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COMPARATIVE GROWTH PERFORMANCE OF MALE MONOSEX AND MIXED SEX NILE TILAPIA (*Oreochromis niloticus L.*) REARED IN EARTHEN PONDS

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ABSTRACT

Comparative growth performance of male monosex and mixed sex Nile tilapia (*Oreochromis niloticus*) was conducted in six earthen ponds each measuring 150 m^2 at the Kenya Marine & Fisheries Research Institute (KMFRI), Kegati Aquaculture Research Station. Male monosex and mixed sex of *O. niloticus* juveniles at an average weight of 12.2 ± 0.02 g and average length of 7.6 ± 0.02 cm were collected from nursery production ponds. The male monosex juveniles were obtained by feeding newly hatched juveniles with feed dosed with 17-α-methyltestosterone hormone for a period of one month. Stocking was at 3 juvenile m^{-2} and feeding was carried out using 28% crude protein diet twice daily for six months at 4% body weight. Selected water quality parameters (dissolved oxygen, temperature, pH, electrical conductivity and total ammonia nitrogen) were measured weekly *in situ*, while sampling for weight and length measurements was conducted on a monthly basis for a period of six months. Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Condition Factor (CF) and survival rate (%) were measured at the end of six months. Data were subjected to one-way analysis of variance (ANOVA). At the end of six months, the average weight of male monosex and mixed sex fishes was 200.8 ± 0.81 g (mean ± SE) and 123.4 ± 0.76 g, respectively, while the average length of male monosex and mixed sex was 22.4 ± 0.21 cm and 18.6 ± 0.23 cm, respectively. The male monosex *O. niloticus* achieved significantly increased final weight and length, SGR, FCR and CF than the mixed sex *O. niloticus* ($p < 0.05$). However, both male monosex and mixed sex fish recorded similar survival rates ($p > 0.05$). There were no significant differences in mean water quality parameters in male monosex and mixed sex ponds ($p > 0.05$). The male monosex fish performed better because most energy was spent on muscle and tissue development while the mixed sex fish spent most energy on reproduction activities at the expense of muscle and tissue development. Further studies should be done in other culture systems such as liner ponds, tanks, cages and raceways.

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INTRODUCTION

Nile tilapia (*Oreochromis niloticus* L.) is a cichlid fish native to Africa. It has been successfully farmed under a wide range of environmental conditions and is an important aquaculture fish species in many parts of the world, particularly in tropical and sub-tropical countries (El-Sayed, 2006; Dagne et al., 2013). It is considered to be one of the most productive and internationally traded food fishes in the world (Chakraborty and Benerjee, 2012; Hernandez et al., 2013; Siddik et al., 2014). Today, *O. niloticus* has become the shining star of aquaculture with many farms beginning and others expanding as consumption rate increases across the globe (Fitzsimmons, 2005; Ogello et al., 2014). The success of *O. niloticus* is related to the fact that it grows and reproduces in a wide range of environmental conditions, has a low trophic level for feeding and tolerates stress induced by handling and poor water quality (Liti et al., 2005; Tsadik and Bart, 2007; Dagne et al., 2013). It is a major delicacy for rural and urban dwellers in Kenya and is preferred in many hotels and restaurants because of its good taste, ease of cooking and the health benefits associated with eating fish (Kyule et al., 2014; Githukia et al., 2014).

However, *O. niloticus* is a paradox in reproduction; relative fecundity is low and is therefore compensated by frequent spawning and high survival rate of juveniles (Phelps and Popma, 2000). Ideally fish produced for aquaculture will not reproduce before reaching market size and from this perspective, *O. niloticus* presents some challenges to fish farmers (Munguti et al., 2014). The relatively young age of sexual maturation for *O. niloticus* leads to high birth and turnover rates (Chakraborty and Benerjee, 2012). Consequently, the rapid reproductive rate has a negative impact on growth rate, leading to stunted fish as a result of a reduction in somatic growth in favour of sexual maturation. This problem culminates in an overall reduction of growth rate at the onset of sexual maturity and precocious and excessive reproduction, leading to various sizes of small fish production which are unmarketable (Chakraborty et al., 2011) and consequent farm losses. Although males and females eat equal amounts of food, males have higher growth rate due to better food conversion efficiency (Shelton et al., 1978; Phelps and Popma, 2000). *O. niloticus* are mouth brooders and since they are filter feeders, during the breeding period the females do not feed. In addition, sex-specific differences in growth are significant where males grow significantly faster, larger and more uniform in size than females (Chakraborty and Benerjee, 2012).

