

Coupling Aquaculture—Crop Productions and Using of Water Drained from Ponds Rearing *Clarias gariepinus* as Fertilizer for Okra Production (*Abelmoschus esculentus* var. *Clemson spineless*, L. Moench)

Louis Dossou Magblénou¹, Justin Kantoussan^{1*}, César Bassène², Dieynaba Yacine Mar Gueye¹, Hamath Sy¹

¹Laboratoire des Sciences Biologiques, Agronomiques et de Modélisation des Systèmes Complexes (LaBAM), UFR des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (UFR S2ATA), Département Aquaculture, Université Gaston Berger (UGB), Saint-Louis, Senegal

²Laboratoire des Sciences Biologiques, Agronomiques et de Modélisation des Systèmes Complexes (LaBAM), UFR des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (UFR S2ATA), Département Productions Végétales et Agronomie (PVA), Université Gaston Berger (UGB), Saint-Louis, Senegal

Email: *justin.kantoussan@ugb.edu.sn

How to cite this paper: Magblénou, L.D., Kantoussan, J., Bassène, C., Gueye, D.Y.M. and Sy, H. (2024) Coupling Aquaculture—Crop Productions and Using of Water Drained from Ponds Rearing *Clarias gariepinus* as Fertilizer for Okra Production (*Abelmoschus esculentus* var. *Clemson spineless*, L. Moench). *Open Journal of Applied Sciences*, 14, 2628-2647.

<https://doi.org/10.4236/ojapps.2024.149173>

Received: August 27, 2024

Accepted: September 24, 2024

Published: September 27, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

The present study concerns the revalorization of drained water from aquaculture ponds rearing *Clarias gariepinus* on okra crops. The rearing was carried out at the farm of Gaston Berger University in 100 m² ponds. In each pond, the individuals of *C. gariepinus* with an average weight of 6 ± 0.3 g were stocked at a density of 11 per m². The water temperature and pH were measured during the experiment. The control fishing is carried out every month to monitor variations in the weight and size of reared individuals. The plant production is carried out in elementary plots measuring 3 m × 1.5 m. Each plot was fertilized with either: drained water from *C. gariepinus* rearing (DWC), poultry droppings (PD), cow dung (CD) and mineral fertilizer (NPK). Treatments are carried out in tripliqua with either river water (RW), RW + the recommended dose of NPK (RD-NPK), RW + RD-PD, RW + RD-CD, DWC, DWC + 25% RD-NPK, DWC + 50% RD-NPK, DWC + 75% RD-NPK, DWC + 25% RD-PD, DWC + 50% RD-PD, DWC + 75% RD-PD, DWC + 25% RD-CD, DWC + 50% RD-CD, DWC + 75% RD-CD. Growth parameters and yield of okra were determined. The average temperature in the rearing environment was 27.6 ± 1.5 °C and pH 7.9 ± 1.1 . After six (06) months of rearing, *C. gariepinus* individuals reached an average weight of 850.12 ± 1.3 g and an average height of

52.44 ± 1.1 cm. The daily weight gain and specific growth rates over this period were 3.9 g per day and 2.8% per day, respectively. The treatment T₁ (RW + DR-NPK) gave the highest mean collar diameter and mean plant height with 2.3 ± 0.9 cm and 61.6 ± 32 cm, respectively. In T₄ (DWC), the mean height of plants was 38.8 ± 23.5 cm and mean collar diameter 1.4 ± 0.8 cm. The growth performance in T₄ was comparable to that of RD-CD (T₃), but different from RD-NPK (T₁) and RD-PD (T₂). The highest average number, average weight, average length and average diameter of fruits were noted in treatments T₁₃ (RW + RD-75%CD) and T₇ (DWC + 75% RD-NPK). The best yields were noted in T₁ (RW + RD-NPK) = 10.8 ± 5.4 t·ha⁻¹, T₅ (DWC + 25% RD-NPK) = 9.2 ± 4.6 t·ha⁻¹ and T₄ (DWC) = 8.6 ± 4.3 t·ha⁻¹ which are comparable and higher than those obtained in T₂ = 5.7 ± 2.8 t·ha⁻¹ and T₃ = 7.5 ± 3.8 t·ha⁻¹.

Keywords

Integrated Aquaculture, Drained Water, Fertilization, *C. gariepinus*, Okra

1. Introduction

Agriculture plays a key role in the socio-economic development of most countries, particularly in Africa. On a global scale, the emphasis is now on sustainable development, and most production activities, including agriculture, are largely concerned with respecting norms, preserving and protecting the environment through the rational use of natural resources, among other requirements [1]. Agriculture thus faces a triple challenge: producing more food for an ever-growing population, preserving the environment and guaranteeing food security [2]. It is estimated that food production will have to double by 2030 to meet the needs of the world's human population [3]. In addition, rising incomes are also shifting diets towards greater consumption of animal products [4]. At the same time, the expansion possibilities of agricultural systems have diminished [5], and it is estimated that one billion people are currently undernourished, even when the quantity of food production is sufficient to meet existing demand [6]. Aquaculture is one of the key sectors contributing to food production, poverty reduction and unemployment worldwide. It will account for almost two-thirds of the world's fish production needed for food by 2030, given the stabilization of capture fisheries volumes and the growing demand for fish from an emerging social middle class in the world, and particularly in China [7].

However, aquaculture practices can pose a real threat to the environment, notably through the production and the no management of waste, resulting especially from the metabolism and decomposition in the farming environment of the artificial feed not consumed by the individuals reared, particularly in semi- and intensive rearing systems. The quality of the feed used in aquaculture in terms of buoyancy, digestibility and feed conversion rate largely determines the level of wastes such as ammonium (NH₄⁺) in the rearing environment [8]. The failure to

transform these toxic components (NH_4^+) for reared individuals by specific bacteria into less toxic forms (NO_3^-) and/or poor water management of the rearing environment can severely affect aquatic and terrestrial ecosystems and lead to losses in biodiversity. For example, mangrove areas around the world have suffered severe degradations in recent decades as a result of shrimp farming often in intensive systems [9]. To avoid some of these problems, the concept of integrating fish production with other forms of production, such as crop production, as part of a complex agricultural system, has been developed [10]. In a farming system combining aquaculture and crop production, wastewater from aquaculture ponds is reused in supplying water to plants. Indeed, this water is often described as being rich in nutrients such as nitrogen and phosphorus [11], which can be assimilated by plants and used as fertilizer for plant production. Aquaculture pond water used in irrigation has a positive effects on crop productions [12]. Hence the interest in coupling aquaculture and crop production in the same productive system to make the most of the water in aquaculture ponds and contribute to environmental preservation [13]. This agricultural approach has at least three advantages: it diversifies the types of food production and family income; it saves water by reusing it for plant production; and it promotes organic production by reducing or avoiding the use of mineral fertilizers in favor of organic fertilizers.

Integrated aquaculture is thus recommended for better use of water resources, diversification of production on farms, increased yields and improved income, waste recycling, pollution reduction and environmental conservation [14]. Compared to a non-integrated approach, this dual use of water in an agricultural system reduces the pressure on natural water reserves to meet water needs on farms. It is even seen as one of the solutions that could help tackle the socio-economic problems and environmental challenges facing communities in developing countries, where the majority of the population depends on agriculture for their income-generating activities [15].

It is against this backdrop that the present study aims to breed the African catfish, *Clarias gariepinus*, using the water drained from rearing ponds as fertilizer for okra production. To understand the effects of drained water from breeding, a comparison is done with those of various fertilizers such as NPK, poultry droppings and cow dung at different doses on the growth and yield parameters of okra, *Abelmoschus esculentus* var. *Clemson spineless*.

