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Comparison of growth performances in mixed-sex populations of *Oreochromis niloticus* (Linnaeus, 1758) from the wild brood's tock collected from the mono, Niger, ouémé watershed and from a fish farm in Benin

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Abstract
In order to evaluate the growth performance of various *Oreochromis niloticus* populations and identify the best performing one mixed-sex production, a study was conducted on populations collected from three river basins (the Mono, Niger, and Ouémé watershed)as well as from the Yohan-Estève fish farm (2 populations) in Benin. Juveniles were produced at the research station at University of Abomey-Calavi from May to August 2017 and growth tests were conducted from September to November 2017. A duplicate of 30 individuals, with an initial mean body weight of 6.70±1.46 g per population, was set up for each of the seven populations and loaded into square basins (0.99 x 0.99 x 1 m) in which the water depth was maintained at 50cm. The fish were fed for 60 days with extruded BIOMAR fish feed (49% protein and 12% lipid) with a daily diet continuously adjusted to their biomass throughout the experimentation. At the end of the experiment, the survival rate was 100% and the final mean body weight ranged from 18.9 ± 5.9g to 40.9 ± 14.5 g. The maximum final mean body weight was 40.9 ± 14.5 g for the Sohoumè population in the Mono watershed while the lowest was 18.93±5.87 g for the Djonougoui population within the same watershed. The specific growth rate ranged from 1.7 to 3%/day, the feed conversion ratio ranged from 1.2 to 2.3 g/g, and feed efficiency ranged from 42.8 to 81.9%. The basis of the results, it appears that the Sohoumé population displays the best growth performances for a mixed-sex production of *O. niloticus*.

Keywords: Nile tilapia, mono, ouémé, Niger, fish populations, fish growth performances

1. Introduction
Over the last three decades, Nile tilapia, *Oreochromis niloticus*, production has been significantly developed all over the world and now it is considered as one of the most productive and internationally traded food fish in tropical and subtropical areas of the world [1–3]. The global production of tilapia is expected to exceed three million tonnes in 2010 and estimated to increase to about 8.9 million tonnes by the year 2020 [4]. This rapid rise in the global production of tilapia is due in part to the increasing intensification of farming systems and this has led to a critical need for large quantities of fingerlings for stocking grow-out systems [5].
Nile tilapia is the common name for 70 species which belong to the Cichlidae family and are native of tropical Africa freshwaters. They include the mouth breeding gender of *Sarotherodon* and *Oreochromis* as well as substrate spawning tilapia [6]. Tilapia is a relatively fast-growing fish that feeds at lower levels of the food chain. In rearing conditions, diet is very plastic (from compound feed fertilization) mainly based on the use of vegetable products and by-products or low-protein (25%) compound diets. Depending on its diet, temperature and oxygen tilapia can reach the market size of 400 g in 8 months [7].
Tilapia species differ markedly from one to another in many traits of evolutionary importance, which also reflect on their suitability for aquaculture. Intraspecific variation among strains has been mainly evaluated in *O. niloticus* [8]. Particular variation of growth performance has been observed in different strains of this specie. The differences found suggest that choosing an appropriate strain for a given set of conditions can improve performance [9-15].

Tilapia remains the flagship species of African fish farming in general and particularly in Benin. It is highly esteemed for its breeding potentials (spontaneous spawning, rapid growth, etc.). *O. niloticus* is easily accepted by the people and is perfectly integrated to their diet. Indeed, in Benin total fish production was dominated in 2010 by cichlids including tilapia (26%) and followed by clarias (3.4%) [16]. Unfortunately, we need to emphasize the fact that production of the Nile tilapia in Africa in general and in Benin in particular is faced with many challenges including the availability of efficient strains for growth. In Benin, the presence of *O. niloticus* has been reported in the Mono, Ouémé and Niger watershed [17-19]. This diversity of populations in the different watersheds in the country suggests a probable variability of zootechnical performances including growth performances. The aim of this study is to compare the growth performance of different populations originating from Mono, Ouémé and Niger rivers in Benin in order to identify the most performant strain.

