Food rations were adjusted weekly based on the average weight of a sample of 30 fish per tank.

2.2 Experimental setup

The study was done using completely randomized design (CRD). Eighteen round plastic tanks of 60 L were each filled with 20 L borehole water. The fry used in this experiment had a mean weight (±S.E.) of 11.6 ± 1.3 mg and mean length (±S.E.) of 7.0 ± 0.6 mm. The fry were reared at three stocking densities of 5 fry/L, 10 fry/L, and 20 fry/L with three replicates each randomly assigned to nine tanks inside and the other nine outside the greenhouse. The tanks stocked at densities of 5 fry/L, 10 fry/L, and 20 fry/L had 100 fry, 200 fry and 400 fry each respectively. The plastic tanks were placed on raised platform both inside and outside the greenhouse. The later tanks were placed a meter away from the greenhouse walls.

2.3 Monitoring of water quality parameters

Water temperature and pH in the tanks were measured *in situ*. Temperature was measured three times a day (0800 hours, 1200 hours and 1600 hours) using an oxygen-temperature meter (Ysi model L57), whereas pH was monitored at intervals of every 5 days using a pH meter (Hanna Instruments, model 8519N, Singapore). Water samples for dissolved oxygen and Total Ammonia-Nitrogen (TAN) were collected every 5 days. Dissolved oxygen was determined using a DO meter (Ysi model L57). While TAN was analyzed following standard methods described in [12].

2.4 Sampling of C. gariepinus fry

A random sample of 30 fry was taken from each of the eighteen tanks for weight and length measurement at day 7, 14, 21, 28, 35 and 42. On the first sampling occasion the fry were weighed together on an electronic balance (readability 0.01 mg, model VI-200) and average weight computed. Total length of each fry was then measured using a measuring board to the nearest 0.1 mm. Tanks were inspected every morning and evening and mortalities recorded. Any dead fish in any tank were removed and replaced with individuals from the original stock. Each treatment had a replacement tank stocked with fish of the same density and age.

2.5 Data analyses

Data on length and weight were used to calculate mean fry weight and length. All results are expressed as mean ± S.E. Comparison of means were made by two way-analysis of variance (ANOVA), followed by Duncan's multiple range test. Statistical analyses were performed using the STATISTICA 9.0 statistical package.

3. Results

3.1 Water quality

The mean (±SE) water quality parameters are shown in Table 1. The temperature inside the greenhouse was higher than the temperature outside the greenhouse ($F = 21.142$, $df = 1$, $P = 0.0000$). There were significant ($p<0.05$) interactions between stocking density and greenhouse in influencing all water quality parameters except water temperature. The greenhouse treatment showed increased water temperatures of average 3.67^{0}C more than in the outside the greenhouse treatment.

3.2 Growth performance

Growth performance for *C. gariepinus* fry under different stocking density for 42 days are shown in Table 2.

It was observed that generally fry in the greenhouse tended to feed with more vigor than the fish outside the greenhouse at all the stocking densities. The mean weights of fry in the greenhouse and outside the greenhouse decreased with increasing stocking density. The mean weight (± SE) of fry in the greenhouse was higher than that of fry outside the greenhouse for all treatments. The highest weight (148.6±10.6mg and lowest weight (85.9 ± 2.97 mg) was recorded in fry reared at 5 fry/L inside the greenhouse and 96.6±1.16 mg and lowest weight 70.1± 2.42 mg recorded in fry reared at 20 fry/L outside the greenhouse respectively. The growth in weight of *C. gariepinus* fry demonstrated significant interaction effects due to stocking density and greenhouse treatment ($F = 127.104$, $df = 2$, $p = 0.000$).

The growth in length of *C. gariepinus* fry demonstrated significant interaction effects due to stocking density and greenhouse treatment ($F = 199.067$, $df = 2$, $p = 0.000$). The mean length of fry in the greenhouse and outside the greenhouse decreased with increasing stocking density (Table 2). The mean length of *C. gariepinus* fry was significantly the highest in fry reared in the greenhouse at 5 fry/L while lowest mean length occurred in fry reared at stocking density of 20 fry/L outside the greenhouse.