2. Material and Methods

2.1. Presentation of the Study Area

The study was carried out at the agricultural farm of the Gaston Berger University (UGB) of Saint-Louis (Figure 1). The farm is located on the university campus in the village of Sanar, 16° 18 N and 16° 29 W and has an altitude of 4 m. It is supplied with water by the Djeuss, a tributary of the Senegal River.

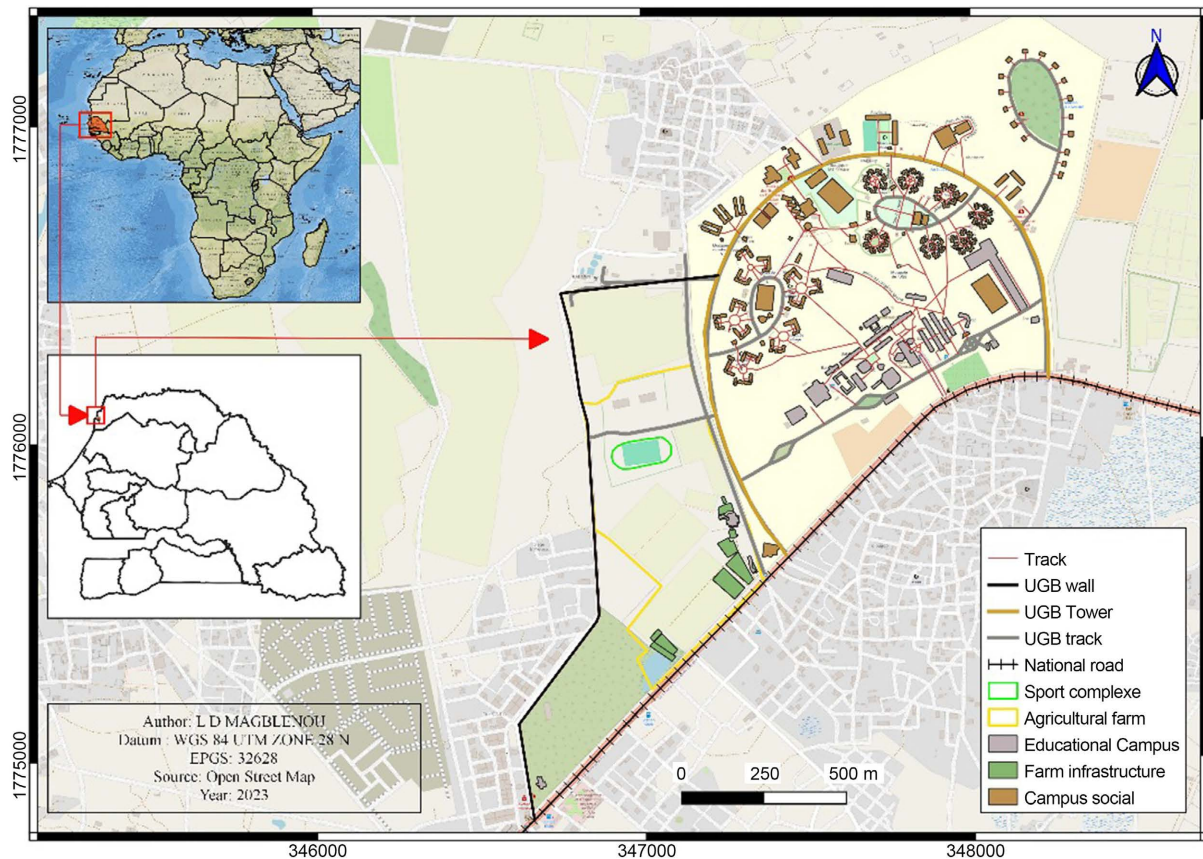


Figure 1. Illustration of the study site.

The climate in this area is sub-canary to Sahelian and is marked by a rainy season from July to October and a dry season from November to June. Annual rainfall is low and varies between 100 and 200 mm [16]. Maximum temperatures recorded in the months of April and May are generally between 35 and 37°C. Minimum temperatures are observed in January (16°C) [17]. It has a flat relief, sandy soil at the 0 - 50 cm horizon and sandy-clay soil at the 50 - 140 cm horizon [18].

2.2. Biological Material

Clarias gariepinus is a disease-resistant species much appreciated by fish farmers for its predisposition to adapt to the changes of abiotic factors in some water bodies, and for its growth performance and flesh quality. It also contains few bones, and its processing into smoked or dried fish is highly appreciated by consumers.

Our interest in okra, *A. esculentus* var. Clemson spineless, is linked to the various uses that can be made of all the parts of this plant (roots, stem, leaves, fruit, seeds) in food, medicine, crafts and industry [19] [20].

2.3. Fertilizers and Irrigation Water

Fertilizers are made up of organic matter such as cow dung and poultry dropping, and mineral fertilizer consisting of nitrogen, phosphorus and potassium (NPK).

The water supply is either river water or *C. gariepinus* rearing water. The

chemical parameters of these waters are shown in **Table 1**.

Table 1. Chemical composition of river water and *C. gariepinus* rearing water [11].

	Water River	Water from <i>C. gariepinus</i> rearing
pH	6.35	6.32
CE ($\mu\text{s}\cdot\text{cm}^{-1}$)	84.1	292
Ca meq/100 g	0.525	0.6
Mg meq/100 g	0.15	0.3
Na meq/100 g	0.105	0.195
K meq/100 g	0.0098	0.021

2.4. Rearing *C. gariepinus*

Clarias gariepinus fingerlings with a mean individual weight of 6 ± 0.3 g from the Station d'Innovation Aquacole (SIA) in Saint-Louis (Senegal) are used to stock breeding ponds at a density of 11 individuals per m^2 . The feed ration is based on fish biomass and size. The individuals are fed 3 times a day at 9 am, 1 pm and 5 pm. Fish are fed with the Gouessan industrial feed made from several ingredients and containing 35% crude protein.

The temperature and pH are measured twice a day at 08:30 am and 4:30 pm during the experiment with a thermometer and a pH-meter, respectively.

Control fisheries are carried out monthly using seine nets. Caught individuals are weighed using an INGCO balance with a precision of 0.01 g and the size of reared individuals is measured with an ichthyometer.

The growth of individuals in weight and height is estimated by Equation (1).

$$w_m = \frac{\sum_{i=1}^n w_i}{n} \quad (1)$$

w_m = average weight; w_i = weight of individual i ; n = number of individuals weighed.

$$l_m = \frac{\sum_{i=1}^n l_i}{n} \quad (2)$$

l_m = average size; l_i = size of individual i ; n = number of individuals measured.

Zootechnical parameters are also determined according to the following expressions:

$$\text{RWG} = \frac{w_f - w_i}{d} \quad (3)$$

RWG = Relative weight gain; w_f = final weight gain; w_i = initial body weight; d = duration of experiment in days.

Specific growth rate:

$$\text{SGR} = \frac{\log(w_f) - \log(w_i)}{d} \times 10 \quad (4)$$

SGR = specific growth rate; w_f = final weight gain; w_i = initial body weight; d = duration of experiment in days.

This coefficient makes it possible to estimate the daily weight gain by reared individuals.

2.5. Experimental Design, Management and Monitoring of Okra Production

The okra, *A. esculentus* var. *Clemson spineless*, is shown in elementary plots. Each plot measuring 1.5 m × 3 m with a spacing of 50 cm × 15 cm with two seeds per planting at a depth of 3 to 5 cm. Each treatment comprises 3 elementary plots, one per block. Treatments are arranged randomly within each block (Figure 2).



Figure 2. Split-plot experimental design with total randomization of treatments (T) by block.