2. Materials and Methods

2.1 Broodstock collection site

The broodstock was collected from three rivers in southern and northern Benin, namely from the Mono, Ouémé, and Niger basins and from a fish farm (Yohan-Estève) in the Abomey Calavi commune in the south of Benin. Fish of Yohan-Estève farm were selected in order to compare the growth performances of the strains already exploited by fish farmers to those of the populations collected in the different basins. Five collection stations, where *O. niloticus* was present [17-19], were selected to cover all the three basins, namely Djonougoui (DJ), Sohoumé (SH), and Toho (TH) in the Mono basin; Gbassa (GB) in the Niger basin, and Gobé (GO) in the Ouémé basin (Figure 1). It should be noted that at the Toho station in the Mono basin, escape of *O. niloticus* specimens from fish farms into the wild has occurred [16]. This explains why several collection stations were selected in this basin. In fact, there are many streams tributary to the Mono River and in which the escaped Nile tilapia has been found. The Yohan-Estève fish farm, from which two samples were collected, was selected in order to evaluate the performance of an already-domesticated population which displays a good growth performance.

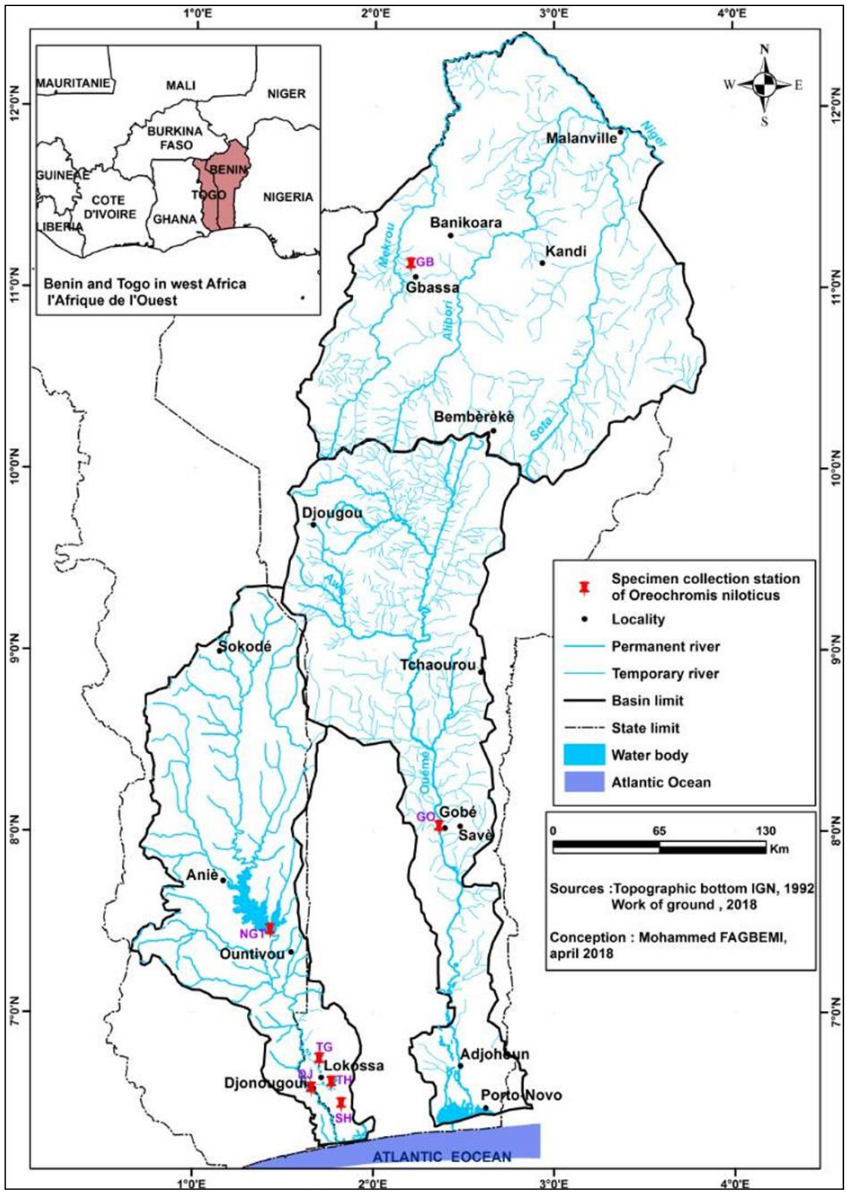

Fig 1: Sample collection stations

2.2 Fry production
For each population, the collected broodstock was acclimated for four months and then coupled in 4 m² concrete tanks with a sex ratio of 2 males to 8 females. For each population, mixed-sex F1 fry obtained were reared together during 70 days till an average weight of 6.7±1.5 g.

