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Effects of water drained from ponds rearing Tilapia on okra production

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ABSTRACT

The present study is part of the revalorization of water drained from the aquaculture ponds of Tilapia (*Oreochromis niloticus*) farms on the culture of okra, *Abelmoschus esculentus* var. *Clemson spineless*. The experimentation was carried out in the agricultural farm of the Gaston Berger University (Senegal) on elementary plots of 3m x 1,5m. The effects of water drained from ponds rearing Tilapia (DWT) on okra production are estimated by comparing them with those of the fertilizers currently used in agronomy such as poultry droppings (PD), cow dung (CD) and mineral fertilizer (NPK). The plots were in triplicate for each treatment. The treatments were done with river water (RW), RW+ recommended dose of NPK (RD-NPK), RW+RD-PD, RW+ RD-CD, DWT, DWT+25% RD-NPK, DWT+50% RD-NPK, DWT+75% RD-NPK, DWT+25% RD-PD, DWT+50% RD-PD, DWT+75% RD-PD, DWT+25% RD-CD, DWT+50% RD-CD, DWT+75% RD-CD. The growth parameters, phenology and yield of okra were determined. The results showed that the mean collar diameter of treatment T_4 (DWT = 1.5±0.6cm) was comparable to that of treatments T_2 (RW+RD-PD = 1.8±0.8cm), T_3 (RW+RD-CD = 1.5±0.7cm) and T_5 (25% RD NPK = 1.7±0.8cm). However, treatments with at least 50% RD-NPK gave higher collar diameters than T_4. For average plant height, T_4 gave the same growth performance as T_2, T_3 and all treatments with NPK at lower than the recommended dose. The average plant height of treatment T1 (RW+RD-NPK) with 62±32cm was higher compared to T_4 (44±26.4cm). As for the yield parameters, diameter, length and average weight of okra fruit, treatments T_1 (RD-NPK), T_2 (RD-PD), T_3 (RD-CD) and T_4 (DWT) gave comparable results. Treatment T_4 with 11.0±5.5 t. ha^{-1} gave the same yield performance as treatment T_1=10.8±5.4 t. ha^{-1} and a higher yield than treatments T_3=7.5±3.8 t. ha^{-1} and T_2=5.7±2.9 t. ha^{-1}.

INTRODUCTION

Global population growth is undoubtedly one of the major challenges of this century. According to the latest projections from the United Nations, the world's population is set to continue growing. Depending on the various assumptions made regarding fertility and life expectancy, it should represent between 8.3 and 11.1 billion inhabitants in 2050 (Mangin, 2014). This situation increases the food needs of this population, while mitigating the impact of production activities on the environment.

Fishing makes a major contribution to reducing the balance of payments deficit, as well as lowering unemployment and satisfying the needs of the local population for animal protein (Allison et al., 2009; Henchion et al., 2017). For decades, production from this sector has been declining due to the degradation of fisheries through overexploitation of many species with high economic value, the effects of climate change and the pollution of aquatic ecosystems (Worm et al., 2009; Doney et al., 2012; FAO, 2020). Thus, the development of aquaculture appears as an alternative to fill the growing gap in demand for fishery products by populations. In aquaculture,

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fish farming is an important source of employment and income for rural communities (FAO, 2020). However, this process of fish farming in a semi-intensive or intensive system uses a lot of water which is often renewed and evacuated after use in the natural environment (FAO, 2006). This discharge water, rich in suspended solids and assimilable nutrients such as nitrogen and phosphorus, can be used by plants (Boyd et al., 2000; Boyd, 2003; Tucker and Hargreaves, 2003). According to Zouakh et al. (2016), this water from aquatic species farms used in irrigation has positive effect on watermelon production. Hence, the interest to combine in the same system the aquacultural and crop productions for valorizing the water from aquaculture ponds and to contribute to environmental preservation (Ingram et al., 2000; Li et al., 2005). This farming approach offers at least three advantages: diversifies the types of production of family food and income; economizes water by reusing it for crop production; and promotes bio production by using organic fertilizer as water drained from ponds rearing Tilapia (DWT).