Table 1: Mean (± SE) of water quality parameters in various treatments stocked with *C. gariepinus* fry

		Water quality parameters			
		Temperature (°C)	pH	TAN (mgl^{-1})	DO (mgl^{-1})
In greenhouse	5 fish/L	24.19 ±0.02	7.01±0.03^c	0.54 ± 0.04^a	3.13 ± 0.02^c
	10 fish/L	24.22 ± 0.02	6.97 ± 0.02^b	0.63 ± 0.05^b	3.07 ± 0.04^b
	20 fish/L	24.21 ± 0.02	6.94 ± 0.03^a	0.79 ± 0.07^c	3.00 ± 0.07^a
Outside greenhouse	5 fish/L	20.50 ± 0.07	6.97 ± 0.02^b	0.44 ± 0.05^a	3.06 ± 0.03^b
	10 fish/L	20.52 ± 0.08	6.93 ± 0.03^a	0.49 ± 0.04^b	3.07 ± 0.04^b
	20 fish/L	20.55 ± 0.06	6.91 ± 0.03^a	0.58 ± 0.09^c	2.08 ± 0.07^a
ANOVA	F	2.556	11.432	13.133	8.654

	P	0.342	0.001	0	0.032

Means with the same letters as superscripts are not significantly different ($p>0.05$). (SE = Standard Error, TAN = Total ammonia nitrogen, DO = Dissolved oxygen

Table 2: Parameters of growth in *C. gariepinus* fry in different treatments during the trial

Parameters	Treatments					
	Inside greenhouse			Outside greenhouse		
Stocking density (fish/L)	5	10	20	5	10	20
Initial weight(mg)	11.6±0.02	11.6±0.24	11.6±0.21	11.6±0.25	11.6±0.23	11.6±0.24
Final weight (mg)	148.6 ± 10.6^{e}	99.3 ± 1.57^{d}	$85.9.\pm2.97^{bc}$	96.6 ± 1.16^{c}	80.1 ± 2.15^{b}	70.1 ± 2.42^{a}
Weight gain(mg)	137.0	87.7	74.3	85.0	68.5	58.5
% weight gain	1178.9	756.0	640.0	732.4	589.6	504.1
SGR(%day^{-1})	6.07	5.11	4.77	5.05	4.60	4.28
Initial length (mm)	7.00±0.42	7.01±0.89	7.01±0.24	7.00±0.26	7.04±0.42	7.01±0.32
Final length (mm)	34.1 ± 7.62^{e}	22.6 ± 2.7^{d}	19.9 ± 1.12^{b}	21.9 ± 0.99^{c}	18.1 ± 0.84^{b}	16.1 ± 0.31^{a}
Length gain(mm)	27.10	15.60	12.90	14.90	11.10	9.04
% Length gain	387.1	222.4	183.7	212.7	157.5	129.0

Mean with different superscript within a row are significantly different ($p < 0.05$). ±SE = Standard Error

Growth curves for *C. gariepinus* fry based on weight for the entire experimental period are presented in Figure 1.

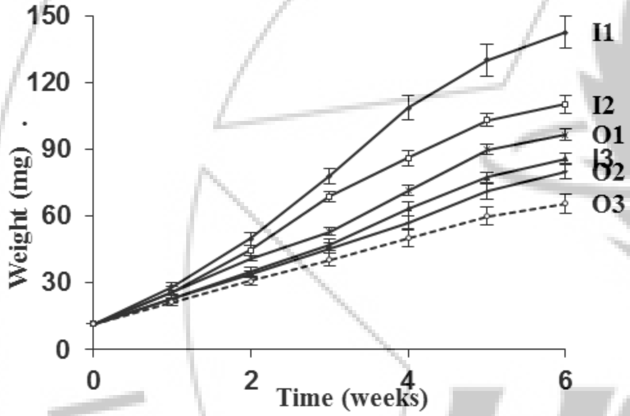

Figure 1: Mean weight (± SEM) of *C. gariepinus* fry during the 42 day experimental period. I1 = Inside Greenhouse (5 fry/L), **I2** = Inside Greenhouse (10 fry/L), **I3** = Inside

Greenhouse (20 fry/L), **O1** = Outside Greenhouse (5 fry/L), **O2** = Outside Greenhouse (10 fry/L), **O3** = Outside Greenhouse (20 fry/L).

Fish stocked at 5 fry/L in the greenhouse realized and maintained highest biomass over the study period than those in the other treatments. On the other hand, fish stocked at 20 fry/L and cultured outside the greenhouse realized the lowest growth in weight after 21 days of culture and maintained low growth trends until the end of the experiment. Both the stocking density and greenhouse significantly affected the growth in weight of fish (F = 123.479, p = 0.000).

Growth curves for *C. gariepinus* fry based on length for the entire experimental period showed similar trend as shown in Figure 2.

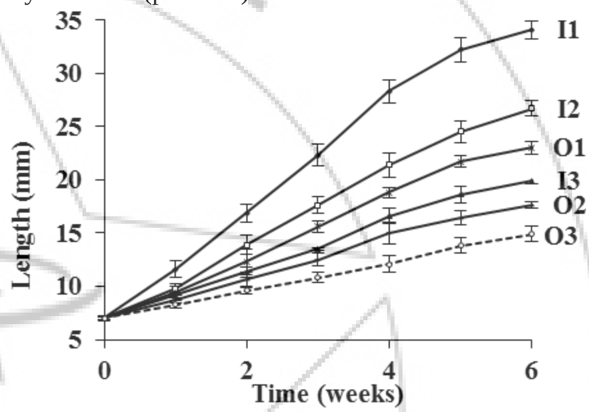

Figure 2: Mean length (±SE) of *C. gariepinus* fry during the 6 weeks of experimental period. I1 = Inside Greenhouse (5 fry/L), I2 = Inside Greenhouse (10 fry/L), I3 = Inside Greenhouse (20 fry/L), O1 = Outside Greenhouse (5 fry/L), O2 = Outside Greenhouse (10 fry/L), O3 = Outside Greenhouse (20 fry/L).