To understand the effects of water drained from ponds rearing *C. gariepinus* on okra growth and yield, a comparison was made with river water and different types of fertilizer at varying doses for crop amendment (Table 2). Mineral fertilizers (NPK) are used to supply precise nutrients according to crop needs, and to maximize plant growth. Organic fertilizers are essentially composed of organic matter from composted cow dung and poultry droppings. They supply the soil with nitrogenous elements, among other things, and help ensure soil and crop fertility.

The recommended agronomic doses of fertilizers according to the technical sheet of okra production [21] used are: cow dung 10 t·ha⁻¹, poultry droppings 6 t·ha⁻¹, DAP 18.46. 50 kg·ha⁻¹, urea 100 kg·ha⁻¹, NPK 10.10.20 and 9.23.30. 250 kg·ha⁻¹. The DAP fertilizers in the NPK, cow dung and poultry dung treatments were initially used as ground fertilizers differently in the respective elementary plots according to the type of treatment applied (organic or mineral) and according to the agronomic doses recommended 3 days before sowing okra. Subsequently, mineral and organic fertilizers were applied every two weeks after sowing.

Only the mineral fertilizer treatment changed. Urea and NPK 10.10.20 were applied 15 and 30 days after sowing, respectively, on the plots treated with mineral fertilizer. NPK 9.23.30 was applied 45 days after sowing, as soon as fruit began to form. Each treatment was triplicated and the 3 elementary plots of a treatment were arranged according to total randomization.

Table 2. Codes and descriptions of treatments [22].

Code	Treatment	Description
T ₀	RW	Elementary plots watered with river water without fertilizer
T ₁	RW + RD-NPK	Elementary plots watered with river water and mineral fertilizer at the recommended dose (100%)
T ₂	RW + RD-FV	Elementary plots watered with river water plus recommended dose of poultry droppings (100%)
T ₃	RW + RD-BV	Elementary plots watered with river water plus the recommended dose of cow dung (100%)
T ₄	DWC	Elementary plots watered with water drained from ponds rearing Clarias without other fertilizer
T ₅	DWC + 25% RD-NPK	Elementary plots watered with water drained from ponds rearing Clarias plus 25% of the recommended dose of NPK
T ₆	DWC + 50% RD-NPK	Elementary plots watered with water drained from ponds rearing Clarias plus 50% of the recommended dose of NPK
T ₇	DWC + 75% RD-NPK	Elementary plots watered with water drained from ponds rearing Clarias plus 75% of the recommended dose of NPK
T ₈	DWC + 25% RD-PD	Elementary plots watered with water drained from ponds rearing Clarias plus 25% of the recommended dose of poultry droppings
T ₉	DWC+50% RD-PD	Elementary plots watered with water drained from ponds rearing Clarias plus 50% of the recommended dose of poultry droppings
T ₁₀	DWC + 75% RD-PD	Elementary plots watered with water drained from ponds rearing Clarias plus 75% of the recommended dose of poultry droppings
T ₁₁	DWC + 25% RD-CD	Elementary plots watered with water drained from ponds rearing Clarias plus 25% of the recommended dose of cow dung
T ₁₂	DWC + 50% RD-CD	Elementary plots watered with water drained from ponds rearing Clarias plus 50% of the recommended dose of cow dung
T ₁₃	DWC + 75% RD-CD	Elementary plots watered with water drained from ponds rearing Clarias plus 75% of the recommended dose of cow dung.

The elementary plots were watered daily using river or water drained from ponds rearing *C. gariepinus*. The quantity of water used per elementary plot depended on the development stages of the plants: 22 L per elementary plot at the start of the experiment during 15 days; 33 L per elementary plot between 16 and 40 days during vegetative development of the plants; and 44 L for each elementary plot from 41th day corresponding to the start of the fruiting stage of the plants until the end of the experiment.

Growth is estimated from measurements height and collar diameter of plants. Growth parameters are measured every week on 3 plants located in the middle of the elementary plot, to take into account the border effect. Height is measured using a tape measure and the collar diameter is taken at the base of the plant using a calliper.

Fruits are weighed with balance at a precision of 0.01 g. Total yield (R) is estimated by extrapolating the total weight of fruits harvested from all plants in each elementary plot per treatment to the hectare ($\text{t}\cdot\text{ha}^{-1}$) as follows:

$$R = \sum_i^n r_i * \frac{S_{ha}}{\sum_1^n s_i} \quad (5)$$

where r_i = yield per experimental plot and per treatment; S_{ha} = area per hectare; s_i = area of experimental plot i ; n = total number of experimental plots corresponding to a treatment.

2.6. Statistical Analysis of Data

The effects of river water, *C. gariëpinus* rearing water and fertilisers on the number of fruits per week depending on the treatment were compared using the Chi-Square test.

The variations of pH and temperature of pond water between mornings and evenings are compared using the Wilcoxon test. Mean collar diameter and mean height of plants, mean diameter and mean weight of fruits according to the treatments are compared using the Kruskal-Wallis test. The Wilcoxon and Kruskal-Wallis tests are applied to these variables because their distributions were not normal and the variances were not homogeneous. When the results of Kruskal-Wallis tests are significant, they are followed by the Pairwise test using Holm's method for p-value adjustment to compare the means two by two.

Lengths of okra fruits according to the treatments showed a normal distribution and variances were homogeneous and are compared using the ANOVA test. This test is followed by Tukey's to identify the means that are different.

In order to determine the hierarchical structure of the plants growth and yield according to the treatment, a Correspondence Analysis [23] was performed on the growth and yield variables per treatment, transformed by $\log(x + 1)$ to homogeneous the relative contribution of the variables. An Ascending Hierarchical Classification (Euclidean distance, average linkage agglomeration method) [24], was then performed using the coordinates of each variable on the two most significant axes of the Correspondence Analysis.

The statistical tests were concluding at the level $\alpha = 0.05$ and were realized using the R software version R i386 3.6. [25].

3. Results

3.1 Water Temperature and pH in Rearing Ponds

The mean daily temperature in the *C. gariëpinus* rearing ponds was $27.6^\circ\text{C} \pm$

1.5°C. The average temperature in the mornings was 26.6°C ± 2°C and in the evenings 28.6°C ± 1.4°C. Average water temperatures in the breeding ponds between mornings and evenings were significantly different ($p < 0.05$).

The daily mean pH of the water in the breeding ponds was 8.4 ± 1.1. The average pH in the mornings was 8.1 ± 1.1. In the evenings, the mean pH value was 8.7 ± 1.3. There was a significant difference in pH values between mornings and evenings ($p < 0.05$).

3.2. Production and Zootechnical Parameters of *C. gariepinus* in Rearing Ponds

The average weight of *C. gariepinus* individuals in the ponds ranged from 6.0 ± 0.3 to 850.1 ± 1.3 g during the 6 months of rearing (Figure 3). The variation in monthly weight gain in *C. gariepinus* individuals was 95.94 g in the 1st month after stocking and 635.33 g in the 5th, rising to 206.67 g and 450 g in the 2nd and 4th months, respectively. Average weight gain during the rearing period was 844.1 ± 1.7 g.