Based on this context, this study focuses on the integration of fish (*Oreochromis niloticus*)and plant (okra, "*Abelmoschus esculentus* var. *Clemson spineless"*) production. It aims at:i) assessing the effects of water drained from ponds rearing Tilapia(*O. niloticus*);comparing them with those of other fertilizers such as organic matter (cow dung and poultry droppings), mineral fertilizer (NPK) and their combinations onokra production; and ii) identifying the treatment that allows better growth and/or yield performance. To understand the effects of DWT on okra production, a comparison is made with those of the poultry droppings (PD), cow dung (CD) and mineral fertilizer (NPK), fertilizers currently used in crop production. The hypothesis underlying this work is that DWT can give comparable performances in terms of growth and yield on crop production to those of PD, CD and NPK.

Oreochromis niloticus is very well adapted to rearing conditions in the tropics and appreciated for consumption by local population. It is the main species for commercial fish farming in Africa (Kestemont, 1996). Its ease of production is linked in part to its relatively plastic diet, its rapid growth and high market demand and makes it an important species in African fish farming (Lazard, 2009).

For okra, all its parts (roots, stem, leaves, fruits, seeds) are used for food, medicinal purposes, etc. (Marius et al., 1997). It is a plant that provides products with nutritional value exceeding even those of tomatoes (Hamon and Charrier, 1997). Its high levels of carbohydrates, proteins, vitamins A and C, iron, phosphorus, potassium and magnesium have been demonstrated by Nzikou et al. (2006). In Nigeria, okra seeds are used as a substitute for coffee (Siemonsma and Hamon, 2004).

MATERIAL AND METHODS

Study area

This study was carried out on the agricultural farm of Gaston Berger University (UGB) in Saint-Louis, Senegal (Figure 1). The farm covers a total area of 33 ha and is located in Sanar Wolof village (16°, 18 N and 16°, 29 W and has an altitude of 4 m). It is located at 12 km from the city of Saint-Louis, on the national road N°2 and at 1.33 km from the Djeuss, branch of the Senegal River that supplies water to the farm (Diack and Razakamananifidiny, 2012). 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 (Diack and Loum, 2014). Maximum temperatures recorded in the months of April and May are generally between 35°C and 37°C. Minimum temperatures are observed in January (16°C) (Diaite et al., 2020). It has a flat relief, sandy soil at the 0-50 cm horizon and sandy-clay soil at the 50-140 cm horizon (Bassène et al., 2018).

Animal and plant biological material

In this study, the biological material used was tilapia fry of the species *O. niloticus* with mean individual weight of 10.25±0.35g. For the plant material, seeds of okra *Abelmoschus esculentus* var. *Clemson spineless* were used.

Non-biological material

For the realization of this study a set of non-biological material was used: two ponds of 10m×10m×1m for tilapia rearing with a stocking density of 10 fish.m^{-2}, a tractor for soil cultivation and watering cans for water supply, an INGCO scale of 0.01g precision for weighing, a caliper for taking measurements and a tape measure of the plants, fertilizers composed of mineral fertilizer (NPK), urea and organic matter such as cow dung and poultry droppings. To this we add irrigation water of two types, river water (RW) and drained water from ponds rearing Tilapia (DWT).

Growing okra

Soil cultivation

The area is ploughed using a disc tractor to a depth between 10 and 20 cm. After ploughing, the surface was leveled with rakes.

Treatments

Different treatments were carried out according to water inputs and types of fertilizers (Table 1). The recommended doses (RD) of fertilizers were provided according to the technical sheets of okra production (Legba et al. 2021). These doses are 10 t. ha^{-1} for cow dung (CD), 6 t. ha^{-1} for poultry droppings (PD), 50 kg. ha^{-1}for DAP 18. 46, 100 kg. ha^{-1} for urea, 250 kg. ha^{-1} NPK (10.10.20 and 9.23.30). The fertilizers DAP, cow dung and poultry droppings were used at the beginning of the culture as background fertilizers according to the treatments and applied according to the recommended doses 3 days before planting okra.

