
SR (%)	89.47 ± 0.02 [a]	88.02 ± 0.02 [b]	<.0001
InBL (cm)	3.67 ± 0.04 [a]	3.48 ± 0.04 [b]	0.001
FnBL(cm)	21.87 ± 0.16 [a]	16.14 ± 0.16[b]	<.0001
InBWd(cm)	1.06 ± 0.02[a]	1.06 ± 0.02 [a]	0.7167
FnBWd(cm)	7.71 ± 0.07 [a]	5.55 ± 0.07 [b]	<.0001
FCR	1.49 ± 0.06[b]	2.16 ± 0.06 [a]	0.0069

*[ab]= Means with the same superscript letter in the same row do not are significantly different (p>0.05). InBW = initial body weight, FnBW = final body weight, InBL = Initial body length, FnBL = final body length, InBWd = Initial body width, FnBWd = final body width, WG = weight gain, DWG = Daily weight gain, SGR = specific growth rate, SR = survival rate, FCR = Feed conversion ratio.

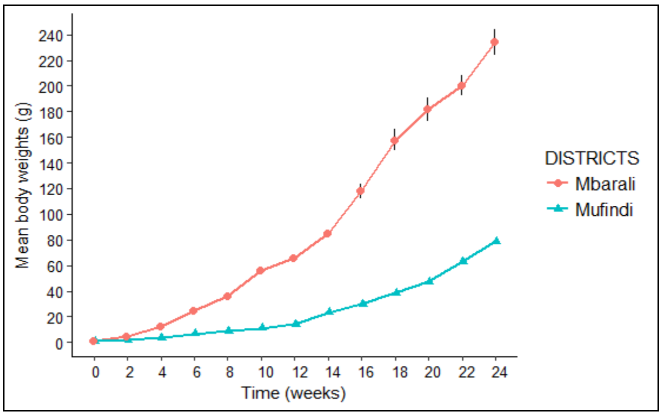

Fig 2: Growth patterns of Nile tilapia reared at Mbarali and Mufindi districts during the experimental period of 24 weeks (six months)

4. Discussion

4.1 Water quality Parameters

This study revealed significant different in temperature levels between the two experimental locations, with higher values in Mbarali than in Mufindi. Temperatures level ranging between 20 and 35 °C is appropriate for tilapia culture [6, 8, 18]. With regards to the findings from this study, it appeared that the temperatures at Mufindi were below the ideal range for proper growth of Nile tilapia compared to the temperatures recorded at Mbarali district.

No significant difference was observed for pH and Dissolved oxygen (DO) values between the two experimental locations. The average pH and DO values in both locations were within optimal ranges. Nile tilapias can survive in water with pH ranging from 3.5 to 12, however they grow best at pH ranging from 6 to 9 [19, 20] and the pH < 4 or >10.5 is lethal [21]. In aquatic ecosystem DO influence the growth, survival, feed utilization, distribution, behaviour and physiology of aquatic organisms [6]. In this study, mean values for DO in both locations were within the suitable range for optimal growth and production of Nile tilapia. DO ranging from 5 to 8 mgL^{-1} has been recommended as suitable for optimal growth and production of tilapia [6, 21, 22, 23]. In line with the findings from this study, it has been observed that, fish growth increased relatively between districts with the increased DO within the tolerable limits [24].

Conductivity is an index of the total ionic content of the water thus, indicates freshness of water. It influences primary productivity and therefore fish production [6]. In this study, conductivity levels varied significantly between the experimental locations. The average conductivity obtained at Mbarali was higher and better for fish growth compared to that of Mufindi. Studies have revealed that conductivity ranging from 100 to 2000 µS/cm is ideal for fish pond [25, 26]. Variation in conductivity levels between the two experimental location could be attributed to factors like soil composition or the bedrock on which the ponds are seated [25], nature of human activities around the ponds [27], but also possibly due to the effect of temperature which influence chemical reactions [6]. As water temperature increases, viscosity decreases resulting into increased ions mobility in water and therefore increasing conductivity [28]. Total alkalinity indicates inorganic carbon content of water. Since inorganic carbon is essential for photosynthesis, alkalinity affects primary production and fish yield [29]. From the present study, alkalinity differed significantly between the two locations. However, the mean values in both locations were within the ideal ranges (50 to 300 $mg^{-}L$) for fish growth [6, 20].

4.2 Influence of physico-chemical parameters on fish growth performance

Regression coefficient "b" defines the direction and the magnitude of the slope of a regression line. The positive 'b' value associated with a particular water quality parameter in each district imply that, for every increase of one unit of that parameter, there was a corresponding increase in fish weight by a certain unit in that particular district and vice versa for the negative 'b' values. For example, the regression equation predicted significant increase of 3.25 g of fish weight with every increase of one unit of temperature at Mufindi. From this study it is shown that, the growth of fish in each district was driven by different factors.

4.3 Production performance

The growth performance of Nile tilapia is highly influenced by environmental conditions of the pond water. The results from this study show that, Nile tilapia performed better in ponds located at Mbarali (high temperature) than at Mufindi (low temperature). The higher water temperature in Mbarali corresponded with significantly higher feed intake, specific growth rate (SGR) and better Feed conversion ratio (FCR). Likewise, final body weight (FnBW), weight gain (WG), survival rate (SR) and estimated annual yield were significantly higher for fish reared in Mbarali than for those reared in Mufindi. These results are supported by the findings from previous studies which reported an increase in growth performance as temperature increases within the tolerable limits [30, 24, 18]. Growth rate and feed utilization efficiency decrease as temperature goes below 20 ^{0}C [8, 14, 31]. This is attributed to the increased energy cost for maintenance metabolism, loss of appetite (reduced feed intake) and decrease in feed digestibility and assimilation efficiency as they are temperature dependent through enzymatic kinetics [32]. It has been recognized that, digestive enzymes work better at optimal temperature and their activities increases as temperatures increase within the optimal range [33, 34, 35, 36]. Therefore, higher growth performance of fish grown at Mbarali could be attributed to desirable temperature which was within the accepted range (i.e. 25 to 35 ^{0}C) for proper growth and survival of Nile tilapia [32, 6, 8, 18].

The results for mean SGR obtained in Mbarali are in line with those reported by previous studies [37] where by, the SGR of between 3.308 and 3.513 %/day was observed when tilapia grown at an average temperature of 27.5 ^{0}C. In agreement with the findings from this study, the higher SR has been reported for Nile tilapia grown in high temperature than in lower water temperatures [8]. The higher SR in Mbarali was possibly attributed to better culture conditions throughout the experimental period, particularly the suitable average water temperature, dissolved oxygen, pH, conductivity and salinity which were in the optimal range for survival of Nile tilapia [6, 18].

However, it has been well-known that, despite of its own effects on fish growth, temperature also influences chemical reactions in water, leading to the alteration of the physical, chemical and biological properties of water [28, 29, 32, 38]. The combined effect of all these factors could have been the reason for the differences observed not only on water quality parameters, but also on fish grown performance between the two experimental locations.

5. Conclusions and Recommendation

From this study, it is concluded that, climatic conditions of an area influence water quality parameters and hence, performance of Nile tilapia. Production is higher for the fish grown in areas where temperature is relative high than in areas where temperature is low. It is recommended that, further studies be done on other fish species that would perform better in lower temperatures. Moreover, further studies should be done seeing if any alteration on management practices would have promising results; however, the economics of production must be observed.

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