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EVALUATION OF GROWTH AND REPRODUCTION CAPACITY OF THREE STRAINS OF NILE TILAPIA, *OREOCHROMIS NILOTICUS*, FOUND LOCALLY IN KENYA FOR USE IN AQUACULTURE

Tenth Work Plan, New Aquaculture Systems/New Species Research 4A (10NSR4A)
Final Report

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ABSTRACT

In a series of experiments, the performance of three strains of Nile Tilapia, *Oreochromis niloticus,* was evaluated in 0.015 ha earthen ponds at Sagana Fish Farm. The strains were acquired from Lake Victoria, Lake Turkana, and Sagana fish farm. The first experiments were conducted from June 2002 to May 2003 and the other from October 2003 to April 2004. Nine ponds were limed at 3.3 tons/ha and treated weekly with urea and di-ammonium phosphate (DAP) at rates of 20 kg N/ha and 8 kg P/ha. The brood stock was conditioned in the ponds, and the F1 generation for each strain was produced. The experimental ponds were stocked with fry from the broodstock strains at 70,000 fry/ha, and raised from 0.5g to between 6-7g for a period of 66 days; their growth performance and survival were evaluated. The 6g frys were harvested and restocked at 50,000 fish/ha and further raised to 22g fingerlings. Later the 22g fingerlings were hand-sexed and the male *O. niloticus* post fingerlings from each strain were stocked at 20,000/ha. Their growth performance was then compared under two different feeding regimes. Relative ficundity was evaluated by counting fry from the bucal cavity of females from a broodstock that was placed in cages. Victoria strain had the highest growth performance, survival and relative fecundity while Turkana and Sagana strains had lower but similar performance. Sagana strain recorded the lowest survival and relative fecundity. The sex ration of the Sagana strain was highly skewed towards females while the wild strains had sex ratios close to I:1. The results of the present study revealed that the Victoria strain was the fastest grower and survivor while the Sagana strain was a inbred strain.

INTRODUCTION

Development of aquaculture in sub-Saharan Africa is hampered by lack of good quality seeds (Leberg, 1990; Moreira et al. 2000). This scarcity is acute in rural areas where hatchery facilities are not available. The group of fishes known as tilapia (Cichlidae: Tilapiine) is endemic to Africa, Israel, and Jordan (Balarin & Hatton, 1979; Beveridge & McAndrew, 2000; Chimit, 1955 Philippart & Ruwet, 1982; Trewavas, 1983). However, in the last century, Tilapias have been introduced throughout the world mainly for food, a process that has led to deterioration of its quality (Teichert-Coddington & Smitherman, 1988). Poor fish management practices has also been reported to be the basis for the deterioration in the quality of *Oreochromis niloticus*. It is widely reported that inbreeding in fish results in significant depression in fish performance (Gjerde, 1988; Bondari and Dunham 1987; Galman et al., 1988; Leberg, 1990; Moreira, et al., 2000). This depression results from the loss of genetic diversity in poorly managed breeding programmes (Vrijenhoek, 1998), hence the growth rate, survival rate and reproduction activities are adversly affected. Some breeding programmes produce skewed sex ratios, which accelerate inbreeding (Vrijenhoek, 1998), and in such circumstances, fish fail to attain market sizes within a production cyle. The ability to reproduce and overpopulate culture facilities constitutes a salient feature of the

biology of *Oreochromis niloticus* (Msiska, 1988; Mair, 1995; Fitzsimmons, 1997).

Nile Tilapia, *Oreochromis niloticus* (Linnaeus), has been the most extensively studied species among the tilapias because of its fast growth and the ability to utilize a wide variety of cheap feeds, both formulated and natural food organisms, including plankton, green leaves, benthic organisms, bacterial films, aquatic invertebrates and detritus (Teichert-Coddington et al., 1997; Fitzsimmons, 2000; Lovshin, 2000). Selection of superior strains and maintenance of their purity is important for *Oreochromis niloticus* producers (Bhujel, 2000), who require seeds of high quality. Studies on selection in *O. niloticus* strains have been done by a number of investigators (Uraiwan and Phanitchai 1986; Teichert-Coddington 1983; Hulata et al., 1986; Bolivar et al. 1993; Eknath et al., 1993). However, inadequate research has been undertaken in the selection on *O. niloticus* strains in Africa. In Kenya, no comparative evaluation has so far been made on the growth and reproductive performance of the locally available strains of *O. niloticus* from different localities within the country. This study was designed to compare the growth and reproductive performance of *O. niloticus* strains from lake Victoria, lake Turkana and Sagana. Sagana strain' in this text will be used as a nominal name for a group of Nile tilapia that has been cultured at the Sagana Fish farm for the last ten years. Over these years, this fish has been used for research and production programs. The origin of the fish was lake Turkana via Baobab Farm, Mombasa, Kenya.

