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ORIGINAL ARTICLE

On-farm growth performance of different strains of tilapia, *Oreochromis niloticus* reared in earthen ponds

Jacob Abwao[1,2] | **Domitila Kyule**[1] | **Joseph O. Junga**[2] | **James E. Barasa**[3] | **Dorcus A. Sigana**[4]

[1]Kenya Marine and Fisheries Research Institute, Sagana Aquaculture Centre, Sagana, Kenya

[2]Department of Animal production, University of Nairobi, Nairobi, Kenya

[3]Department of Fisheries and Aquatic Sciences, University of Eldoret, Eldoret, Kenya

[4]Department of Biology, University of Nairobi, Nairobi, Kenya

Correspondence
Jacob Abwao, Kenya Marine and Fisheries Research Institute, Sagana Aquaculture Centre, Sagana 451–10230, Kenya.
Email: Abwao.jacob@gmail.com

Abstract

The growth of aquaculture sector in Kenya has been anchored on farmed Nile tilapia *Oreochromis niloticus*. Different strains of the species exist in Kenya with unknown quality due to lack of stock improvement programmes coupled by variations in breeding and management practices in different hatcheries. The seeds supplied to farmers have not exhibited good performance and resilience to changing climate. There is need to validate the quality of strains supplied to fish farmers in Kenya. This study sought to compare the growth performance of three strains of farmed Nile tilapia; Sagana strain (SAG-F8) produced through selective breeding, super YY strain (KAM-YY) from Kamuthanga fish farm and the local strain (LOC-T) obtained from Siaya County. The fish were stocked in fertilised earthen ponds measuring 300 m^2 in triplicates at 3 fish/m^2. The fish were fed on 35% crude protein diet for 180 days at Bukani Aquapark located in Busia County, Kenya. There was no significant difference in mean weight gain (MWG) between SAG-F8 and LOC-T strain exhibiting 159.786 ± 6.76 g and 158.623 ± 4.67 g, respectively. However, under similar conditions, the KAM-YY strain had a significantly lower MWG (131.74 ± 4.75 g) compared to the two strains. Food conversion ratio (FCR), specific growth rate (SGR) did not demonstrate any significant difference among the different strains. The body protein content in the SAG-F8 fish strain was higher (65.40 ± 0.20%) followed by LOC-T strain (61.23 ± 2.34%) and lastly KAM-YY strain had the lowest (60.37 ± 0.89%). In this study, the impact of genetic improvement has been demonstrated to influence growth and feed efficiency as well as body composition. These improved strains will substantially increase fish production and productivity, hence, a positive impact on the fish farmers' livelihoods when supplied to the farmers and seed multipliers.

KEYWORDS
aquaculture, genetics, productivity, strain, tilapia

1 | INTRODUCTION

Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) is the most widely cultured tilapiine species, due to its fast growth rate, high fecundity and survival, tolerance to diseases, ability to feed on diverse food materials, and tolerance of a wide range of environmental variables (Liping & Fitzsimmons, 2011). The species is also known to exhibit high genetic diversity, which is significant for breeding heterosis. The native range of the species is the Niilo-Sudanian ichthyologic province, extending from the Nile waters of Ethiopia and Kenya (Trewavas, 1983), to the Niger, and the lakes and streams once historically associated with these (Nyingi & Agnèse, 2007). Global average annual production of farmed tilapias has exceeded 6 million tonnes (MT), placing tilapia as the second most farmed fish after carps in the world with a further projection of 7.3 MT by 2030 (FAO, 2020). China alone accounts for more than 30% of the world tilapia production. The bulk of farmed tilapias are also produced in Asia, with some notable producing countries including Indonesia, India, Vietnam and Bangladesh. This is mainly because these countries use improved strains, especially the Genetically Improved Farmed Tilapia (GIFT), that is now widely adopted by farmers. Several improved strains of the species are also used in different countries, including the Genetically Enhanced Tilapia 2000 (GET 2000), Genetically Enhanced Tilapia with Excellent qualities (GET-EXCEL 2002), GenoMar Supreme Tilapia (GST) and the Freshwater Aquaculture Centre (FAC) Selected Tilapia (FAST) (Ponzoni et al., 2011). These strains exhibit different levels of superior growth relative to unimproved strains, leading to high tilapia production (Ponzoni et al., 2011).