Due to these challenges associated with the breeding and growth performance of *O. niloticus*, the desire of using male monosex populations of *O. niloticus* is well established for increased production potential and low management requirements (Beardmore et al., 2001; El-Sayed, 2006). Of the various techniques that have been developed to produce all male *O. niloticus* broods, hormonal sex-reversal is the most effectively and commonly used procedure (Phelps and Popma, 2000). Since newly hatched tilapia juveniles (less than 7 days post hatching) do not have a developed gonad, the hormone intervenes by directing gonadal development to produce desired male monosex populations in a process commonly referred to as sex-reversal. The 17-α-methyltestosterone is one such hormone which controls the phenotype by overriding the expression of genotypically determined sex (Pandian and Sheela, 1995). It is considered to be the most effective and economically feasible method of obtaining all male populations (Smith and Phelps 2001). Due to stimulating effects of the Kenyan government fish farming program, huge interest in fish farming has developed (Musa et al., 2012). Farmers therefore need practically demonstrated fish farming techniques aiming at maintaining high growth rate to boost income. The aim of the present study was to compare the growth performance of male monosex and mixed sex *O. niloticus* grown under semi-intensive culture system in earthen ponds, which is popular with the majority of Kenyan fish farmers.

MATERIALS AND METHODS

Fingerling collection, stocking and sampling

This study was conducted at the Kenya Marine and Fisheries Research Institute, Kegati Aquaculture Research Station, Kenya (00°42″S; 034°47″E) between April and October 2013. Six earthen ponds each measuring 150 m^2 were identified and limed at the rate of 2500 kg ha^{-1} with $CaCO_3$ and fertilized at a rate of 20 kg N and 8 kg P ha^{-1} with urea and diammonium phosphate (DAP), respectively. Male monosex juveniles were obtained by feeding newly hatched fry with feed dosed with 17-α-methyltestosterone hormone for a period of one month. This feed was prepared by mixing finely ground fresh water shrimp (*Caridina niloticus*) and wheat bran at 40% crude protein. Sixty mg of 17-α-methyltestosterone was dissolved in one liter of alcohol and mixed with one kilogram of the feed. The feed was dried under a shade for 12 hours and stored in the refrigerator at 4°C. Male monosex and mixed sex *O. niloticus* juveniles (Chwele fish farm, Kenya and Lake Victoria strain) of an average weight 12.2 ± 0.02 g (mean ± SE) and average length 7.6 ± 0.02 cm were collected from the nursery production ponds. Male monosex and mixed sex juveniles were randomly allocated to three ponds per group (total of 6 ponds). Stocking was at 3 juvenile m^{-2} and hand feeding was effected using 28% crude protein diet twice daily for six months at 4% body weight. Feeding was carried out at 1000 and 1600 hours daily.

Sampling for growth rate (total weight and length) was performed once a month from each experimental pond using a seine net. A group of 30 fish was sampled to monitor growth and adjust feed rations. The average sampling weight was used to adjust the feeding rate for the next month.

Selected key water quality parameters such as dissolved

oxygen (DO), temperature, pH, electrical conductivity and total ammonia were measured weekly using a multi parameter water quality meter, model H19828 (Hanna Instruments Limited., Chicago, IL., USA).

Evaluation of growth rate

At the end of the study, all fish from the ponds were harvested and weighed. Growth performance of the two groups of fish was evaluated by measuring final mean weight and length, Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Condition Factor (CF) and survival rate (%). The following formulae were used for the calculations, according to Ricker (1979):

SGR (%) = 100 (lnWt − lnW_0/t) where ln = Natural logarithm, W_0 = initial weight (g), Wt = final weight (g) and t = time in days from stocking to harvesting.....1

FCR = feed given (g)/body weight gain (g) 2

CF = 100W (g)/ L^b (cm), where W = body weight and L = total length and b = the value obtained from the length-weight equation.....3

Survival rate (%) = Fish stocked/Fish harvested × 100.....4

Statistical analysis

Results were expressed as means ± SE. Data were subjected to a one-way analysis of variance (ANOVA). All the statistical analyses were carried out using Statistica software (Version 10). Differences were considered statistically significant at $p < 0.05$.