METHOD AND MATERIALS

This study was conducted at Sagana fish farm which is located 2.6 km north west of Sagana town and 105 km to the northwest of Nairobi. The farm is located at 1,231m above mean sea level at coordinates $0^0$19'S and $37^0$12'E. Water was supplied to the farm by gravity from Ragati River through a 1.5 km long canal .

Three strains of the Nile tilapia, *Oreochromis niloticus* were acquired from lake Victoria, lake Turkana and Sagana fish farm and used for the experiment. Victoria strain was obtained from Ndunga bay using cast nets between 20.00 and 1.00 hours. Part of Victoria strain also came from Kibos fish farm at the shores of lake Victoria where they had been kept for a year. Turkana strain was seined from the Fugerson's gulf of lake Turkana, close to the Longech spit beaches. The weight of individual fish for the starting brood stock ranged from 50 to 200g for all the strains.

Before the start of the experiment, fish were stocked in three blocks with each block comprising three ponds for each strain, with each block separated from others by empty ponds to prevent mixing of the strains. The broodstocks were fed on wheat bran and allowed to grow and reproduce in the ponds. After each spawning the pairs of sexes in ponds was exchanged among ponds within each strains. The resulting F1 fry of each strain was graded using different size graders (plastic basket with mesh (7mm x 10 mm) and wire mesh (5 mm x 5 mm)), and hapa nets (1 mm x 1 mm). The frys were consequently, based on weight separated in to small (0.5g), medium (1.0g) and large (1.5g). The small size (0.5g) frys were used for the experiments because the number of other sizes was not adequate in number to start the experiment.

This study involved four experiments which were conducted in two phases in 0.015ha ponds. In the first phase which had two experiments, 0.5g fish fry were stocked at a rate of 70,000/ha and raised to weights between 6 and 7g and their growth performance was monitored and compared among the three strains. In the second experiment of phase one, the 6-7g fry were stocked at 50,000/ha and raised to fingerlings (25-32g). In the first phase, the experimental ponds received the normal fertilization rates while fish were fed with wheat bran at 1.5% body weight. The performance of the strains was evaluated and compared among strains.

In the second phase, two experiments were conducted based on two different feeding strategies.

In the first experiment of this phase hand-sexed fingerlings were grown using organic manure and cassava leaves and their performances in terms of growth and survival compared among strains. The fish were fed on fresh cassava leaf meal at 10 % body weight, but later the feeding rate was adjusted upwards to 31% to cater for the weight of leaf stalks that were not consumed by the fish. The unconsumed leaf stalks were removed from ponds at 8.00 hrs the following morning, prior to the application of next batch of leaves at 10.00hrs.They were weighed to determinethe actual amount of leaf-meal consumed by the fish. The ponds were also fertilized weekly with dry cow manure at the rate of 250 kg per hectare. The second experiment in the second phase phase involved raising the strains fingerlings in ponds treated with inorganic fertilizaters of urea and DAP at 20kgN/ha and 8kgP/ha and supplemented with wheat bran at 1.5 % of body weight. All the experiments were conducted in completely randomized design (Zar, 1996) with three replicate ponds. The reproductive capacity of the strains was evaluated and compared among strains by holding males and females for each strain at a ratio of 1:2 in three replicate cages per strain.

Fish were sampled biweekly to monitor fish growth and make adjustment for the daily feed ration. Fish in each pond were seined, counted and batch weighed. Data on lengths and weights were measured and used to calculate length-weight relationship. Relative condition factor (Kn) was calculated from adjusted mean

weights using covariance. Samples for water quality were obtained using a 1 m long column sampler Boyd & Tucker, 1992). Water samples were taken from three different points in the experimental ponds between 7.00 a.m and 8.00 a.m and and mixed in a bucket. From the mixed water sample, sub-samples were drawn for analyses of water quality variables. The water quality variables were analyzed biweekly and included alkalinity and other nutrients including NO_2-N, NO_3-N, PO_4-N, total ammonia nitrogen (TAN) and chlorophyll *a*. The nutrients were analyzed as described in APHA (1989) while temperature and dissolved oxygen measurements were obtained by using YSI model 57 meters. pH was measured by glass electrode, Hi-9024 microcomputer. Chlorophyll *a* was determined by a method described by Boyd and Tucker (1992). A 25-cm Secchi disk was used to determine transparency.