The most elite improved strain of *O. niloticus* is the GIFT established in 1988 through a collaborative research approach involving Asian development bank (ADB) and other institutions in Asia. The programme was executed by the International Centre for Living Aquatic Resources Management (ICLARM) and AKVARFOSK in Norway (Ekanth et al., 1998). The GIFT project helped increase annual farmed production in the Philippines by 186% between 1990 and 2007, reduced production costs by 32 to 35% and increased employment opportunities by 45–64% (ADB, 2005). The reason for this high performance was the strong genetic variation of the base population of GIFT strain, due to the incorporation of all the genotypes used as founders (Eknath et al., 1993), which increased the vigour of the strain for growth. Over time, the GIFT strain has undergone selective breeding in many generations, substantially increasing genetic gain by 10–15% per generation (Ponzoni et al., 2011) in many countries of Asia, which is comparable to the gain made in the livestock industry.

Despite being the source of the natural germplasm for tilapia used globally by farmers, annual cultured tilapia production in Africa is low, mainly because of use of unimproved strains. This is further compounded by uncontrolled transfer of tilapia strains across regions or basins, hybridisation among tilapia species (Shechonge et al., 2018), that yields viable hybrids (Bradbeer et al., 2019) and introgression (Bartley et al., 2022). These, coupled with poor husbandry practices, especially poor quality feeding regimes and poor management of brood stock, create considerable managerial challenges for farmers. Except for Egypt which is the lead producer of farmed tilapias in Africa and the third largest producer globally with 1,150,000 million tonnes, most of the African countries produce less than 110,000 tonnes each annually (FAO, 2020). After Egypt are Uganda, Zambia, Nigeria, Kenya, Malawi, Tanzania and South Africa as other notable producers of farmed tilapias. However, in East Africa, enormous potential exists to increase farmed tilapia production substantially, to bridge the gap occasioned by declining tilapia landings from Lake Victoria as well as other inland fisheries. Tanzania, for instance, harbours a spectacular natural diversity of *O. niloticus* strains, as well as other tilapia species such as *O. leucostictus*, *O. urolepis* and *O. shiranus* (Kajungiro et al., 2019; Shechonge et al., 2018). These constitute unique genotypes, which may harbour suitable traits for culture, and if well harnessed, could help increase production. Mbiru et al. (2021) reported faster growth rate and weight gain by improved strains over nonimproved strains in Tanzania, in the absence of or limited genetics by environmental (G*E) interaction. These research efforts have partly contributed to increased annual production of farmed tilapias in Tanzania, with figures rising from 3613 tonnes in 2015 to 17,254 tonnes in 2020 (URT, 2020). On the other hand, Uganda annual aquaculture production is estimated at 35,000 tonnes. This production is linked to increased cage culture of tilapia in Lake Victoria by foreign and local investors (LARIVE International, 2022). Furthermore, access to quality fingerlings and strong regulatory frameworks has been key in stimulating aquaculture growth in Uganda.

The current aquaculture production in Kenya is approximately 19945 tonnes (Kenya National Bureau of Statistics, 2020). Nile tilapia production is approximately 14,952 tonnes representing 75% of the total production (FAO, 2020). This production has been on a steady increase since 2012 when the National Fish Farming Enterprise Productivity Program which increased interest of farmers in fish production. Total farmed tilapia production could increase substantially, if the current opportunities such as tilapia cage culture in Lake Victoria are fully exploited. One way of ensuring this is the adoption of improved strains by cage culture farmers, especially since seeds from improved strains often show higher survival, and so could help reduce mortality of seed stocked in cages, which is currently a challenge. Low annual production of Nile tilapia in Kenya is largely the result of inferior brood stock that is derived from improper strain improvement programs (Abwao et al., 2021). There is therefore, need for efforts and initiatives that integrate genetics into breeding and seed supply systems for improved quality seed strains of tilapia such as selective breeding. In this breeding program, the genetic diversity contained in desirable qualities within a population is utilised to enhance the target species' production, competitiveness and sustainability (Brummett & Ponzoni, 2009).

Currently there are no clear national policy guidelines on seed production and stock improvement of tilapia in Kenya. Hatcheries typically produce fingerlings on a small scale in open earthen pond sizes between 50 and 600 m^2. Farmers that use these ponds as hatcheries also supply fish with irregular sizes, unclear lineage and poor management practices. Furthermore, such gaps lead to inbreeding in the

hatcheries, which leads to erosion of genetic diversity (Brummett & Ponzoni, 2009); this also contributes to inbreeding depression, which is linked to lower growth rates, poorer survival rates and reduced fecundity. In order to overcome these challenges a stock improvement programme was initiated at the national aquaculture research development and training Centre, Sagana targeting faster growth rate and survival as the most important traits of economic importance.