Fish growth in length in the 5 fry/L treatment in the greenhouse maintained highest growth rates compared to other treatments after two weeks of experiment. Lowest growth was realized in the treatment with the highest stocking density of 20 fry/L cultured outside the greenhouse ($p < 0.05$). Both stocking density and greenhouse significantly affected the growth in length (F = 221.468, p = 0.000).

3.3 Survival of *C. gariepinus* fry

Fry raised in tanks inside greenhouse had better survival at all stocking densities than those in tanks outside the greenhouse (Figure 3).

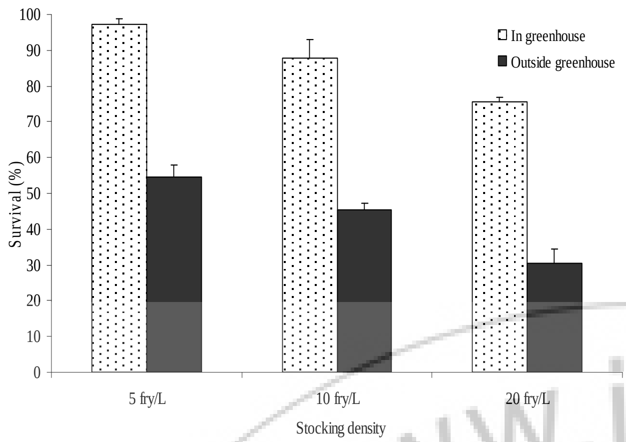

Figure 3: Mean survival of *C. gariepinus* fry in various experimental setups after 6 weeks. Error bars indicate S.E. (Standard Error)

Percentage survivals were ranging from 82- 97.33% for fry inside greenhouse at the three stocking densities and 30.6 - 55% outside the greenhouse. Fry survival decreased with increasing stocking density. The highest survival (97.33%) was obtained at the lowest stocking density (5 fry/L) in the greenhouse, whereas the lowest survival was 30.6 % for fry stock at 20 fry/L outside the greenhouse. There were significant interactions between stocking density and greenhouse treatment on survival of fry.

4. Discussion

4.1 Water Quality

The rise in temperature recorded in the present study is probably due to the fact that during sunshine hours total solar radiation received by the greenhouse cover is partly reflected, absorbed and transmitted inside the greenhouse through walls and roofs [13, 14]. A large portion of this transmitted radiation is absorbed by water and hence utilized in the raising water temperature [14].

All the measured water quality parameters in this experiment were within the range for growth of *C. gariepinus* similar to the measurements found by [15, 16] whose results were (pH 7±0.1, Dissolved oxygen 3.2± 0.2 and Ammonia 0.005± 0.001). The total ammonia nitrogen (TAN) recorded in the rearing tanks in the present study was probably due to the excretion done by the fish. This is in agreement with work done by [17, 18] that attributed the presence of ammonia in water to excretion by the larvae. However, generally water quality was poor in tanks stocked at higher stocking densities than in lower densities. These findings corroborate with those of other workers who have associated higher stocking densities with deterioration of water quality which causes stress to fish [19]. The lower dissolved oxygen recorded in tanks with high stocking densities would be attributed to higher oxygen consumption in those tanks, and this is in agreement with work done by [20] who found out that when African catfish *Chrysichthys nigrodigitatus* were stocked at higher stocking densities resulted in the fish consuming more dissolved oxygen.

4.2 Growth performance of C. gariepinus fry

The results of the present study clearly demonstrated that growth performance of *C. gariepinus* fry was influenced by both greenhouse effect and stocking density. The findings of better growth inside greenhouse in the present study compared well with those of [21, 22] that attributed better growth of common carp to the higher greenhouse temperatures with fish reared in the greenhouse having a mean average weight of 309 g whereas outside the greenhouse 216.5 g . Work done on *Labeo rohita*, [23] also reported higher mean fish growth in greenhouse ponds than in open ponds. Statistical analysis revealed significant interaction effects on both stocking density and greenhouse on the growth performance of the fry stocked inside and outside the greenhouse. This implied that both stocking density and greenhouse affect the growth of fry.