2.3 Experimental setup
Growth experiments took place from September to November 2017 at the Laboratory of Hydrobiology and Aquaculture (LHA) research station of University of Abomey-Calavi. The experimental setup consisted in fourteen 1 m² concrete tanks (0, 5 m depth) in flow-through system. Tanks were half covered with wooden panel to limit the impact of various sources of stress. 7 batches of 30 fingerlings (mean weight 6.7 ± 1.5) in duplicate originating from were constituted and reared 60 days. Fish were fed with Biomar commercial feed (49% protein and 12% lipid) manually distributed three times a day and the diameter of the food ration was readjusted after each control on the basis of Coppens International feeding table. Dissolved oxygen, pH, and temperature were measured every day before each feeding.

2.3 Control of zoo technical parameters
Growth and survival were controlled every two weeks. Each individual per batch was weighted and counted. The control was done early in the morning between 7 and 10 am in order to limit any stress related to manipulation and the rise of temperature.

2.4 Statistical analysis
Growth and feed conversion parameters, specific growth rate (SGR), feed conversion ratio, and feed efficiency along with the coefficients of variation were computed per population. In order to verify normality of the raw data collected, the Ryan Joiner and Leven tests were conducted. The various parameters and indices calculated were subjected to one-way variance analyses (ANOVA1) and to Fisher's LSD test for two-way comparisons.

3. Results
3.1 Physicochemical parameters
At the end of the experiment, the mean temperature, pH, and dissolved oxygen were respectively 28.1 ± 1.3 ° C, 5.4 ± 0.3, and 4.7 ± 1.6 mg / l. One-way ANOVA analysis of the mean values of those parameters showed no significant difference between treatments ($p > 0.05$).

3.2 Growth and survival performances
Growth, survival, and feed conversion were calculated at the end of the experiment and are synthesized in Table 1.
At the beginning of the experiment the average individual weight of fish was 6.70 ± 1.5g. After 60 days of rearing it ranged from 18.9 ± 5.9 g for the Djonougoui fry; 26.1 ± 11.2 g for Toho fry; 28.7 ± 15.4 g for the Gbassa fry; 31.7 ± 10.2 g for Gobé; 35.2 ± 11 g and 35.5 ± 11.8 g respectively for the populations of Yohan-Estève I and Yohan-Esteve II and 40.9 ± 14.5 g for Sohoumè (Table 1 and figure 2). The maximum mean weight (40.93 g) was obtained with the Sohoumè population in the Mono basin; the minimum was recorded with the Djonougoui population (18.9 g) within the same basin. One-way ANOVA shows a significant difference between the populations ($p<0.05$).

Table 1: Summary of the growth parameters

Populations/Parameters	Start		End		SGRm (%/Day)	K	FCR	FE (%)	Survival rate (%)
	Ptmi	CV	Ptmf ??	CV					
GB	6.7±1.8	27.6	28.7±15.4^{a}	51.6	2.5±0.7^{a}	1.3	1.6	61.9	98.3
DJ	6.7±1.9	28.8	18.9±5.9^{ab}	31	1.7±0.5^{a}	1.3	2.3	42.8	100
GO	6.7±1.2	17.3	31.7±10.2^{a}	32.2	2.6±1.2^{a}	1.6	1.6	61.5	100
SH	6.7±0.9	13.4	40.9±14.5^{bc}	35.4	3±0.7^{a}	1.7	1.2	81.9	100
TH	6.7±1.4	21.3	26.1±11.2^{ac}	42.9	2.3±0.5^{a}	1.6	1.7	58.2	100
YEI	6.7±1.4	21.2	35.2±10.9^{a}	31.1	2.8±0.8^{a}	1.6	1.3	79.9	100
YEII	6.7±1.4	20.8	35.5±11.8^{a}	33.3	2.8±0.9^{a}	1.7	1.4	69.8	100

GB: Gbassa; DJ: Djonougoui; GO: Gobé; SH: Sohoumè; TH: Toho; YHI: Yohan Estève I; YHII: Yohan Estève II
SGRm: Specific growth rate, K: Condition factor, FCR: Feed conversion rate, FE: Feed efficiency, Ptmi: Initial mean body weight, Ptmf: final mean body weight
Values in the same line having different letters (a, b, and c) are significantly different ($p<0.05$).