Environmental variability and its genetic interactions are important considerations in designing a breeding programmes. Research focusing on strain performance in different environments has been carried out; for example, Mbiru et al. (2021) tested for growth and genetics by environment interaction of different strains of Nile tilapia in fresh and brackish water. In their findings, the GIFT strain demonstrated superior performance in growth compared to the other strains. However, the authors realised that G*E interaction was weak and not significant for prioritisation in the breeding programme. This, however, is contrary to findings by de Araújo et al. (2020), where there was a strong G*E effects on three generations of tilapia cultured in ponds and cages. Other studies where improved Nile tilapia has demonstrated superior performance include (Dee et al., 2022; Ridha Mohamed, 2006).

On-station trials have been carried out at Sagana with results demonstrating the superiority of improved strain promising, faster growth rate, reduced grow-out time, improved feed efficiency and better survival rate (Omasaki et al., 2016). However, there is need for ecologically based validation in farms in a variety of ecoregions and culture conditions in Kenya. Upon this background, a study was conducted at Bukani Aquapark, Busia County in Kenya to evaluate the performance of different strains of *O. niloticus* at on-farm level. To sustain quality and boost aquaculture productivity in Kenya, these recommendations will be significant for tilapia breeders and farmers.

2 | METHODOLOGY

2.1 | Study area

On-farm growth performance of improved *O. niloticus* was undertaken for 180 days at Bukani Aquapark located in Busia County in Kenya: latitude 03.19669° and longitude 34.071674°. The County is riparian to Lake Victoria and generally hot throughout the year with average temperature 21–23°C and annual average precipitation of 760–1250 mm (MoALF, 2016). The Aquapark was initiated by the County government of Busia to accelerate fish production in the County.

2.2 | Experimental fish

Experimental fish included three different strains of Nile tilapia. An improved *O. niloticus* designated as F8 (SAG-F8) produced at Sagana National Aquaculture Research Development and Training Center (NARDTC) located in Kirinyaga County in the central part of Kenya. This strain was produced through selective breeding with the founder population consisting of the F7 generation from NARDTC, Sagana back crossed with wild stock from Winam Gulf, Lake Victoria. The second strain designated as KAM-YY was obtained from Kamuthanga fish farm, located in Machakos County in the Eastern Part of Kenya. The strains are offspring of super YY tilapia originally procured from the Netherlands. The third strain was LOC-T, obtained from a local hatchery, Agunja fish farm, located in Siaya County within proximity to the shores of Lake Victoria, Kenya. This farm had no stock improvement programme apart from normal good aquaculture practices applied as a condition within guidelines for hatchery authentication in Kenya. The original broodstock was obtained from Uganda; however, the farmer did not indicate any form of improvement nor control of inbreeding and exchange of broodstock at the source

2.3 | Experimental design

Nine earthen ponds measuring 300 m^2 were earlier prepared by draining, desiltation, liming and fertilisation at appropriate rates. Fish were transported from respective farms in oxygenated bags then acclimatised to the field conditions at the Bukani Aquapark for 14 days by feeding them 3 mm floating pellets, commercial diet of 35% crude protein (CP), 10% crude fat and 6% crude fibre. Fingerlings of average weight 5.0 ± 0.8 g were randomly stocked in nine earthen ponds in triplicates at a stocking density of 3 fish/m^2. The ponds were covered using predator nets to control birds and other predators. The fish were fed to satiation twice a day at 1000 and 1600 h on commercial diet of 35% CP procured from Unga feeds limited, Nairobi, Kenya

2.4 | Growth performance evaluation

Growth performance was monitored monthly. During sampling, 30 fish were harvested using seine nets and held in holding tanks. A digital weighing balance, a precision balance (WTC, 2000) measuring to the nearest 0.001 g, was used to estimate weight. The total length of the fish was measured using a measuring board.

The following metrics were used to analyse growth and feed efficiency and were calculated using the formula described in Workagegn et al. (2014):

- Specific growth rate (SGR, %) = 100 × [(Ln BW final (g) – Ln BW initial (g))/days of experiment]
- Body weight gain (BWG, g) = Final weight (g) – Initial weight (g)
- Feed conversion ratio (FCR) = feed provided/live weight gain (g)
- Survival rate (%) = (number of fish harvested)/(number of fish stocked) × 100
- Condition factor (CF), $K = 100 \times (\text{final } W/TL^3)$; where K = Fulton's condition factor, L = total length of fish in cm, W = total weight of fish in grams.