The results were analyzed using Statigraphics Plus for windows (version 2.1, 1994-1996). One-way analysis of variance was applied to determine significant differences and multiple range test to determine which means were different from each other. Significant differences were decleared at 0.05.

RESULTS

First Phase

Results of the first fry culture in fertilized ponds are shown in Table 1. There were no significant differences ($P > 0.05$) in mean fish weight and growth but significant differences ($P < 0.05$) were observed in percent survival of the fry among the three treatments. Victoria and Turkana strains had the highest survival while Sagana strain had significantly lower ($P < 0.05$) survival than Victoria and Turkana strains. Turkana strain had significantly higher ($P < 0.05$) condition factor than Victoria and Sagana but the latter pair had similar values ($P > 0.05$). All the strains maintained a steady weight increase with approximately linear growth (Figure 1).

Table 2 presents data on the water quality variables monitored during the first experiment. All the water quality variables which were monitored during the study period were not significantly different ($P > 0.05$) among treatments.

The water quality parameters are shown in Table 4.

Grow-Out With Organic Matter and Cassava Leaves

There were significant differences in mean weight of the fish among treatments ($P < 0.05$).The mean weights of the fish over the experimental period are depicted in Figure 2 Turkana strain had the least performance, while Sagana strain and Victoria strain had higher weight tan the former. At 65 days post stocking, clear differences in weight gain emerged, with Victoria strain taking a clear lead. At the time of harvest, 128 days post stocking, Victoria strain led with a mean weight of 87.93 ± 2.70 g, which was significantly different. Sagana strain followed with a mean weight of 72.80 ± 2.70 g. Turkana was last with a mean weight of 67.60 ± 2.70 g which was significantly different from Victoria but similar to Sagana.

A total of 1218 fish of Sagana strain were hand-sexed, and after sexing, only 440 fish were males. This translated in to female domination ratio of 2:1. From 1781 fish of Turkana strain sexed, at the end of the second experiment, 826 were males and 955 females, a sex ratio of near 1:1. Similarly for Victoria, a total of 1,675 fish gave 839 males and 836 females also with a 1:1 ration.

Egg-brooding females were first observed in the Sagana strain 59 days or five months after stocking. In Victoria strain, eggs were observed 74 days after stocking, while in Turkana strain, brooding females were observed 89 days after stocking. The corresponding mean weights of females at first spawning were 22.6 g, 23.9 g and 23.2 g for Sagana, Victoria and Turkana strains respectively. There were significant differences ($P < 0.05$) in ficudity among strains. Victoria strain had the highest ficudity (4.6 ± 0.19) followed Turkana strain (2.8 ± 0.17) while Sagana had significantly the least ficundity (2.0 ± 0.3).

There were no significant differences in the condition factor among treatments ($P > 0.05$). Sagana strain had the highest condition factor of 2.87 ± 0.39 which is closer to 3, followed by L.Turkana strain with kn of 2.81 ± 0.08. L.Victoria was last with kn of 2.67 ± 0.0.08.

Water Quality

The results of inorganic fertilizer-wheat bran feeding regime are shown in Table 6. Victoria strain had significantly higher ($P < 0.05$) mean weight and growth rate. Sagana and Turkana had statistically similar mean weights ($P > 0.05$) but significantly lower than those for Victoria strain.

DISCUSSION

In the first experiment of phase, all the strains had similar growth performance. The ability of an individual to out compete the others becomes apparent when food and environmental factors become limiting. During the early stages of growth in the present study, it appears that fish frys had enough supply of natural food while the water quality was not limiting. Thus, differences in growth may not have been expected to occur. In the second experiment in phase one, the growth performance was significantly different among all strains with Turkana strain recording the lowest and Sagana the highest growth performance. However, the survival of the Sagana strain was low and therefore, the higher growth

in this strain may have occurred due to low density of fish in the ponds. In the first experiment of phase one, the growth performance was also significantly different among strains, with Turkana strain recording the lowest while Victoria and Sagana had the highest and similar growth performance The results of this study demonstrates that Victoria strain is the most superior in terms of growth among all the strains studied. Significant differences in growth performance of the strains in this experiment demonstrates aan environmental and genetic influence on the growth performance of the different strains.