RESULTS

Growth rate

Data on the growth performance, SGR, FCR, CF and survival rate of male monosex and mixed sex *O. niloticus* are presented in Table 1. Though both male monosex and mixed sex fish were stocked at the same initial weight (12.2 ± 0.02 g) and length (7.6 ± 0.02 cm) (Fig 1 and 2), at harvesting the male monosex fish had gained significantly more weight and length ($p < 0.05$) than their mixed sex counterparts. After six months, the fish attained an average weight of 200.8 ± 0.81 g and 123.4 ± 0.76 g for male monosex and mixed sex, respectively, while increase in length was 22.4 ± 0.21 cm and 18.6 ± 0.23 cm for male monosex and mixed sex, respectively. Male monosex fish had recorded faster monthly weight and length gain, whereas mixed sex fish showed a slower monthly weight and length gain (Figures 1 and 2). The SGR values obtained for male monosex and mixed sex *O. niloticus* were 1.83 ± 0.15 and 1.47 ± 0.18, respectively, suggesting that male monosex fish had a significantly higher SGR ($p < 0.05$) than the mixed sex fish.

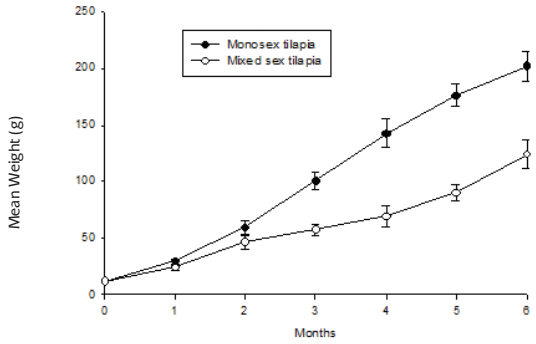

Fig 1. Monthly mean weight ± SE of male monosex and mixed sex *O. niloticus* fish

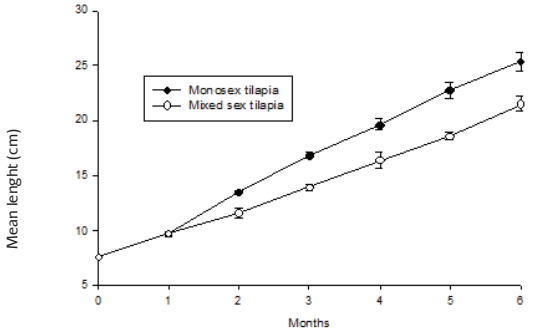

Fig 2. Monthly mean length ± SE of male monosex and mixed sex *O. niloticus* fish

In nutrient utilisation, there was a significant difference ($p < 0.05$) in the FCR between the different fish groups, with male monosex fish having a FCR of 1.51 ± 0.01 and mixed sex having a FCR of 1.98 ± 0.03. Male monosex fish had a significantly better CF ($p < 0.05$) than the mixed sex fish. However, there was no significant difference ($p > 0.05$) in the percentage survival rate between the groups of fish. Per cent survival rate of fish was 92.0 ± 0.14 and 91.8 ± 0.18 in male monosex and mixed sex fish, respectively (Table 1).

Table 1. Growth performance of male monosex and mixed sex fish during the study period (values are expressed as mean ± SE)

Variable	Male monosex fish	Mixed sex fish
Initial mean length (cm fish $^{-1}$)	7.6 ± 0.12^a	7.6 ± 0.12^a
Initial mean weight (g fish $^{-1}$)	12.2 ± 0.02^a	12.2 ± 0.02^a
Final mean length (cm fish $^{-1}$)	22.4 ± 0.21^a	18.6 ± 0.23^b
Final mean weight (g fish $^{-1}$)	200.8 ± 0.8^a	123.4 ± 0.76^b
SGR (% day $^{-1}$)	1.83 ± 0.15^a	1.47 ± 0.18^b
FCR	1.51 ± 0.01^a	1.98 ± 0.03^b
CF	1.97 ± 0.05^a	1.73 ± 0.09^b
Survival (%)	92.0 ± 0.14^a	91.8 ± 0.18^a

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

Selected water quality parameters

The mean values of selected water quality parameters in the two culture systems are given in Table 2. There were no significant differences in mean water quality parameters in male monosex and mixed sex ponds ($p > 0.05$).