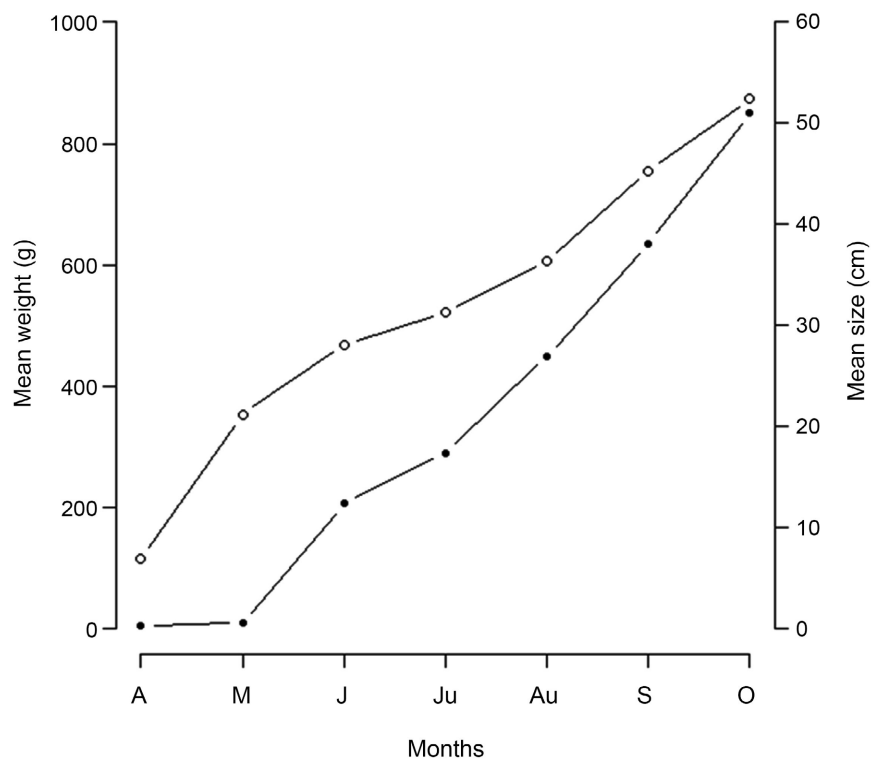


Figure 3. Variations in the average weight and size of *C. gariepinus* individuals during the rearing period (solid circle = average weight; hollow circle = average size).

The average size of *C. gariepinus* individuals reared in the ponds ranged from 7.0 ± 0.5 to 52.4 ± 1.1 cm during the rearing period (Figure 3). Growth in size was estimated at between 21.2 cm in the 1st month and 52.44 cm in the 6th month. Growth was 31.37 cm, 36.43 cm and 45.3 cm at 3rd, 4th and 5th months, respectively.

Daily weight gain (DWG) was 3.9 ± 0.5 g·day⁻¹ in the reared individuals. Specific growth rate (SGR) in *C. gariepinus* was 2.8 ± 0.2 per day in rearing pond.

3.3. Effects of Drained Water from Ponds Rearing *C. Gariepinus* on Growth Parameters of Okra

3.3.1. Collar Diameter of Okra Plants

The lowest mean collar diameter of plants was observed in treatment T₀ with 1.0 ± 0.5 cm watered with river water and the highest value was 2.3 ± 0.9 cm in T₁ treated with 100% RD-NPK and watered with river water. The collar diameter noted in T₇ watered with water drained from ponds rearing *C. gariepinus* plus 75% RD-NPK was 1.9 ± 0.9 cm (Figure 4). The mean collar diameters of plants in treatments T₂, T₃ and T₄ were 1.8 ± 0.8 cm; 1.5 ± 0.7 cm and 1.4 ± 0.8 cm, respectively. Differences in plant collar diameters between treatments were significant ($p < 0.05$). These differences are noted between the mean collar diameter of T₀ and all other treatments, except T₁₀. Treatments with NPK with a dose above or equal to 75% of the recommended dose had mean plant collar diameters significantly different to T₄. However, the mean collar diameter of T₄ was comparable to that of treatments with poultry dung (T₂), cow dung (T₃) and NPK at doses below 75% of the recommended dose.

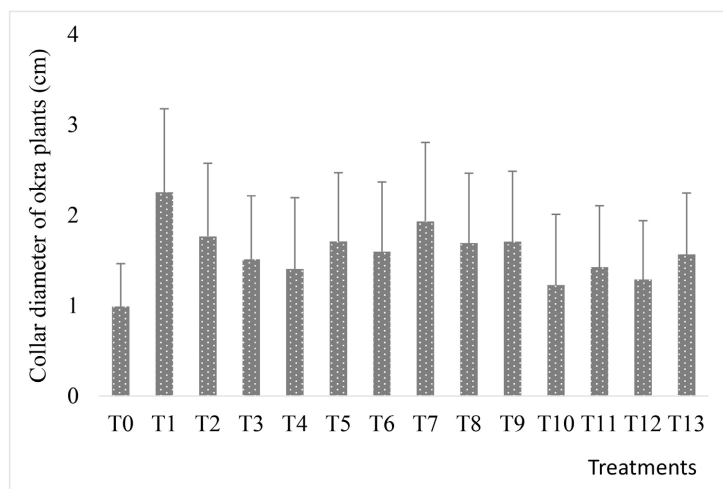


Figure 4. Variation in mean diameter at the crown of okra plants according to treatments.

3.3.2. Height of Okra Plants

The average height of plants ranged from 24.5 ± 13.8 cm in the control treatment T₀, watered with river water, to 61.6 ± 32 cm in T₁ watered with river water plus 100% RD-NPK (Figure 5). Average heights of plants were 44.8 ± 24.7 cm in T₂, 42.4 ± 25.4 cm in T₃ and 38.8 ± 23.5 cm in T₄. Average height of plants was 50.3 ± 28.4 cm in T₇. Average height of plants in T₀ was significantly different from other treatments, except in T₁₀ and T₁₂. A statistical difference was also noted between the mean heights of plants in T₄ and T₁. However, the mean height of plants in treatment T₄ is comparable to those of treatments T₂, T₃, T₅, T₆ and T₇.

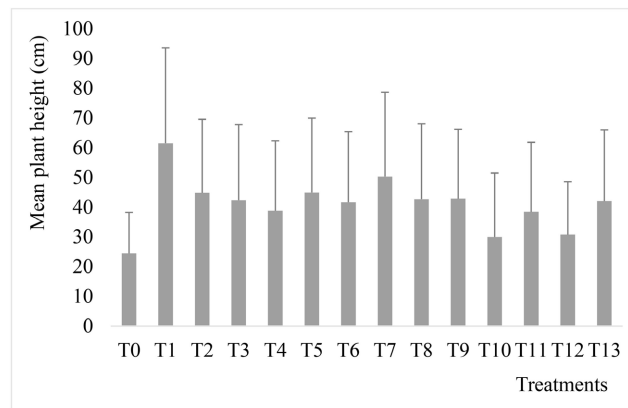


Figure 5. Variation in average height of okra plants according to treatments.

3.3.3. Structure of Okra Growth According to the Treatments

The Hierarchical ascending classification (**Figure 6**) based on growth parameters enabled to distinguish four (04) main groups between treatments. The group *I* is made up of two 2 subgroups: *Ia* which is made up of T₉, T₈, T₅, T₂ and T₇ and *Ib* made up of T₁₃ and T₆. The group *II* is constituted of treatments T₁₂, T₄, T₁₁, T₃ and T₁₀; group *III* is composed of T₁ and group *IV* of T₀. This structuring of treatments according to okra plant growth parameters shows that the treatment with water drained from ponds rearing *C. gariepinus* (T₄) gave different growth performances to those obtained with river water (T₀), RD-NPK (T₁) and RD-PD (T₂). The treatment T₄ gave growth performances close to those of the treatment watered with water drained from ponds rearing *C. gariepinus* plus 50% (T₁₂) or 25% (T₁₁) of the recommended dose of cow dung, the recommended dose of poultry droppings (T₃) and that with drained water plus 75% of poultry droppings (T₁₀). According to this result, the combined effect of DWC + NPK; DWC + CD or DWC + PD would influence okra growth more than the use of only the water drained from ponds rearing *C. gariepinus*.