2.5 | Water quality

The in situ physicochemical water quality parameters (water temperature, dissolved oxygen, pH, salinity and conductivity) were monitored

TABLE 1 Growth performance analysis for KAM-YY, LOC-T and SAG- F8 Nile 1 tilapia strains for the 180 days' culture period

	Fish strains			
Parameter	**KAM-YY**	**LOC-T**	**SAG-F8**	***P*-value**
Initial weight (g)	4.963±0.031[a]	5.044±0.031[a]	4.985±0.036[a]	0.4
Mean Final length(cm)	19.41±0.29[b]	20.31±0.20[a]	20.21±0.28[ab]	0.24
Mean Final weight (g)	138.253±4.49[b]	158.623±4.67[a]	159.786±6.76[a]	0.002
MWG (g)	131.74±4.75[b]	153.62±4.67[a]	154.39±6.66[a]	0.002
Daily weight gain	0.74±0.025[a]	0.853±0.026[b]	0.86±0.038[b]	0.003
Mean SGR (% day-1)	2.69±0.02[b]	2.77±0.02[a]	2.77±0.02[a]	0.004
Feed conversion ratio	2.58±0.02[b]	2.57±0.02[b]	2.55±0.02[b]	0.18
Average FI (% BW)	12.9 ± 0.4[a]	14.8 ± 0.4[b]	14.9 ± 0.6[b]	0.003
Condition factor (K)	1.97±0.01[b]	1.94±0.01[b]	2.05±0.02[a]	0.001
Survival (%)	85±1.0[a]	87±2.3[a]	83±2.9[a]	0.488

*** Means within the same row with different superscript letters are significantly different at $p < 0.05$. BWG-Body weight gain; SGR - Specific growth rate; FI- Feed intake. Values represent mean ± standard error. KAM-YY (Kamuthanga super YY strains), LOC-T (Local tilapia strain) and SAG-F8 (NARDTC selectively bred generation 8 tilapia).

monthly and estimated using YSI industries, yellow springs, OH, USA, multiparameter water quality meter.

2.6 | Analysis of body composition

At the end of the experiment, 10 fish from all the experimental strains were taken at the end of the experiment for analysis of body composition. The fish were oven dried at a constant temperature of 70°C. The samples were ground and proximate analysis for moisture, fat, protein, ash energy and minerals were performed in triplicates through standard methods (AOAC International, 1995). The parameters analysed for included energy, moisture, fat, protein, major and trace minerals.

2.7 | Statistical analysis

Statistical analyses were performed using MS Excel and SPSS statistics (version 21). Normality of collected data was confirmed using Shapiro-Wilk test after which growth parameters were subjected to one-way analysis of variance (ANOVA). Whenever significant differences were recorded ($p < 0.05$), Tukey's HSD post hoc test was used.

3 | RESULTS

3.1 | Growth performance

Results of growth performance of three different *O. niloticus* strains reared in earthen ponds at farm level are presented in Table 1. At the end of the experiment, the growth parameters were significantly affected by strains. The SGR and MWG was significantly greater in treatment SAG-F8 and LOC-T than the KAM-YY strain ($p < 0.05$). The SAG-F8 recorded the highest value for SGR (2.77 ± 0.02% day^{-1}) and MWG (154.39 ± 6.66 g). LOC-T treatment recorded the same SGR but a slightly lower MWG (2.77 ± 0.02% day^{-1} and 153.62 ± 4.67 g, respectively).

The mean final weight (MFW) and mean final length (MFL) demonstrated significant differences among the strains. The MFL of LOC-T strain was significantly higher (20.31 ± 0.20 cm), followed by SAG-F8 (20.21 ± 0.28 and KAM-YY (19.41 ± 0.29 cm). Fish from SAG-F8 strain ponds demonstrated the best growth performance in terms of MFW (159.786 ± 6.76 g), although not significantly different from those cultured in LOC-T strain ponds. There was significantly lower growth performance ($p < 0.05$) from ponds with KAM-YY strains.