Turkana strain, a wild strain recorded consistedly lower growth performabce compared to Sagana strain. This is observation differs somewhat from the findings of Eknath et al. (1991), who observed better performance with the *O. niloticus* strains collected from the wild than the domesticated ones. Turkana and Sagana strains were originally residents of the lake Turkana. However. Turkana strain had a similar growth performance to Sagana strain, contrary to the above expectation. This may be attributed to the fact that while Sagana strain had been domesticated in ponds at Sagana Fish Farm for ten years, while.Turkana strain was collected from the Ferguson Gulf and immediately used for this experiment. During this period, there are higher chances that the Sagana strain could have crossed with other locally available species of tilapia, which had improved its growth performance. Some fan tail banding characteristics of *Oreochromis spirulus* have been observed in Sagana strain. This observation suggests that Sagana strain is no longer the pure strain it used to be ten years ago. The effects of inbreeding in *O. niloticus* strain has also been reported. Hulata (2000), reported the failure of a local strain of *O. niloticus* in Viet nam to reach the minimum commercial size of 100 to 200 g within the normal growing season. The authors attributed this to high level of inbreeding which led to substantial decline in the yields and availability of quality tilapia stocks.

During the present study, a total of 1,218 fish of Sagana strain were hand-sexed, and after sexing, only 440 fish were males. This translated in to female domination ratio of 2:1. From the 1,781 fish of Turkana strain sexed, at the end of the second experiment, 826 were males and 955 females, a sex ratio of near 1:1. Similarly for Victoria, a total of 1,675 fish gave 839 males and 836 females also with a 1:1 ration. This highly skewed sex ratio in the Sagana strain towards females could be attributed to a compensatory mechanism to counter the effects of routine hormonal application to obtain an all-male population. It is, therefore, likely that without sex reversal, the Sagana, strain will produce more females than males. The unbalanced contribution of males and females to form the next generation enhances inbreeding (Moreira et al. 2000). It is apparent that, if this was allowed to go on for long, inbreeding would cut across many generations of *O. niloticus* in Sagana fish farm with unprecedented declines in fish yields.

During fecundity evaluation, egg-brooding females were first observed in the Sagana strain 59 days or five months after stocking. In Victoria strain, eggs were observed 74 days after stocking, while in Turkana strain, brooding females were observed 89 days after stocking. The corresponding mean weights of females at first spawning were 22.6 g, 23.9 g and 23.2 g for Sagana, Victoria and Turkana strains respectively. In natural waters (rivers, lagoons and lakes), *Oreochromis niloticus* maintains a steady growth over a span of two to three years (Kolding, 1993), achieving a total length of 50 cm and body weight of 7,000 g (Moreau et al. 1986; Pauly, et al. 1988). Furthermore, this maximum size was reported to decreases with the decrease in the size of the watermass inhabited (De Silva, 1986; Duponchelle and Panfili, 1998).

Deterioration in the quality of Nile tilapia strains, in which a physiological switch from somatic growth to reproductive growth at a tender age, is a common, but poorly understood phenomenon (McConnell, 1982; Little and Hulata, 2000; Lorenzen, 2000). At this small size of maturity, Nile tilapia reproduces every 3 to 6 weeks, a process in which energy is allocated to gamete production and spawning behaviour. Such high spawning frequency reduces the growth of fish, and it becomes a rarity for the fish to attain market size in a reasonable culture time. The early maturation for all the strains observed in the present study suggests that domestication in small fish ponds may have accelerated the rate of sexual maturity.

The growth performance of *O. niloticus* strain from lake Victoria in all the trials except in second experiment of phase 1,was more superior than the other strains. However, higher growth rate of the Sagana strain in one of the experiments may be attributed to the lower survival rate in this treatment. The growth rates recorded in this study were lower than those observed by Khater & Smitherman (1988), in a study which evaluated three strains of *O. niloticus*. In that experiment, males from Egyption strain grew at 1.63g/day; Ivory Coast at 1.50 g/day and Ghana strain at 1.35 g/day. Elghobashy et al. (2000), evaluated the growth of four strains of *O. niloticus* under different farm conditions in Egypt and obtained higher growth rates than in the present study. The differences between the growth rates of the present study and those of the previous studies may be attributed to differences in hybridization and other environmental conditions. In rice fields, Elghobashy et al. (2000) observed growth rates that were comparable to those obtained in the current study. Although there was no supplementary feeding in the rice plots, fish grew fast, and this could be an attribute of a rich natural food resource including aquatic insects, snails and plankton populations which are prevalent in inun-

dated rice fields and irrigation channels.