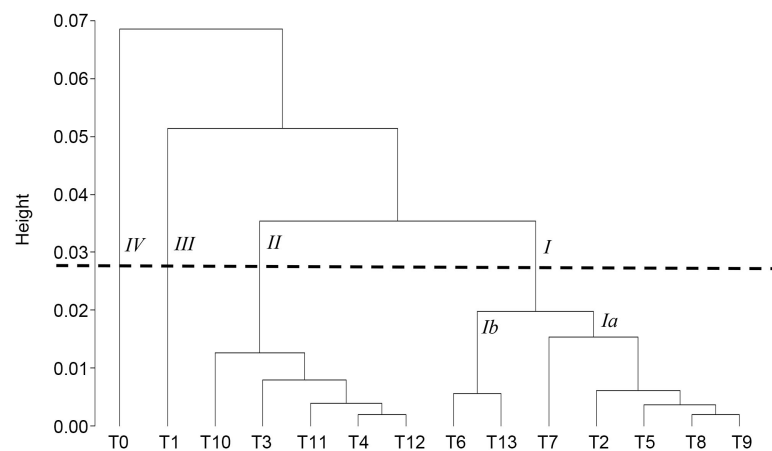


Figure 6. Hierarchical ascending classification of treatments according to okra growth parameters using the mean-link method based on the coordinates of the correspondence analysis axes (for treatment codes, see **Table 2**).

3.4. Effects of Drained Water from *C. gariepinus* Farms on Okra Yield Parameters

3.4.1. Number, Weight and Average Length of Okra Fruits

The lowest mean number of fruits per plant was observed in treatment T₀ with 5.7 ± 0.3 and the highest in treatment T₇ with 20.2 ± 1.2 , watered with water drained from ponds rearing *C. gariepinus* plus 75% RD-NPK (Table 3). The number of fruits in treatments T₁, T₂, T₃ and T₄ was 19.4 ± 1 , 14.0 ± 0.8 , 13.1 ± 0.5 and 7.0 ± 0.5 , respectively. The Chi-square test showed that the mean number of fruits by treatment was a function of time ($p < 0.05$).

Table 3. Variation in weight, number and average length of okra fruits according to treatments.

Treatments	Average number of fruits per plant	Average fruit weight (g)	Average fruit length (cm)
T ₀	5.7 ± 0.3	7.1 ± 3.5^c	6.6 ± 2.0^b
T ₁	19.4 ± 1.0	12.8 ± 4.9^b	8.3 ± 2.2^a
T ₂	14.0 ± 0.8	10.8 ± 5.4^{ab}	7.4 ± 2.5^{ab}
T ₃	13.1 ± 0.5	12.9 ± 6.2^{ab}	8.2 ± 2.5^a
T ₄	7.0 ± 0.5	11.2 ± 5.1^{ab}	7.9 ± 2.1^{ab}
T ₅	18.3 ± 0.9	12.7 ± 5.6^b	8.3 ± 2.3^a
T ₆	14.6 ± 0.6	11.5 ± 4.8^{ab}	8.1 ± 2.2^a
T ₇	20.2 ± 1.2	12.8 ± 5.8^b	7.7 ± 2.2^{ab}
T ₈	16.4 ± 1.3	11.2 ± 4.7^{ab}	7.7 ± 2.2^{ab}
T ₉	12.8 ± 0.5	10.9 ± 4.8^{ab}	7.7 ± 2.2^{ab}
T ₁₀	6.4 ± 0.5	12.7 ± 6.7^{ab}	7.6 ± 2.8^{ab}
T ₁₁	11.1 ± 0.5	10.7 ± 4.6^{ab}	7.6 ± 2^{ab}
T ₁₂	8.8 ± 0.5	10.0 ± 5.3^a	7.6 ± 2.4^{ab}
T ₁₃	14.6 ± 0.7	9.2 ± 4.5^a	7.7 ± 2.6^{ab}

Values with the same letter in the column are not significantly different, and those with different letters are statistically different at the $\alpha = 5\%$ threshold.

The lowest average fruit weight was noted in treatment T₀ with 7.1 ± 3.5 g and the highest of 12.9 ± 6.2 g in the treatment (T₃) watered with river water plus RD-CD (Table 3). Average fruit weight was 12.8 ± 4.9 g in T₁, 10.8 ± 5.4 g in T₂ and 11.2 ± 5.1 g in T₄. It was 12.7 ± 5.6 g in T₅ watered with water drained from ponds rearing *C. gariepinus* plus 25% RD-NPK and 12.8 ± 5.8 g in T₇ treated with drained water plus 75% RD-NPK. Mean fruit weight showed significant differences between T₀ and all other treatments ($p < 0.05$). However, average fruit weight in T₄ was comparable with T₁, T₂, T₃, T₅ and T₆ ($p > 0.05$).

Mean fruit length ranged from 6.6 ± 2.0 cm in T₀ to 8.3 ± 2.3 cm in T₅, watered with water drained from ponds rearing *C. gariepinus* plus 25% RD-NPK. It was 8.3 ± 2.2 cm for T₁, 7.4 ± 2.3 cm for T₂, 8.2 ± 2.5 cm for T₃ and 7.9 ± 2.1 cm for T₄

(Table 3). Fruit length differed between treatments ($p < 0.05$). These differences were noted between T_0 and treatments T_1 , T_3 , T_5 and T_6 . However, no significant differences were noted between T_4 and the other treatments.

3.4.2. Okra Fruit Diameter

The lowest average fruit diameter was observed in T_8 with 1.5 ± 0.3 cm, treatment watered with water drained from ponds rearing *C. gariepinus* plus 25% RD-PD (Figure 7). The largest fruit diameter was noted in treatment T_7 with 1.8 ± 0.3 cm watered with DWC plus 75% NPK. The treatments T_1 , T_2 and T_4 had the same average fruit diameter at 1.6 ± 0.3 cm. It was 1.7 ± 0.3 cm in T_3 . Fruit diameters differed statically between treatments. The differences were noted between treatments T_2 - T_7 , T_2 - T_{13} , T_3 - T_8 and T_3 - T_{13} .

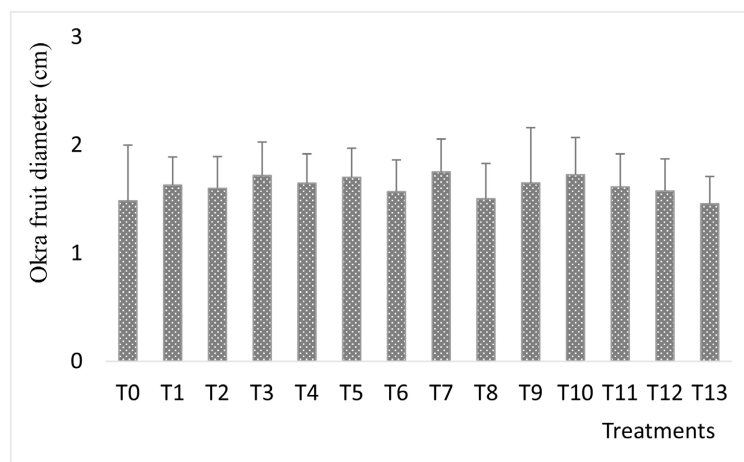


Figure 7. Variation in okra fruit diameter according to treatments.