Food conversion ratio (FCR) in the present study was not significantly affected among the different strains. However, the lowest (FCR) (2.55 ± 0.02) value was obtained from the ponds stocked with SAG-F8 strain while KAM-YY strain had the highest FCR. These FCR values correspond proportionately to feed intake (FI) capacity of the two strains where SAG-F8 and LOC-T were determined at 14.9 ± 0.6% and 14.8 ± 0.4%, respectively. These feed intake values of SAG-F8 and LOC-T, however, were significantly higher ($p = 0.003$) than KAM-YY (12.9 ± 0.4)

In this study, survival rates were not significant different ($p > 0.005$) but generally were high across all the strains (85 ± 1.0%, 87 ± 2.3% and 83 ± 2.9%) for KAM-YY, LOC-T and SAG-F8, respectively.

There was significant variation in condition factor among the different strains. Fish in SAG-F8 treatment exhibited significantly higher condition factor (*K*) (2.05 ± 0.02) followed by KAM- YY (1.97 ± 0.01) although insignificantly the same with LOC-T strains (1.94 ± 0.01)

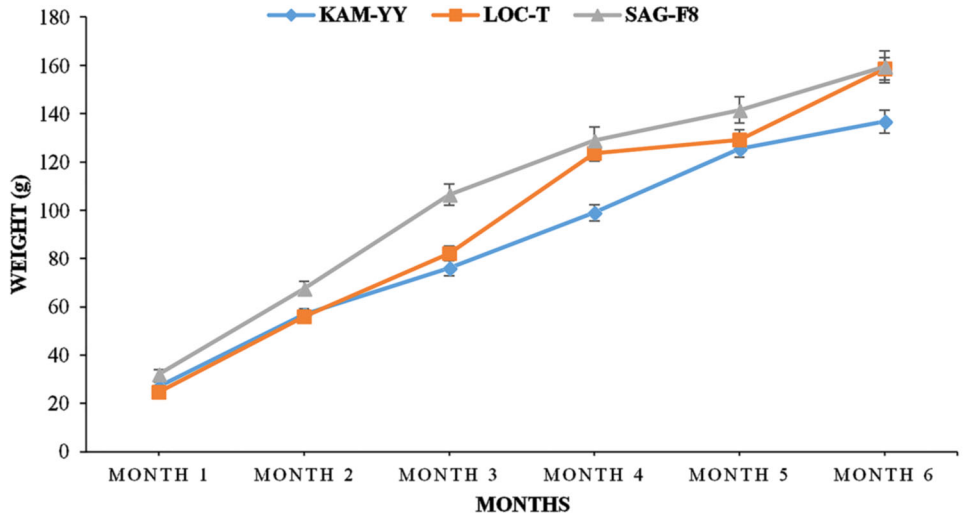

FIGURE 1 Growth curves of the mean body weight (g) of the three Nile tilapia strains (KAM-YY, SAG-F8 and LOC-T) at Bukani fish farm in Busia County.

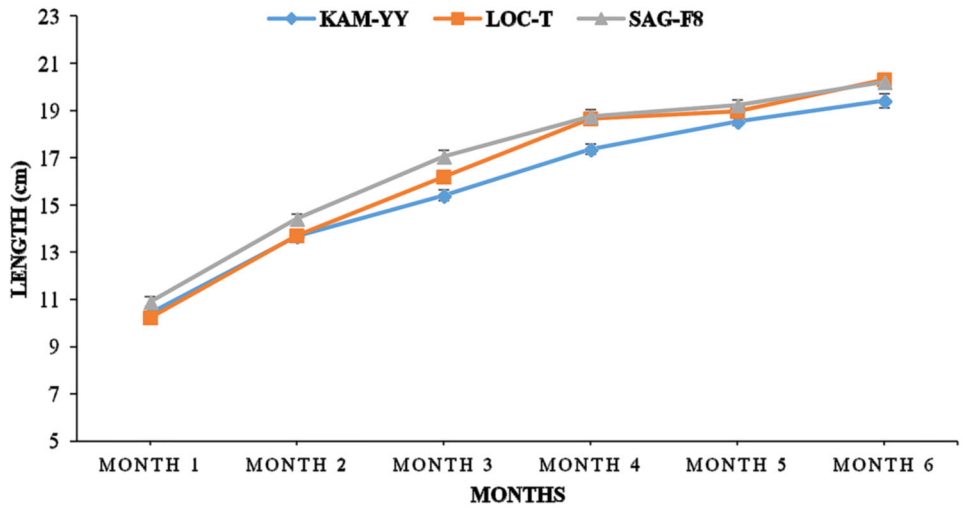

FIGURE 2 Growth curves of mean length (cm) of the three Nile tilapia strains (KAM-YY, SAG-F8 and LOC-T) at Bukani fish farm in Busia County.