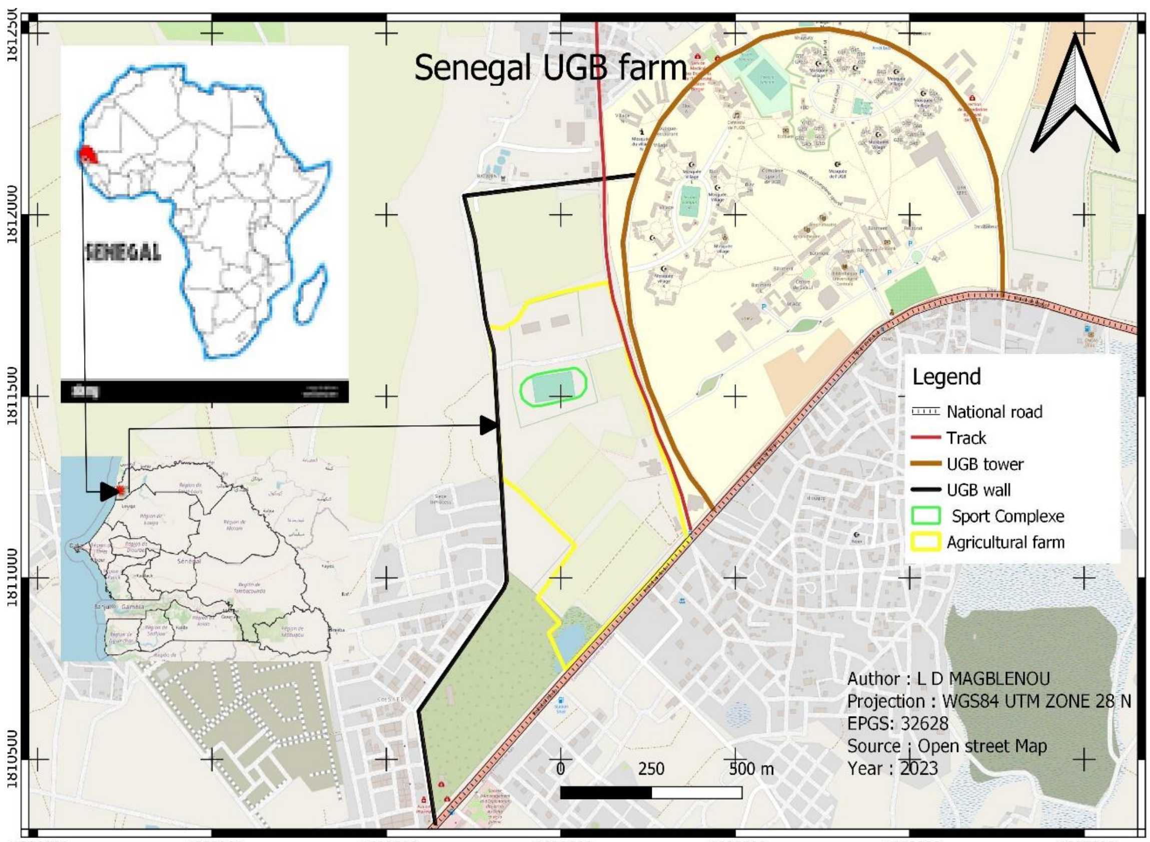

Figure 1: Illustration of the study site

Table 1: Codes and description of treatments

Code	Treatment	Description
T0	RW	Elementary plots watered with river water without fertilizer
T1	RW+RD-NPK	Elementary plots watered with river water and mineral fertilizer at the recommended dose (100%)
T2	RW+RD-FV	Elementary plots watered with river water plus recommended dose of poultry manure (100%)
T3	RW+RD-BV	Elementary plots watered with river water plus the recommended dose of cow dung (100%)
T4	DWT	Elementary plots watered with water drained from ponds rearing tilapia without other fertilizer
T5	DWT+25% RD-NPK	Elementary plots watered with water drained from ponds rearing tilapia plus 25% of the recommended dose of NPK
T6	DWT+50% RD-NPK	Elementary plots watered with water drained from ponds rearing tilapia plus 50% of the recommended dose of NPK
T7	DWT+75% RD-NPK	Elementary plots watered with water drained from ponds rearing tilapia plus 75% of the recommended dose of NPK
T8	DWT+25% RD-PD	Elementary plots watered with water drained from ponds rearing tilapia plus 25% of the recommended dose of poultry droppings
T9	DWT+50% RD-PD	Elementary plots watered with water drained from ponds rearing tilapia plus 50% of the recommended dose of poultry droppings
T10	DWT+75% RD-PD	Elementary plots watered with water drained from ponds rearing tilapia plus 75% of the recommended dose of poultry droppings
T11	DWT+25% RD-CD	Elementary plots watered with water drained from ponds rearing tilapia plus 25% of the recommended dose of cow dung
T12	DWT+50% RD-CD	Elementary plots watered with water drained from ponds rearing tilapia plus 50% of the recommended dose of cow dung
T13	DWT+75% RD-CD	Elementary plots watered with water drained from ponds rearing tilapia plus 75% of the recommended dose of cow dung

Figure 2: Randomized experimental design in Fisher blocks

Fertilizer was applied every two weeks after sowing. Only the mineral fertilizer treatment changed. Urea and NPK 10.10.20 were applied two weeks and 30 days after sowing, respectively. The NPK 9.23.30 was applied 45 days after sowing once the fruits started to form. Okra is sown at a distance of 50 cm x 15 cm with 2 seeds per planting at a depth of 3 to 5 cm.

Experimental design for plant production

The experimental area was stratified into three blocks separated by main aisles of 1 m wide. Each block is subdivided into elementary plots of 1.5 m x 3 m each. They are separated by 50cm for secondary alleys. Each treatment consists of 3 elementary plots, with one per block. The treatments were dispersed randomly in each block (Figure 2).