3.4.3. Okra Fruit Yields

The lowest yield was obtained with the control treatment (T_0) = 4.1 ± 2.1 t·ha⁻¹. The highest yields were recorded in T_1 with 10.8 ± 5.4 t·ha⁻¹ followed by T_5 = 9.2 ± 4.6 t·ha⁻¹, T_7 = 8.8 ± 4.4 t·ha⁻¹ and T_{11} = 9.1 ± 4.5 t·ha⁻¹ (Figure 8). The yields were 5.7 ± 2.8 t·ha⁻¹ in T_2 , 7.5 ± 3.8 t·ha⁻¹ in T_3 and 8.6 ± 4.3 t·ha⁻¹ in T_4 . Yields differed statistically between treatments ($p < 0.05$). The yield obtained in T_0 is significantly different from those of most treatments (T_1 , T_3 , T_4 , T_5 , T_7 , T_8 , T_9 and T_{10}). Differences are also noted between T_1 , on the one hand, and treatments T_6 , T_9 , T_{10} , T_{12} and T_{13} , on the other hand. The yield in T_4 was also significantly different to T_2 . However, the yields of treatments T_1 , T_3 and T_4 are comparable ($p > 0.05$).

3.4.4. Structure of Okra Yield by Treatment

Hierarchical ascending classification (Figure 9) of the different treatments based on yield variables enabled to distinguish three (03) main groups. The group I is made up of two subgroups: subgroup Ia comprises treatments T_9 , T_3 , T_8 , T_{13} and subgroup Ib is made up of T_{12} , T_6 , T_{10} and T_2 . The group II comprises treatment T_0 and group III treatments T_5 , T_4 , T_{11} , T_7 and T_1 . Treatment T_4 with water drained

from ponds rearing *C. gariepinus* gave yield performances comparable to those of fertilization with DWC + 25% RD-NPK (T₅), DWC + 25% RD-cow dung (T₁₁), DWC + 75% RD-NPK (T₇) and RW + RD-NPK (T₁). These treatments, forming group *III*, gave the best okra yields. Thus, in some cases, the combined effects of DWC + NPK; DWC + CD or DWC + PD allowed to improve okra yields.

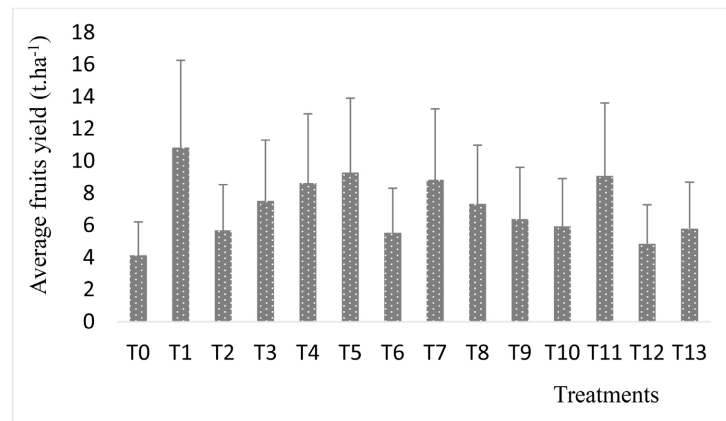


Figure 8. Variation in average okra fruit yields according to treatments.

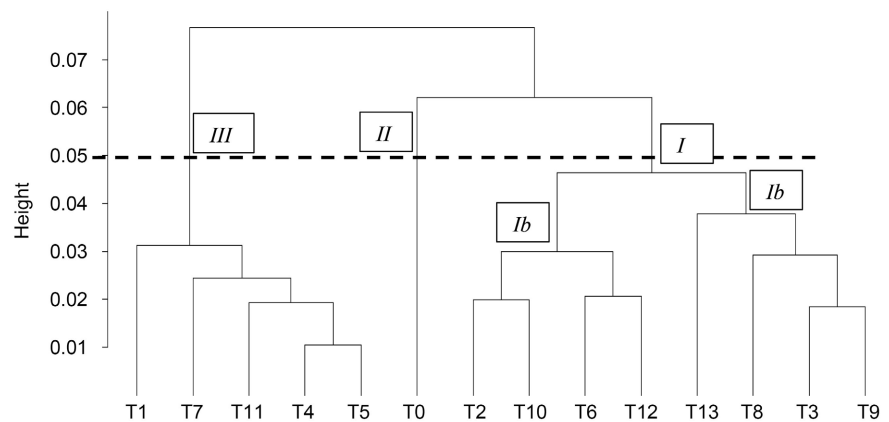


Figure 9. Hierarchical ascending classification of treatments according to okra yield parameters using the mean-link method based on the coordinates of the correspondence analysis axes (for treatment codes, see Table 2).

4. Discussion

4.1. Physico-Chemical Parameters of Rearing Pond Water

The mean daily water temperature in *C. gariepinus* breeding ponds was $27.6^{\circ}\text{C} \pm 1.6^{\circ}\text{C}$. The values obtained are suitable for breeding *Clariidae*. The authors such as [26] [27] indicated that the range of temperatures preferred by this group of catfish, including *C. gariepinus*, for good growth is between 27°C and 32°C .

The average daily pH of the water in ponds rearing was 8.4 ± 1.1 . This pH value is within the range recommended for rearing most of the species. In fact, pH values between 6.5 and 8.5 are those that give the best growth performance for majority of the reared species, including *C. gariepinus* [28]-[30].

The average weight of reared individuals ranged from 6 ± 0.3 to 850.12 ± 1.3 g, and average size from 7 ± 0.5 to 52.44 ± 1.1 cm during the 6 months of breeding. These relatively good growth performances can be explained in part by the quality of the feed used and the good management of water quality in the rearing ponds. According to [31], catfish can grow from 1 to 800 g in seven months of rearing at temperatures between 26°C and 28°C .

The growth performances of *C. gariepinus* obtained in this study are similar to those obtained by [32], who showed that this species can reach between 500 and 1000 g in 8 months of rearing.

Daily weight gain in *C. gariepinus* was $3.9 \text{ g}\cdot\text{day}^{-1}$ in the rearing pond. For a given species, average daily weight gain is influenced by many of factors, including rearing water quality, feeding method, length of rearing cycle, stocking density, rearing device and rearing system. Indeed, the RWG value reported by [31] in *C. gariepinus* was $3.2 \text{ g}\cdot\text{d}^{-1}$ in bamboo cage, rearing lower than that found in this study.

The specific growth rate obtained after 180 days of rearing *C. gariepinus* in ponds was 2.8% per day. This rate is comparable to that obtained by [33], which is 2.88% per day after 120 days of rearing *C. gariepinus* in cages. It is lower than those recorded by [31] which are 3.33%; 3.25% and 3.43% per day after 150 days of rearing for individuals with initial average weights of 5.6 ± 0.23 g, 5.9 ± 0.23 g and 6.3 ± 0.23 g, respectively.

The specific growth rate of *C. gariepinus* $2.8\%\cdot\text{day}^{-1}$ found in this study is better than that of [34] who have obtained a specific growth rate of $0.78\%\cdot\text{day}^{-1}$ in tilapia reared during 6 months. It is also better than the specific growth rates of $2.77\%\cdot\text{day}^{-1}$ and $2.38\%\cdot\text{day}^{-1}$ found by [35] in males and females of *Oreochromis niloticus*, respectively, after 91 days of rearing in tanks.

The fact that the growth rate in our study is lower than those found by [31] and [33] for the same species, could be explained by a difference in protein rate in the feed used. In our study, the protein rate in the feed used is 35%, which is lower than 42% in the feed used by these authors during the rearing of *C. gariepinus* individuals.