Growth trend curves for the experimental tilapia strains are illustrated by Figures 1 and 2 for mean weight and length, respectively. The mean body weight and length in the three strains showed a positive linear progression with time. As demonstrated in Figure 1, during the study period, SAG-F8 had the highest growth followed by LOC-T strain and lastly KAM-YY strain. The separation of SAG-F8 curve is apparent right from the first month while KAM-YY and LOC-T strains displayed similarities up to the third month where the separation begins. At the sixth month, growth curves for SAG-F8 and LOC-T nearly converge and demonstrate no significant difference in growth performance. The mean length illustrates convergence between SAG-F8 and LOC-T in the fourth month while KAM-YY has a small separation in growth all through to the last month of experimentation (Figure 2).

3.2 | Physicochemical parameters

Water quality parameters analysed are presented in Table 2. The parameters were within optimum and acceptable levels for the culture of Nile tilapia. These parameters did not show any significant differences during the study period. However, conductivity in ponds rearing the KAM-YY strain was significantly higher ($p = 0.001$) than the other strains.

3.3 | Body composition

The final body composition of different tilapia strains in this study are presented in Table 3. Apart from copper that exhibited

TABLE 2 Water quality analysis in the ponds with Kamuthanga, Local and Sagana fish strains

				ANOVA-test	
Parameter	KAM-YY	LOC-T	SAG- F8	F-value	p-value
Temperature (°C)	24.45±0.30[a]	24.69±0.19[a]	24.78±0.21[a]	0.46	0.634
DO (mg/l)	4.45±0.39[a]	4.29±0.38[a]	4.71±0.49[a]	0.25	0.778
pH	8.06±0.51[a]	7.89±0.38[a]	7.82±0.46[a]	0.07	0.934
Salinity	1.04±0.82[a]	0.19±0.00[a]	0.18±0.00[a]	1.1	0.337
Conductivity (µS/cm)	434.7±5.12[a]	383.4±12.3[b]	347±16.1[b]	12.43	0.001

*** Means within the same row with different superscript letters are significantly different at $p < 0.05$. KAM-YY (Kamuthanga super YY strains), LOC-T (Local tilapia strain) and SAG- F8 (NARDTC selectively bred generation 8 tilapia.

TABLE 3 Proximate body composition of the experimental fish strains (KAM-YY, SAG-F8 and LOC-T)

		Fish strains			ANOVA test	
Component	Unit	KAM -YY	LOC-T	SAG-F8	F-value	p-value
Energy	MJ/Kg	29.87±1.15[a]	30.97±1.29[a]	32.55±0.55[a]	1.17	0.382
Moisture	%	2.03±0.59[a]	2.03±0.40[a]	5.44±1.82[a]	4.51	0.076
Ash	%	15.87±1.99[a]	12.93±1.72[a]	15.00±0.30[a]	0.81	0.497
Fiber	%	12.50±1.06[a]	13.63±0.44[a]	13.75±0.45[a]	0.79	0.503
Fat	%	19.67±3.14[a]	22.23±4.23[a]	24.60±1.30[a]	0.43	0.674
Protein	%	60.37±0.89[a]	61.23±2.34[a]	65.40±0.20[a]	2.71	0.209
P	%	2.90±0.35[a]	2.37±0.12[a]	2.96±0.11[a]	1.74	0.264
Ca	%	5.25±0.73[a]	4.22±0.29[a]	5.44±0.2[a]	1.55	0.299
K	%	1.05±0.08[a]	1.00±0.07[a]	1.03±0.01[a]	0.13	0.884
Mg	%	0.13±0.01[a]	0.12±0.01[a]	0.14±0.00[a]	2.57	0.171
S	%	0.77±0.03[a]	0.77±0.03[a]	0.76±0.00[a]	0.05	0.947
Na	mg/kg	3817±510[a]	3243±251[a]	3675±145[a]	0.66	0.556
Mn	mg/kg	16.10±5.16[a]	8.54±1.63[a]	17.05±2.95[a]	1.54	0.301
Zn	mg/kg	78.23±5.63[a]	69.33±1.68[a]	75.00±3.80[a]	1.28	0.355
Cu	mg/kg	31.80±8.57[b]	61.70±11.10[ab]	103.80±5.2[a]	12.63	0.011
Fe	mg/kg	107.30±19.40[a]	96.90±19.00[a]	80.70±7.30[a]	0.47	0.650
Mo	mg/kg	0.12±0.02[a]	0.10±0.00[a]	0.21±0.08[a]	2.75	0.156
B	mg/kg	0.41±0.08[a]	0.22±0.15[a]	0.39±0.19[a]	0.65	0.562
Co	mg/kg	0.06±0.03[a]	0.07±0.04[a]	0.01±0.00[a]	0.80	0.500
FFA	%	9.20±1.61[a]	7.41±1.28[a]	6.96±1.24[a]	0.67	0.554