Table 2. Selected water quality parameters recorded in male monosex and mixed fish ponds during the study period (values are expressed as mean ± SE)

Parameter	Male monosex fish	Mixed sex fish
Dissolve oxygen (mg L^{-1})	8.01 ± 0.09[a]	7.89 ± 0.10[a]
Temperature (°C)	23.52 ± 1.02[a]	23.61 ± 1.03[a]
pH	6.84 ± 0.01[a]	6.86 ± 0.02[a]
Electrical conductivity (µs)	82.04 ± 0.23[a]	81.97 ± 0.20[a]
Total Ammonia Nitrogen (mg L^{-1})	0.18 ± 0.01[a]	0.19 ± 0.01[a]

Values in the same row having different superscript letters are significantly different ($p < 0.05$)

DISCUSSION

The water quality data for dissolved oxygen, temperature, pH, conductivity and ammonia measured during the study period were all within the optimum range for rearing *O. niloticus* (Xu et al., 2005; Azaza et al., 2008). In addition, there was no significant environmental difference(s) between treatments ($p > 0.05$).

The results of this study revealed that growth hormone treated male monosex *O. niloticus* achieved significantly greater ($p < 0.05$) final weight and length at harvesting than mixed sex fish. These results concur with the findings of Siddik et al. (2014) who reported a final weight gain of 141.45 ± 2.54 g and 107.60 ± 2.02 g in male monosex and mixed sex *O. niloticus,* respectively, when stocked at 4.81 ± 0.20 g. Chakraborty and Benerjee (2012) also observed that male monosex *O. niloticus* reared in cages grew much faster than mixed sex *O. niloticus* under the same culture conditions. The findings of this study also corroborate a number of studies that have reported a faster growth rate in male monosex when compared to mixed sex *O. niloticus* (Mair et al., 1995; Dan and Little, 2000; Little et al., 2003; Chakraborty et al., 2011). Dagne et al. (2013) highlighted that lack of energy expenditure in egg production and mouth brooding by females and lower energy expenditure on courtship are some of the reasons behind faster growth rate in male monosex tilapia. In addition, the higher growth rate of male monosex tilapia may have been due to the influence of 17-α-methyltestosterone hormone used for sex-reversal, which has been shown to be a growth promoter in *Oreochromis mossambicus* (Kuwaye et al., 1993). Findings by Shepherd et al. (1997) also revealed that growth-promoting actions of 17-α-methyltestosterone in *O. niloticus* were linked to elevations in growth hormone metabolism and consequently to insulin-like growth factors. Male monosex fish had a significantly higher SGR ($p < 0.05$) than the mixed sex fish. Similar SGR values were reported by Dan and Little (2000) who obtained SGR estimates of 1.81 and 1.40 for male monosex and for mixed sex fish, respectively. The current SGR values are slightly higher when compared with ranges reported by Opiyo et al. (2014) who obtained SGR estimates of 1.25, 1.01 and 1.16 for *O. niloticus* stocked in earthen ponds and fed with three different feed types.

Feed conversion ratio (FCR) is an important indicator of the quality of fish feed and a lower FCR indicates better utilization of the fish feed (Mugo-Bundi, 2013). The FCR of 1.51 ± 0.01 obtained for male monosex fish means that these fish used less feed to gain more weight when compared with the mixed sex fish which had FCR of 1.98 ± 0.03. These findings are in agreement with Hossain et al. (2005) who found FCR of 1.58 ± 0.04 and 1.64 ± 0.02 for male monosex and mixed sex *O. niloticus*, respectively, when fed on formulated diet. Siddik et al. (2014) also reported a FCR of 1.71 ± 0.07 and 1.78 ± 0.03 for male monosex and mixed sex, respectively, while assessing over-wintering growth performance in ponds. The current FCR values coincided with ranges reported for *O. niloticus* ranging from 1.43 to 2.30 (Opiyo et al., 2014).

Condition factor (CF) is essentially a measure of relative bone growth and is a good indicator for the robustness and wellbeing of the fish in their habitat (Ridha, 2011). Male monosex fish had a CF of 1.97 ± 0.05 while mixed sex fish had a CF of 1.73 ± 0.09. These values are much higher than those obtained by Golam and Al-Misned, (2013) who found CF values of 1.16, 1.02 and 1.09 for male, female and mixed sex, respectively. Lower CF values indicate that fish are growing relatively in length more than in weight and have a more elongate shape, whereas higher CF values indicate that fish attain more weight as they grow in length and therefore are plumper and more marketable. Crab et al. (2009) suggested that in ponds CF values less than 1.8 are an indication of poor culture conditions, whereas CF values greater than 2 indicate good fish and culture conditions. There were better culture conditions in male monosex ponds than in mixed sex ponds.