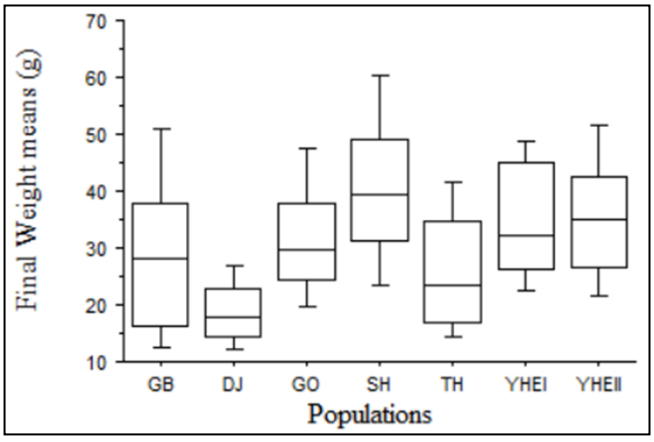

Fig 2: Comparaison of average weights between of the populations at the end of the experiment.

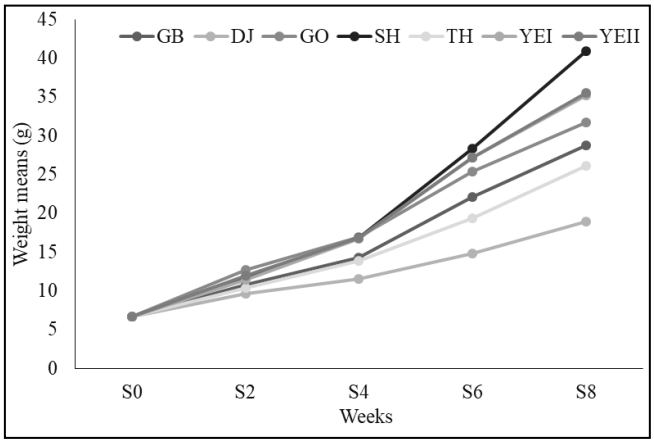

Fig 3: Time-based changes in the average weight of the fry per station

Table 2: Values of the average individual weight (grams) of *O. niloticus* specimens during the experiment.

Populations	S0	S2	S4	S6	S8
GB	6.7 ± 1.8	10.8±4.6	14.3±6	22.1±11	28.7±15.4[a]
DJ	6.7±1.93	9.7±2	11.5±2.6	14.8±4.1	18.9±5.9[ab]
GO	6.7±1.2	12.7±2.6	16.9±3.9	25.4±6.8	31.7±10.2[a]
SH	6.7±0.9	11.7±2.6	16.9±4.2	28.3±8.2	40.9±14.5[bc]
TH	6.7±1.4	10.4±2.9	13.9±4.8	19.4±7.8	26.1±11.2[ac]
YHEI	6.7±1.4	11.4±2.4	16.7±4	27.2±7.8	35.2±11[a]
YHEII	6.7±1.4	12±2.9	16.8±4.5	27.2±8	35.5±11.8[a]

S: week, between two S we have 14 days of feeding
Values in the same line having different letters (a, b, and c) are significantly different (p<0.05).

A difference was also observed between the weeks taken two by two using Fisher's LSD test. Also, considering the mean weights obtained at the end of the experiment, except for the Gbassa-Gobé, Gobé-Yohan-Esteve I, Gobé-Yohan-Esteve II, Yohan-Esteve I-Yohan-Esteve II, and Gbassa-Toho pairs which display no significant difference (p >0.05), all the other populations taken by twos show a significant difference (p<0.05) with the Sohoumé population (Mono basin) which has a final average weight greater than that of the other populations (Table 2).

Regarding the specific growth rate (SGR), the lowest growth rate was recorded in the Djonougoui population (1.7 ± 0.5) and the highest one was observed in Sohoumè (3 ± 0.7) (Table 2). Based on the statistical analysis, apart from the Djonougoui-Sohoumé pair which shows a significant difference (p<0.05), there is no significant difference (p>0.05) between the SGRs of the other fish populations taken in pairs (ANOVA 1 test).

The highest condition factor was recorded in the Sohoumè population (1.7 ± 0.2) while the lowest value was observed in the Gbassa population (1.3 ± 0.1) (p<0.05). Furthermore, Fisher's LSD test confirms this difference between all populations taken two by two, except those of Gobé-Sohoumè and Gobé-Yohan-Estève I.

The highest food conversion rate was obtained in the Djonougoui population (2.3) while the lowest was obtained in the Sohoumé population (1.2). In terms of food efficiency, we also note that the Sohoumé population (Mono basin) remains the one that has a high rate of food ingestion (81.9%), as opposed to that of the Djonougoui population of the same watershed and which presents the lowest ingestion rate (42.8%).

At the end of the experiment, survival rates ranged from 98.3% to 100% but were not significantly different (p >0.05).