4.2. Effects of Water Drained from Rearing *C. gariepinus* on Okra Growth

For plant height and collar diameter, the lowest values were obtained in the control treatment (T_0) watered with river water and no fertilizer added. The values of vegetative parameters such as plant height and collar diameter were highest in treatments T_1 and T_7 . The values obtained in these treatments seem to indicate comparable effects of the fertilizers used in these treatments on okra growth. This may be explained by the fact that their compositions in mineral elements are fairly similar. The T_1 corresponds to the treatment with RD-NPK and T_7 to the treatment with 75% RD-NPK + DWC. As for the treatment with only water drained from rearing *C. gariepinus* (T_4), it seems to have comparatively performed less on

growth parameters than treatments T₁ and T₇. This could indicate that DWC alone lacks certain nutrients required for optimal okra growth. However, it is reputed to be very rich in nitrogen, considered as one of the main components used by plants in the production of molecules such as proteins, nucleotides, nucleic acids and chlorophyll [36]. In a “cycled” rearing pond, this nitrogen in the form of nitrate comes mainly from the decomposition and mineralization by specific bacteria of the uneaten feed supplied, dead organisms and the metabolic excreta of the reared individuals [37]-[41]. The rate of N content in DWC and its content of other mineral elements such as phosphorus, potassium, etc. enable growth performances comparable to those of fertilizers such as RD-CD (T₃).

Thus, the combination of minerals and micronutrients from organic fertilizers and DWC has a greater effect on okra plant development. These results are similar to those found [38], who showed that okra plant growth differed considerably according to the type of fertilizer applied, and that the combined effects of organic and mineral fertilizers had a significant influence on the vegetative development of okra.

4.3. Effects of Water Drained from Rearing *C. gariepinus* on Okra Production Parameters

The highest mean number, mean weight, mean length and diameter of fruits were noted in T₃, watered with river water plus RD-CD and T₇, which was watered with water drained from rearing *C. gariepinus* plus 75% RD-NPK.

The combined effects of the minerals and micronutrients present in the cow dung, the mineral fertilizer and the drained water from rearing *C. gariepinus* resulted in higher yields in terms of number, average weight, diameter and length of fruits. The combined application of nutrients in different forms, such as ground phosphate and organic fertilizer, was shown to significantly improve production parameters of crops such as okra, *A. esculentus*, and sorghum, Sorghum growth, compared to the application of each form of fertilizer separately [39]-[41].

The highest yields were obtained with the treatments T₁ and T₅. The results obtained with these treatments can be explained by the presence of nutrients such as nitrogen, phosphorus and potassium in the NPK, to which are added the mineral elements supplied by the water drained from rearing *C. gariepinus*. In addition, analysis based on hierarchical ascending classification shows that the T₄ treatment achieved yield performances comparable to those of treatments with T₅, T₁₁, T₇ and T₁. This could indicate that the levels of essential nutrients for production namely N, P in the water drained from rearing *C. gariepinus* are closer to those contained in the NPK fertilizer. This richness in nutrients such as nitrogen, phosphorus, carbon, trace elements, etc. [11] could be explained by the fish's metabolic capacity, which partly influences the level of discharge in water of the rearing environment [42]. On the other hand, the single use of DWC (T₄) resulted in higher okra yields than fertilization with RD-PD or RD-CD. Combining these fertilizers with DWC improved yields. Thus, our results are conforming with those

of [38] who showed that a combination of organic and inorganic fertilizers improves fruit yield and provides balanced nutrients to the okra crop.

5. Conclusion

Finally, water drained from ponds rearing *C. gariepinus* (T4) gave growth performances closer to a recommended dose of cow dung (T3) than those of recommended doses of poultry droppings (T2) and NPK (T1). The fertilization with the best growth performance was that with water drained from *C. gariepinus* rearing ponds plus 75% of the recommended dose of NPK and river water plus the recommended dose of NPK. For yield parameters, water drained from ponds rearing *C. gariepinus* gave the same yield performance as recommended dose of NPK and a higher yield than treatments with recommended doses of poultry droppings and cow dung. In sum, water drained from ponds rearing *C. gariepinus* is a good fertilizer for okra production.

Acknowledgements

The authors are grateful to Ms. Elisabeth ONOJA (MATIC, LEA Department, UFR LSH/UGB) for the reading this paper and helpful comments and Parfait Henry Gédéon TOUSSOUNGAMANA NZOUZI (Founder of HARMAZI digital agency) for setting up the experimental system of the study area. The authors also thank the anonymous reviewers for their very useful and constructive comments.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Boyd, C.E.B., Lim, C.L., de Queiroz, J.F., Salie, K.S., de Wet, L. and McNevin, A. (2008) Best Management Practices for Responsible Aquaculture (Vol. 10). USAID.
- [2] Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., *et al.* (2010) Food Security: The Challenge of Feeding 9 Billion People. *Science*, **327**, 812-818. <https://doi.org/10.1126/science.1185383>
- [3] Tilman, D. (1999) The Ecological Consequences of Changes in Biodiversity: A Search for General Principles. *Ecology*, **80**, 1455-1474. <https://doi.org/10.2307/176540>
- [4] Pingali, P. (2007) Westernization of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy. *Food Policy*, **32**, 281-298. <https://doi.org/10.1016/j.foodpol.2006.08.001>
- [5] Rudel, T.K., Schneider, L., Uriarte, M., Turner, B.L., DeFries, R., Lawrence, D., *et al.* (2009) Agricultural Intensification and Changes in Cultivated Areas, 1970-2005. *Proceedings of the National Academy of Sciences*, **106**, 20675-20680. <https://doi.org/10.1073/pnas.0812540106>
- [6] FAO (2009) The State of Food Insecurity in the World 2009: Economic Crises—Impacts and Lessons Learned. FAO.
- [7] FAO (2014) La situation mondiale des pêches et de l'aquaculture 2014.
- [8] Ackefors, H. and Enell, M. (1994) The Release of Nutrients and Organic Matter from

- Aquaculture Systems in Nordic Countries. *Journal of Applied Ichthyology*, **10**, 225-241. <https://doi.org/10.1111/j.1439-0426.1994.tb00163.x>
- [9] FAO (2007) The World Mangroves 1980-2005. FAO.
- [10] Little, D., and Muir, J. (1987) A Guide to Integrated Warm Water Aquaculture. Institute of Aquaculture, University of Stirling, 255.
- [11] Diatta, A.A., Manga, A.G.B., Bassène, C., Mbow, C., Battaglia, M., Sambou, M., et al. (2023) Sustainable Production of Tomato Using Fish Effluents Improved Plant Growth, Yield Components, and Yield in Northern Senegal. *Agronomy*, **13**, Article 2696. <https://doi.org/10.3390/agronomy13112696>
- [12] Zouakh, D.E., Ferhane, D. and Bounouni, A. (2016) Integration De La Pisciculture a L'agriculture En Algerie: Cas De La Wilaya De Ouargla. *Revue des Bioressources*, **6**, 66-82. <https://doi.org/10.12816/0045897>
- [13] Li, B., Pattenden, S.G., Lee, D., Gutiérrez, J., Chen, J., Seidel, C., et al. (2005) Preferential Occupancy of Histone Variant H2AZ at Inactive Promoters Influences Local Histone Modifications and Chromatin Remodeling. *Proceedings of the National Academy of Sciences*, **102**, 18385-18390. <https://doi.org/10.1073/pnas.0507975102>
- [14] Miller, J., Atanda, T., Asala, G. and Chen, W.H. (2010) Opportunités de l'intégration de l'irrigation et de l'aquaculture au Nigéria: Le programme Spécial pour la Sécurité Alimentaire et la rizipisciculture au Nigéria. In: Halwart, M. and van Dam, A.A., Édts., *Intégration de l'irrigation et de l'aquaculture en Afrique de l'Ouest: Concepts, pratiques et perspectives d'avenir*, FAO, 125-133.
- [15] Acharya, A. (2004) How Ideas Spread: Whose Norms Matter? Norm Localization and Institutional Change in Asian Regionalism. *International Organization*, **58**, 239-275. <https://doi.org/10.1017/s0020818304582024>
- [16] Diack, M. and Loum, M. (2014) Caractérisation par approche géostatistique de la variabilité des propriétés du sol de la ferme agropastorale de l'Université Gaston Berger (UGB) de Saint-Louis, dans le bas Delta du Fleuve Sénégal. *Revue de géographie du laboratoire Leïdi*, **12**, 1-5.
- [17] Daité, B., dalanda Diallo, M., Goalbaye, T., Diédhiou, S., Diallo, A., Talla, R., et al. (2020) Effet de l'application de différentes doses de fertilisants organiques sur la croissance et le rendement de la tomate (*Solanum lycopersicum* L.) en conditions semi-contrôlées. *Journal of Animal & Plant Sciences*, **44**, 7553-7566. <https://doi.org/10.35759/janmplsci.v44-1.2>
- [18] César, B., Nicolas, M., Rahimi, M., Aziz, C.A., Samba, M.M. and Kandjouira, N. (2018) Structure et caractéristiques de la flore adventice de la ferme agricole de l'Université Gaston Berger de Saint-Louis (Sénégal). *European Scientific Journal*, **14**, 229-244. <https://doi.org/10.19044/esj.2018.v14n24p229>
- [19] Maruis, C., Gerad, V. and Antoine, G. (1997) Le gombo, *Abelmoschus esculentus* (L.), une source possible de phospholipides. *Agronomie et Biotechnologies. Oléagineux, Corps Gras, Lipides*, **4**, 389-392.
- [20] Siemonsma, J.S. and Hamon, S. (2004) *Abelmoschus esculentus* (L.) Moench: Ressources Végétales de l'Afrique Tropicale. Fondation PROTA, Wageningen-Pays-Bas, 25-30.
- [21] Legba, E.C., Romaric, G., Ahlincou, R., Atchanhouin, L.A., Aglinglo, R.A., Francisco, V., Fassinou, H.E.G. and Achigan-Dako, E.G. (2018) Fiche technique de la production de gombo. Laboratory of Genetics Horticulture and Seed Science (GBioS), Bibliothèque Nationale du Bénin, 6.
- [22] Magblénou, L.D., Kantoussan, J., Bassène, C., Gueye, D. and Sy, H. (2023) Effects of