In the present study, similar survival rates were observed in both male monosex and mixed sex culture systems. This means that treating fish with hormone does not negatively affect the survival rate. This is in agreement with findings by Chakraborty and Benerjee (2012) who observed similar survival rates in male monosex and mixed sex fish in cage culture.

CONCLUSIONS AND RECOMMENDATIONS

The results of the present study revealed that the growth performance of male monosex and mixed sex *O. niloticus*

reared under earthen pond semi-intensive culture conditions was significantly different, whereas the hormone treated male monosex fish showed higher growth rates than their mixed sex counterparts. Therefore, culturing male monosex *O. niloticus* will enable fish farmers to attain more body weight of fish within a relatively shorter period of time. The growth performance of fish directly affects the profit margins for semi intensive and intensive systems. Therefore, the use of all male monosex fingerlings for grow-out stages is encouraged. The research team further recommends related studies to be tested in other culture systems such as liner ponds, tanks, cages and raceways.

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Sažetak

USPOREDNA PERFORMANSA RASTA MUŽJAKA ISTOG SPOLA I MJEŠOVITOG SPOLA NILSKE TILAPIJE (*Oreochromis niloticus* L.) UZGAJANIH U ZEMLJANIM RIBNJACIMA

Usporedna performansa rasta mužjaka istog spola u odnosu na mješoviti spol Nilske tilapije (*Oreochromis niloticus*) provedena je u šest zemljanih ribnjaka veličine 150 m^2 u Kenijskom institutu za istraživanje mora i ribarstva (KMFRI), Akvakulturna stanica u Kegatiju. Nedozrele jedinke mužjaka istog spola i mješovitog spola *O. niloticus* prosječne mase 12,2 ± 0,02 g i prosječne dužine 7,6 ± 0,02 cm prikupljene su iz mladičnjaka. Nedozrele jedinke mužjaka su dobivene hranjenjem novoizleglih ličinaka s hranom doziranom hormonom 17 -metil-testosteronom u razdoblju od mjesec dana. Nasad je proveden u gustoći od 3 mladunca / m^2 i hranidbom od 28% sirovih proteina dva puta dnevno tijekom šest mjeseci na 4% tjelesne težine. Odabrani fizikalno-kemijski parametri vode (otopljen kisik, temperatura, provodljivost i ukupni amonijak) mjereni su tjedno *in situ,* dok su izmjere dužina i masa provedene na mjesečnoj bazi tijekom 6 mjeseci. Specifična stopa rasta (SGR), omjer konverzije hrane (FCR), kondicijski faktor (CF) i stopa preživljavanja (%) izmjereni su na kraju perioda od šest mjeseci. Podaci su analizirani jednosmjernom analizom varijance (ANOVA). Na kraju promatranog perioda od 6 mjeseci, prosječna težina mužjaka istog spola iznosila je 200,8 ± 0,81 g (prosjek ± standardna devijacija) i mješovitog spola 123,4 ± 0,76 g, a prosječna dužina mužjaka istog spola iznosila je 22,4 ± 0,21 cm i mješovitog spola 18,6 ± 0,23 cm. Mužjaci istog spola *O. niloticus* postigli su značajno veću konačnu težinu i dužinu, SGR, FCR i CF nego mješoviti spol ($p < 0,05$). Međutim, kod obje skupine zabilježene su slične stope preživljavanja ($p > 0,05$). Nije zabilježena značajna razlika u kvaliteti mjerenih parametara u vodi ribnjaka promatranih skupina riba ($p > 0,05$). Mužjaci istog spola imaju bolje rezultate jer je većina energije potrošena na mišiće i razvoj tkiva, dok je mješoviti spol trošio najviše energije na reprodukcijske aktivnosti na račun mišića i razvoj tkiva. Daljnja istraživanja bi trebala biti usmjerena ka drugim sustavima uzgoja poput obloženih ribnjaka, zatvorenih bazena, kaveza i protočnih kanala.

Ključne riječi: mužjaci istog spola, mješoviti spol, Nilska tilapija, performansa rasta

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