CONCLUSIONS

Victoria strain had the highest performance. L.Turkana and Sagana strain recorded similar mean harvest weight and the latter revealed a highly inbred strain.

ANTICIPATED BENEFITS

It is envisaged that the research-based information generated by this study will recommend the best strain for higher yields with locally available inputs. This expected to stimulate interest in commercial tilapia production among the resource poor rural farmers in Kenya and the East African region at large. Also it is expected that adoption of the results will enhance income generation as well as house hold food security in the region. The aquaculture research and extension fraternity in biodiversity conservation will develop a protocol for the identification of strains of *O.niloticus* and other fish species for use.

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Table 1. Fry performance of the three strains of *O. niloticus* during the first phase (mean±SEM).

Parameter	Treatments		
	Turkana	*Victoria*	*Sagana*
Mean Weight (g)	6.5 ± 0.82a	6.8 ± 0.71a	7.2 ± 0.71a
Growth Rate (g/ day)	0.1± 0.01a	0.1 ± 0.01a	0.10 ± 0.01a
Survival (%)	82.92 ± 2.81ab	89.8 ± 2.43a	80.48 ± 2.43b
Kn	3.70 ± 0.29a	2.8 ± 0.25b	2.89 ± 0.25b

Means with the same letters in a row are not significantly different. .SEM = Standard Error of Mean.

Table 2. Mean water quality variables in three treatments for experiment 1 phase 1 (±SEM).

Variable	Treatments		
	Turkana	*Victoria*	*Sagana*
Total alkalinity	51.33± 7.38ab	63.90 ± 6.39b	58.45 ± 6.39b
Soluble reactive phosphorus	0.15 ± 0.06a	0.14 ± 0.06a	0.18 ± 0.06a
Total nitrogen	0.60 ± 0.15a	0.61 ± 0.15a	0.63 ± 0.15a
NO_2-N	0.014 ± 0.01a	0.014 ± 0.01a	0.02 ± 0.01a
Chlorophyll-a	89.67 ± 18.16a	96.25 ± 15.73a	60.0 ± 15.73a
Temperature ^{0}C	22.02 ± 0.25a	22.06 ± 0.25a	22.20 ± 0.25a
Temperature ^{0}C	24.54 ± 0.59a	24.94 ± 0.59a	25.02 ± 0.59a
Dissolved oxygen	4.41 ± 0.84a	3.96 ± 0.84a	4.18 ± 0.84a
Dissolved oxygen	8.37 ± 1.32a	8.66 ± 1.32a	8.38 ± 1.32a
Secchi depth	29.10 ± 4.31a	27.7 ± 4.31a	25.87 ± 4.31a
pH	7.97 ± 0.36a	8.12 ± 0.36a	8.93 ± 0.36a
pH	8.82 ± 0.38a	8.92 ± 0.38a	9.51 ± 0.37a

Means with the same letter in a row are not significantly different, DO= dissolved oxygen,Temp.= Temperature.

Table 3. Fingerling harvest mean weight of O. niloticus strains.

Variable	Treatments		
	Turkana	*Victoria*	*Sagana*
Harvesting mean weight (g)	22.85 ± 1.17a	27.0 ± 1.17b	31.43 ± 1.17c
Growth rate (g/day)	0.17 ± 0.01a	0.2 ± 0.01ab	0.23 ± 0.01b
Survival (%)	84.0 ± 3.10b	84.98 ± 3.10b	57.02 ± 3.10a
Kn	2.00 ± 0.39a	2.67 ± 0.39a	3.00 ± 0.39a

Means with the same letter in a row are not significantly different.
SEM is the Mean Standard Error.

Table 4. Mean Water quality parameters (±SEM) for the treatments.