*** Means within the same row with different superscript letters are significantly different at $p < 0.05$. KAM-YY (Kamuthanga super YY strains), LOC-T (Local tilapia strain) and SAG- F8 (NARDTC selectively bred generation 8 tilapia. FFA is free fatty acids.

significant ($p = 0.011$) differences among the different strains, there were no marked variations in parameters among the fish strains. The body protein content in the SAG-F8 fish strain was higher (65.40 ± 0.20%) followed by LOC-T strain (61.23 ± 2.34%) and lastly KAM-YY strain had the lowest (60.37 ± 0.89%). The same trend is observed in body fat composition where SAG-F8 has the highest fat content (24.60 ± 1.30%) while KAM-YY had the lowest body fat (19.67 ± 3.14%). The ash content was lowest (12.93 ± 1.72%) in LOC-T

strain and highest in KAM-YY strain 15.87 ± 1.99%. Iron content did not show any significant different among the test strains, but KAM-YY had the highest (107.30 ± 19.40 mg/kg) while SAG-F8 had the lowest (80.70 ± 7.30 mg/kg).

4 | DISCUSSION

Cultured tilapias often suffer erosion and deterioration of genetic potential as a result of introgression and inbreeding, especially if reared under poor husbandry or where broodstock are not well managed. Growth parameters including MFW, BWG SGR and daily weight gain (DWG) have demonstrated significantly different results among the different strains under the study. Generally, SAG-F8 and LOC-T had significantly better performance in terms of SGR, BWG, DWG, FCR and condition factor than the KAM-YY. While there were no significant differences in the MFW, BWG and DWG between SAG-F8 and LOC-T strains, the SAG-F8 strain exhibited the best performance in all the parameters compared to the other strains. This could be due to the fact that SAG-F8 has undergone selection across generations, up to the 8th generation in Kenya, and its superior performance could be due to the genetic gain made over the entire period of selective breeding programme. Genetic gain made by a species under selective breeding is often inherited (Boudry et al., 2021). According to Ansah et al. (2014), these populations have the capacity for faster growth, resistance to diseases and suited for culture in a variety of fish farming conditions. Other studies on performance of selectively improved O. *niloticus* reported similar results especially experimentation on the genetically improved farmed tilapia (GIFT) strain against other strains (Mbiru et al., 2021; Ridha, 2006). Horn et al. (2021) compared the performance of juvenile GIFT strain and a local strain in Tank system and revealed the superiority of better growth performance by the GIFT strain in terms of growth rate and survival resulting in higher economic returns.

Food conversion ratio (FCR) is an important economic indicator and trait to target in designing a breeding programme. This borders on efficient feed utilisation hence lowering feed wastage. In this experiment, FCR was lowest in SAG-F8 (2.55 ± 0.02), followed by LOC-T (2.57 ± 0.02) and highest in KAM-YY (2.58 ± 0.02). According to de Verdal et al. (2018), genetic improvement has the potential to improve feed efficiency in farmed aquatic animals and achieving sustainability. This is also supported by Kause et al. (2022) who affirmed that selective breeding in rainbow trout (*Oncorhynchus mykiss)* promotes improved FCR thus signifying that genetic improvement is important in resource efficiency.

Survival of tilapia was (85 ± 1.0%, 87 ± 2.3% and 83 ± 2.9%) for KAM-YY, LOC-T and SAG-F8, respectively. The average survival across all the strains was 85% hence deemed high and this was probably contributed by application of good management practices and overall control of the experiment. This ensured environmental stability and ideal experimental conditions. This was exemplified in water quality parameters, which were within levels recommended for farmed tilapia. These conditions are critical hence should be managed well for high growth and survival of fish (Makori et al., 2017; Soto-Zarazúa et al., 2010).