All parameters of growth performance including weight gain; length gain and SGR for fry stocked at high stocking density (20 fry/L) were lower than those of fry raised at stocking density of 5 fry/L both inside and outside the greenhouse. These results are consistent with earlier experiments [24-26] which reported lower growth rates of fish stocked at higher densities. It has also been reported that there is a great influence of stocking density on growth and SGR in *C. batrachus* larvae reared in tanks in that the higher the stocking density the lower the growth and SGR (Stocking density of 100 fish/m^2 had a SGR of 9.85± 0.09 whereas 500 fish/m^2 had a SGR of 4.93± 0.15) [25]. Several workers have also noted that as the fish stocking density increases the competition for food also increases [7, 27]. This probably explains the observed low growth performance of fry in tanks with high stocking densities compared to those in tanks stocked at low density in the present study. Fry stocked in tanks outside the greenhouse structure realized lower growth performance compared to those stocked inside the greenhouse at all the three densities investigated in the present study.

4.3 Survival of C. gariepinus fry

The results of the present study indicate that survival of *C. gariepinus* fry was affected by both stocking density and greenhouse. Fry raised inside the greenhouse had higher percentage survival compared to those in tanks outside the greenhouse. These results are in agreement with the findings of several workers who have reported higher survival rate of common carp (*Cyprinus carpio)* reared inside greenhouse [14, 23, 28] and they reported survival values of 84 – 88 % for greenhouse ponds and 74 % for open ponds. The higher survival of fry in tanks inside the greenhouse in the present study therefore appears to be related to response of fish to modulated temperature regimen that would allow optimal feeding and physiological activities, consistent with earlier findings of [29].

However, findings of other workers suggest that the effect of stocking density on fry survival depends on the species of fish. In larvae of *Rachycentron canadum* [25, 30], survival was significantly highest (p<0.05) for fish stocked at 100 and 200 m^{-2} whereas for *Solea solea* [31] reared in plastic tanks, survival was reported to decrease as stocking density increased. It has also been reported from studies done by [4] that stocking density did not affect survival of *C. gariepinus* larvae reared in floating cages. This was contrary to other catfishes like *Heterobranchus longifilis* [32], *C. batrachus* [25] and *Chrysichthys nigrodigitatus* [20] larvae which had higher survival rate at the initial stages of growth.

Generally the greenhouse treatment gave a higher percentage survival than the outside the greenhouse with the lowest density of 5 fry/L giving the highest percentage survival whereas the highest stocking density of 20 fry-L gave the lowest % survival. This is in agreement with work done by [33, 34] who reported that when fish are stocked at lower densities they give better survival than seen in the higher density treatments. Lower stocking densities also provide more space, food and less competition as reported by various authors including [33, 35] who recommended that stocking fish at optimal stocking densities was essential for maximization of the species growth, survival, production and hence profitability. The above findings support the results of the present study where survival was found to be negatively influenced by stocking densities.

The low water temperature outside the greenhouse was likely a major constraint to good feeding. During the study period more uneaten food was siphoned in the outside greenhouse tanks than in the inside greenhouse indicating poor feed consumption outside the greenhouse tanks. This would result in fish not growing as fast as in the greenhouse environment where good feeding resulted in better growth performance. This concurs with work done by [36] who indicated that low temperature was responsible for poor feed response of the black 190 chinned tilapia *Sarotherodon melanotheron* (Cichlidae), which would probably ultimately affect the survival of fish. Similarly, [23] recorded higher survival (82.86%) of Labeo *rohita* in greenhouse treatments than in open ponds treatments (57.15%).

5. Conclusion

In conclusion, the present study has demonstrated that the use of greenhouse resulted in significant increase in temperatures within the greenhouse which enhanced the growth of African catfish fry raised within the greenhouse. The stocking density and rearing the fry in the greenhouse affected the growth performance of fish with higher growth performance in terms of SGR, mean length and weight gain recorded in fry raised inside the greenhouse. Rearing inside the greenhouse also enhanced the survival of *C. gariepinus* fry since higher % survival was recorded inside the greenhouse than outside the greenhouse.

6. Future Prospects

Basing on the findings of this study we hence recommend that more research be done so as to evaluate the economic viability of adoption of this technology to promote the production of *C. gariepinus* by small scale farmer in high altitude areas.

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Authour Profile

Josiah Ani Sabwa has a MSc. in Aquaculture and a BSc. (Hons) in Fisheries and Aquatic Sciences from Moi University, Kenya. He is currently enrolled as a PhD student in the same University.

Mlewa Chrisestom Mwatete is an associate professor and has a PhD and a MSc. in Biology from Memorial University, Newfoundland, Canada. He is currently the Dean, School of Graduate Studies Pwani University, Kilifi, Kenya.

James Njiru is an Associate Professor and has a PhD in Environmental biology from Moi University. He teaches fresh water ecology and other related subjects in both undergraduate and postgraduate studies at the University of Eldoret, Kenya.