Parameter	Treatments		
	Turkana	*Victoria*	*Sagana*
Total alkalinity	43.37 ± 8.04ab	44.21 ± 8.04ab	47.98 ± 8.04a
SRP	0.01 ± 0.01a	0.0 ± 0.01a	0.00 ± 0.01a
TAN	0.09 ± 0.03a	0.09 ± 0.03a	0.60 ± 0.03a
NO_2-N	0.01 ± 0.004a	0.00 ± 0.004a	0.01 ± 0.004a
Chlorophyll *a*	62.33 ± 12.47a	50.56 ± 9.66a	63.9 ± 9.66a
	40.13 ± 9.17a	38.62 ± 7.10a	50.44 ± 7.10a
Temp.°cmorning	23.85 ± 1.05a	23.81 ± 1.05a	23.67 ± 1.05a
Temp.°c_afternoon	27.30 ± 0.30a	28.45 ± 0.30b	28.10 ± 0.30ab
DO_morning	3.57 ± 0.68a	3.30 ± 0.68a	3.50 ± 0.68a
DO_afternoon	6.51 ± 0.83a	7.10 ± 0.83a	7.71 ± 0.83a
Secchi depth	26.50 ± 2.80a	24.87 ± 2.80a	19.23 ± 2.80a
pH morning	7.77 ± 0.29a	7.63 ± 0.29a	7.88 ± 0.29a
pH afternoon	8.09 ± 0.45a	8.21 ± 0.45a	8.51 ± 0.45a

Means with the same letters in a row are not significantly different. Dissolved oxygen, Temp.=Temperature.

Table 5. Results of fish growth on organic matter supplemented with cassava leaves regime.

Variable	Treatments		
	Turkana	*Victoria*	*Sagana*
Mean Weight (g)	67.6 ± 2.69a	87.9 ± 2.69b	72.8 ± 2.69a
Growth Rate (g/ day)	0.28 ± 0.02a	0.44 ± 0.02b	0.33 ± 0.02a
Survival (%)	84.8 ± 3.89a	90.40 ± 3.89a	87.33 ± 3.89a
Kn	2.81 ± 0.08a	2.67 ± 0.0.08a	2.87 ± 0.39a

Means with the same letters in a row are not significantly different.
SEM is the Mean Standard Error.

Table 6. Results of fish growth on inorganic fertilizer supplemented with wheat bran.

Parameter	Treatments		
	Turkana	*Victoria*	*Sagana*
Mean Weight (g)	141.2± 6.74a	184.5± 6.74b	150.1 ± 6.74a
Growth Rate (g/ day)	0.8± 0.03a	1.0 ± 0.03b	0.8 ± 0.03a
Survival (%)	74.3 ± 3.53a	76.1 ± 3.53a	74.7 3.53a

Figure 1. Growth curves of L.Turkana (TRT 1), L.Victoria (TRT 2) and Sagana (TRT3) strains.

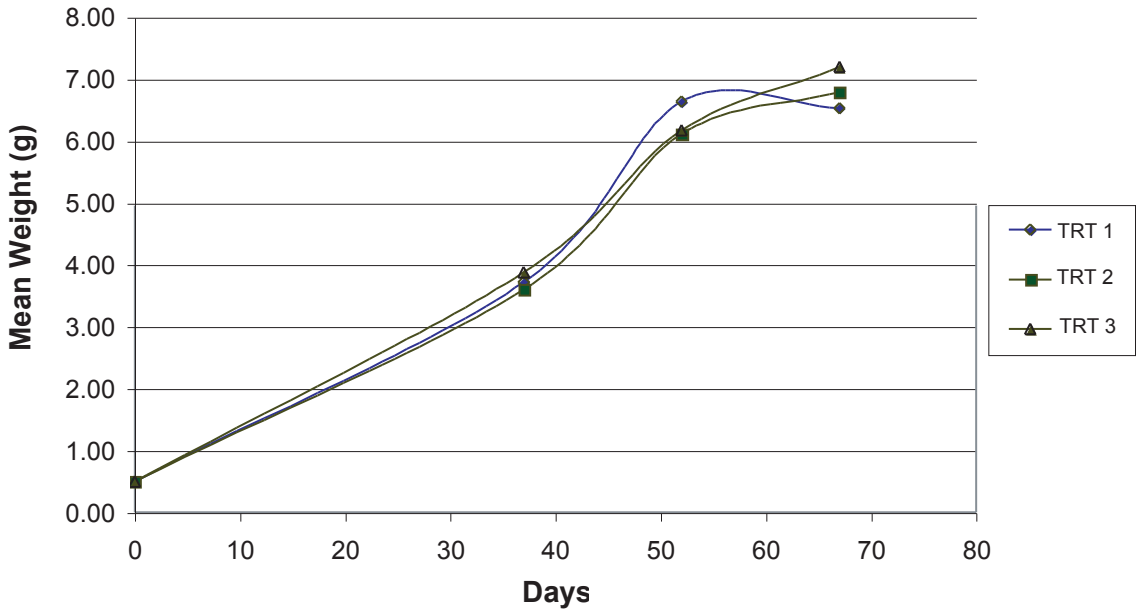


Figure 2. Growth curves of Turkana (TRT 1),.Victoria (TRT 2) and Sagana (TRT3) strains.