- Water Drained from Ponds Rearing Tilapia on Okra Production. *International Journal of Natural and Social Sciences*, **10**, 38-49.
<https://doi.org/10.5281/zenodo.10042453>
- [23] Greenacre, M.J. (1984) Theory and Applications of Correspondence Analysis. Academic Press, 364.
- [24] Sneath, P.H. and Sokal, R.R. (1973) Numerical Taxonomy. The Principles and Practice of Numerical Classification. W.H. Freeman and Company, 15, 573.
- [25] R Core Team (2021) The R Project for Statistical Computing.
<https://www.R-project.org/>
- [26] Viveen, W.J. (1985) Practical Manual for the Culture and Fisheries of the African Catfish (*Clarias gariepinus*). Department of Fish Culture and Fisheries of the Agricultural, University of Wageningen, 121.
- [27] Ducarme, C. and Micha, J.C. (2003) Technique de production intensive du poisson chat africain, *Clarias gariepinus*. *Tropicultura*, **21**, 189-198.
- [28] Boyd, C.E. (1998) Water Quality in Pond for Aquaculture. Alabama Agricultural Experiment Station, Auburn University, 37.
- [29] Sigma, Environmental Consultants Ltd. (1983) Summary of Water Quality Criteria for Salmonids Fishes. Department of Fisheries and Oceans, SECL 8067, 49-58.
- [30] Tabaro, S.R., Micha, J.C. and Ducarme, C. (2005) Essais d'adaptation de production massive de juvéniles de *Clarias gariepinus* en conditions rurales. *Tropicultura*, **23**, 231-244.
- [31] Dasuki, A., Auta, J. and Oniye, S. (2014) Effect of Stocking Density on Production of *Clarias gariepinus* (Tuegels) in Floating Bamboo Cages at Kubanni Reservoir, Zaria, Nigeria. *Bayero Journal of Pure and Applied Sciences*, **6**, 112-117.
<https://doi.org/10.4314/bajopas.v6i1.23>
- [32] Fermon, Y. (2011) La pisciculture de subsistance en étangs en Afrique: Manuel technique. Action contre la faim. ACF-International Network, Paris, 276.
- [33] Pèlèbè, R.O.E., Ouattara, I.N., Agbohessi, P.T., Attakpa, E.Y., Mattah, P.A.D., Effah, E., *et al.* (2023) Growth Performance and Proximate Composition of African Catfish (*Clarias gariepinus*) Cultured in Cages and Pens in Northern Benin Water Reservoirs Exposed to Cotton-Field Effluents. *Aquaculture Studies*, **23**.
<https://doi.org/10.4194/aquast1038>
- [34] Amon, N.Y., Konan, S.K., Kouassi, D.K. and Yao, K. (2020) Performances zootechniques des mâles de *Oreochromis niloticus* (Linné, 1758), *Sarotherodon melanotheron* (Rüppell, 1853) et leurs hybrides en phase de grossissement en cages installées en étang. *International Journal of Biological and Chemical Sciences*, **14**, 1611-1617.
<https://doi.org/10.4314/ijbcs.v14i5.10>
- [35] Owusu-Frimpong, M., Attipoe, F.Y.K. and Padi, J.N. (2005) Comparison of Some Traits of Economic Importance in Tilapias (*Oreochromis niloticus* and *Sarotherodon galilaeus*) with Particular Reference to Their Culture in Ghana. *Naga the World Fish Center Quarterly*, **28**, 33-36.
https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/1952/na_2_355.pdf?sequence=1&isAllowed=y
- [36] Batamoussi, M.H., Tovihoudji, P.G., Tokore, O.M., Boulga, J. and Essegnon, I.M. (2016) Effet des engrais organiques sur la croissance et le rendement de deux variétés de tomate (*Lycopersicum esculentum*) dans la commune de Parakou (Nord Bénin). *International Journal of Innovation and Scientific Research*, **24**, 86-94.
- [37] Yinhe, P. (1996) Ecological Effects of Rice-Fish Culture. In: MacKay, K.T., Ed., *Rice-*

Fish Culture in China, International Development Research Centre, 189-193.

- [38] Olaniyi, J.O., Akanbi, W.B., Olaniran, O.A. and Ilupeju, O.T. (2010) L'effet des engrais organominéraux et inorganiques sur la croissance, le rendement en fruits, de la qualité chimique et Compositions de gombo. *Journal of Animal & Plant Sciences*, **9**, 1135-1140.
- [39] Babatola, L.A. (2013) Effect of NPK 15:15:15 on the Performance and Shelf Life of Okra (*Abelmoschus esculentus*). *Journal of Agriculture, Biotechnology and Ecology*, **6**, 95-101. <https://www.cabidigitallibrary.org/doi/pdf/10.5555/20143048281>
- [40] Bayu, W., Rethman, N.F.G., Hammes, P.S. and Alemu, G. (2006) Effects of Farmyard Manure and Inorganic Fertilizers on Sorghum Growth, Yield, and Nitrogen Use in a Semi-Arid Area of Ethiopia. *Journal of Plant Nutrition*, **29**, 391-407. <https://doi.org/10.1080/01904160500320962>
- [41] Akande, M.O., Oluwatoyinbo, F.I., Makinde, K.A., Adepoju, A.S. and Adepoju, S. (2010) Response of Okra to Organic and Inorganic Fertilization. *Nature and Science*, **8**, 261-266.
- [42] Guillaume, J., Kaushik, S., Bergot, P. and Métailler, R. (1999) Bases de la nutrition des animaux aquatiques: Physiologie digestive et digestibilité des nutriments. Nutrition et alimentation des poissons et crustacés. INRA-IFREMER, 71-74.