4. Discussion

Except for the Gbassa population with the lowest survival rate (98.3%), all the other populations have a survival rate of 100%, indicating the good breeding conditions and the care taken in the treatment of the fish during the control sampling.

Starting from an initial mean weight of 6.7±1.5g, the final weights ranged from 18.9±5.9g to 40.9±14.5g. The Sohoumè population in the Mono basin fish displayed the best growth performance and food conversion parameters. The maximum final mean weight obtained at the end of the experiments is in favor of the Sohoumé population in the Mono basin (40.9± 14.5g) and shows a significant difference with the various populations considered. This could be explained by a better food conversion process and by the genetic performances [21] of this population. Weight gain was noted in all populations throughout the period of the experiment. The mean weight values obtained in the present study are higher than those obtained by Elegbe *et al*. [22] for fry raised at the same density, over the same duration, and in fish holes as they are than those obtained by Adjanke *et al*. [23]. The fry growth performance observed in our study is also greater than that of Ouedraogo [24], which obtained an SGR value lower than the one we've obtained for the Sohoumè population. Also, it should be noted that the variability of the growth performances recorded between the different populations during the study could be due to the variability of the genetic potential of each population. Indeed, several comparative studies of the growth performance of different strains of *O. niloticus* have shown that the growth performance of this species varies significantly from one strain to another, depending on the production environment [12, 25, 26]. Thus, for this study, the experimental conditions and the food having been identical for all the populations tested, the results obtained suggest an influence of the genetic potential on the growth performances of the different populations.

The specific growth rate, is also in favor of the Sohoumè population in the Mono basin (3±0.7). From one control to the other, a significant difference is observed while no significant difference between the various populations is observed considering the SGR at the end of the experiment (p >0.05). The highest SGR is obtained for the Sohoumè population, which showed the best weight gain in 60 days of breeding. The Sohoumè SGR is higher than those obtained by, Elegbe *et al*. [22] and Sarr *et al*. [27] who obtained respectively 1.8%/D and 0.02%/D SGR and fed the fish with extruded imported feed containing 45% and 33% protein respectively. This could be on the one hand to the quality of the food used for this study, to a better valorization of the food and the resources of the breeding environment and on the other hand to the genetic potential of this population. Indeed although Elegbe *et al*. [22] used an imported food 45% protein and that the tests were conducted in a pond that remains a breeding environment with a higher natural production compared to a basin, it obtained a lower SGR than that obtained in the present study; this implies that genetically, the population of Sohoumé has higher growth performance than all the other populations tested.

The feed conversion rate (FCR) and the feed efficiency (FE) vary respectively from 1.2 to 2.3 and from 42.8 to 81.9%. The FCR value of 1.2 found for the Sohoumè population indicates that it takes 1.2 kg of the feed used for the experiment to produce 1kg of fish; this is explained by the high rate of ingestion of the feed (81.9%). Under the same conditions, in order to produce 1kg of fish from the Djonougoui population, 2.3 kg of this same feed would be needed, as evidenced by the low rate of efficiency (42.8%) of the same feed by this population. The Sohoumè fish therefore take better advantage of the feed and of the resources available in the environment than those of Djonougoui in the same watershed. We could therefore link the better feed conversion rate observed in the Sohoumè population to the more or less balanced

consumption of the food made available to all the individuals in the population. On the other hand, at the Djonougoui station, a food competition and the establishment of a hierarchy between the individuals of this population for the consumption of the available food could be the reason for the weak performances observed in this population. The best feed conversion rate obtained in our study is better than those obtained by Sarr *et al*. [27], Houndonougbo *et al*. [28] and Adjanke *et al*. [23] who respectively obtained a best average feed conversion rate of 1.6 g/g; 1.3g/g and 1.5g/g.

Among the seven populations studied, the highest specific growth rate, the lowest feed conversion rate were observed for Sohoumè. All these conditions combined make this population of the Mono watershed the one with the best growth performance for purposes of production of mixed-sex fry in flow througt systeme. These results are consistent with those of Kondombo [29] who worked on 11-day-old larvae after yolk sac resorption of the same populations and who obtained the best values of growth indices at the Sohoumè station after 39 days feeding.

5. Conclusion and suggestions

The present study compared the growth performance of various *O. niloticus* populations collected from the Mono, Ouémé, and Niger basins as well as from a fish farm. The results indicate that the Sohoumé population in the Mono basin display the best growth performance indicators in an open water circuit for mixed-sex *O. niloticus* production. in order to improve the productivity, it would be interesting to conduct a similar study with all male fish.

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