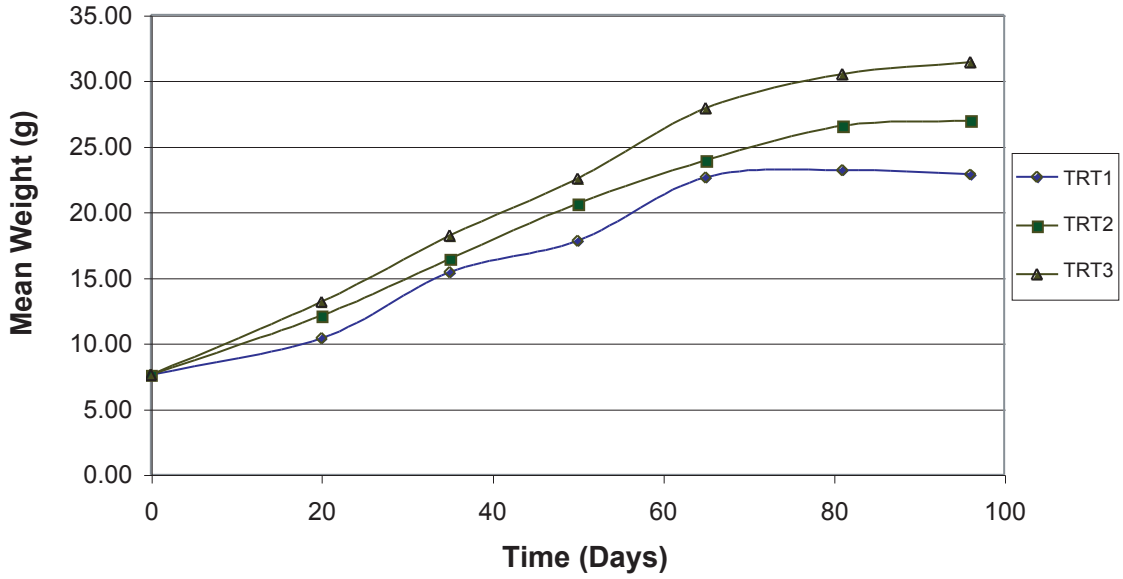


Figure 3. Growth curves for different strains on Nile tilapia *O. niloticus*.