The growth curve trend of the three strains indicated that at the fifth month, the selectively improved SAG-F8 had a significantly better growth performance compared to LOC-T and KAM-YY. However, at the sixth month, the LOC-T curve intersects with the SAG-F8 with a nonsignificant margin ($p > 0.05$). This could be attributed to the adaptability of the local strain to the environment compared to the other strains. At Agunja farm where the LOC-T population was collected from, the brooders are paired in earthen ponds, fingerlings are sex reversed and nursed in nursery hapa nets before they are sold to fish farmers. This farm has similar environmental and climatic conditions to the experimental site in Bukani, Busia County. The pioneer LOC-T brooders were obtained from Uganda, probably due to their superior quality. Therefore, the LOC-T strain could be having strong genetic variance resulting from control on inbreeding and cohort based crosses. Moreover, many private commercial hatcheries in Kenya strive to conform to good hatchery management practices as per the government guidelines for authentication and certification.

The KAM-YY strain recorded unexpectedly significantly lower growth in terms of MFW, BWG and SGR compared to SAG F-8 n and LOC-T strains. The KAM-YY strain is genetically male tilapia (GMT) produced from parental super YY males while LOC-T and SAG-F8 are sex-reversed populations using 17 α-methyltestosterone. The hormone promotes male sexual traits in *O. niloticus* due to anabolic and androgenic impacts. This therefore enhances growth and masculinity (El-Greisy & El-Gamal, 2012; Opiyo et al., 2020).

Studies on fish body composition are important because consumers are aware, not only about cost but also to the quality of fish they consume. In this study, the fish body composition was not significantly affected by fish strains under study. However, it was observed that body protein was highest in SAG-F8 (65.40 ± 0.20%) followed by the local strain (61.23 ± 2.34%) and lastly the KAM-YY strain (60.37 ± 0.89%). This indicates the potential for protein deposition in the selectively bred tilapia compared to the KAM-YY and LOC-T strain. The same trend is seen on body fat and energy. There was a proportional correlation between the protein and energy because as a source of energy, excess protein is stored as perivisceral adipose tissue (Ng & Hanim, 2007). Selective breeding has also been confirmed to influence fat adiposity in rainbow trout (Weil et al., 2013). Abdel-tawwab (2004) compared growth performance of four different strains of Nile tilapia in Egypt and, reported lower values of protein and lipids among the those strains compared to the present study. This was influenced by the different dietary protein since the fish in this experiment were fed a protein diet of 35% while the former were fed 27% crude protein.

The growth of *O. niloticus* is influenced by genetic materials, environmental factor, food quality among other extrinsic and intrinsic factors (Eknath et al., 1993; Gjedrem et al., 2012). Results from this study have confirmed the effect of genetic materials in the growth of Nile tilapia. Though relatively limited in application in aquaculture species, selective breeding in genetic improvement has an advantage of producing permanent genetic gains that are cumulative compared to other genetic improvement methods such as hybridisation,

chromosomal manipulation, cross breeding and transgenesis (Chavanne et al., 2016). Perhaps the higher growth rates shown by the improved SAG-F8 strains is due to increased capacity for feed consumption, greater efficiency in converting nutrients into body mass, or both.

5 | CONCLUSION

This study has demonstrated the impact of strain improvement in enhancing growth and feed efficiency. The Sagana strain (SAG-F8) produced through selective breeding exhibited better weight gain and FCR. These traits are very important for fish farming enterprises because they are the most economically important. The improved strains will substantially increase fish production and productivity, which will have a positive impact on the fish farmers' livelihoods.

AUTHOR CONTRIBUTIONS

Jacob Abwao: conceptualisation; data curation; formal analysis; methodology; supervision; validation; writing – original draft. **Domitila Kyule**: conceptualisation; funding acquisition; resources; writing – review & editing. **Joseph Junga**: conceptualisation; supervision; writing – review & editing. **James Barasa**: conceptualisation; supervision; writing – review & editing. **Dorcus Sigana**: conceptualisation; supervision; writing – review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The national and institutional guidelines were adhered to in handling the fish. The authors confirm that the current manuscript has not been submitted to any other journal for simultaneous review.

ORCID

Jacob Abwao https://orcid.org/0000-0002-2419-3797
Domitila Kyule https://orcid.org/0000-0003-1264-3743
Joseph O. Junga https://orcid.org/0000-0002-1022-9891
James E. Barasa https://orcid.org/0000-0001-7221-6618
Dorcus A. Sigana https://orcid.org/0000-0002-1743-7079

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