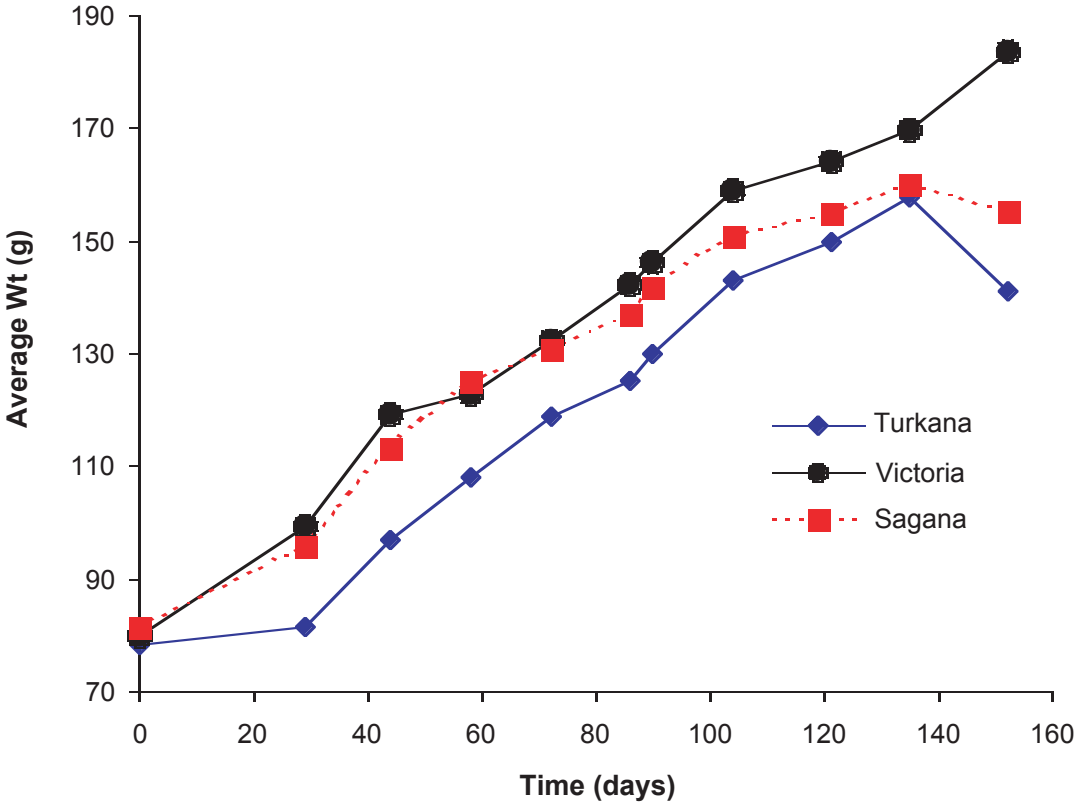
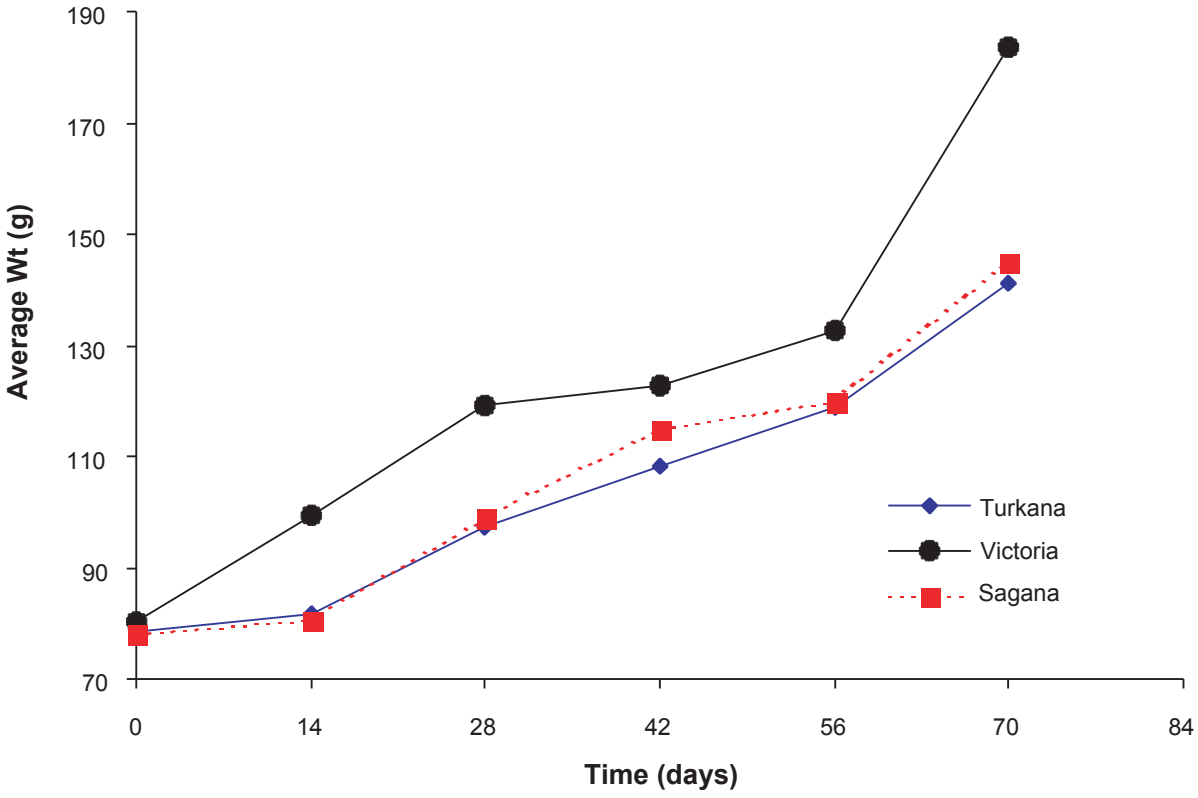


Figure 4. Growth curves for different strains of Nile tilapia *Oreochromis niloticus*.



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