The elementary plots were watered manually with 11 L watering cans throughout the experiment. The frequency of watering the plots depended on the humidity and the development stage of the okra plants. These plots were watered daily in the morning and/or evening with 22 L per watering during the first fifteen days. Then, 33 L per elementary plot were brought between the 16th and the 40th days at the time of vegetative development of the plants. Finally, from the 41th day corresponding to the beginning of the fruiting stage until the end of the experiment, each plot was watered with 44 L.

Plant measurements and observations

Determination of the emergence rate of sown seeds

Emergence rate was determined by counting the total number of emerged pits in the elementary plots 7 days after sowing okra. The ratio of the total number of emerged seeds per planting to the number of seeds planting sown per treatment multiplied by 100 gives the estimated of the emergence rate as follows:

$$\text{Emergence rate} = \frac{\text{RPS}}{\text{SP}} * 100$$

Where RPS = number of raised planted seeds; SP = number of seeds per planting.

Okra growth parameters

Growth is estimated from measurements of height, collar diameter, number of branches and number of flowerings when 100% flowering rate has been obtained on 15 plants. Except for flowering, measurements of growth parameters are taken each week on 3 plants located at the middle of the elementary plot to avoid border effect. Height is measured with a measuring tape. Collar diameter of the plants is measured with a caliper.

Observation of flowers is done on 15 plants of each elementary plot. The counting of flowers is done daily and stopped when 100% flowering rate has been obtained on the 15 plants of one of the elementary plots of each treatment.

Parameters and performance determination of the yield

Fruit diameter, fruit length and fruit weight are taken on the three plants selected in the middle of the elementary plot on all days of the okra harvest. On each elementary plot, the number of fruits per plant is counted. The diameter of the fruit is measured at its middle and the length is taken between the upper end and the base of the fruit using a caliper.

The mean fruit diameter (d_m in cm) is estimated as follows:

$$d_m = \frac{\sum_i^n d_i}{n}$$

Where d_i= diameter of the given fruit *i*; n = number of fruits measured.

The mean fruit length (l_m in cm) is determined as follows:

$$l_m = \frac{\sum_i^n l_i}{n}$$

With l_i= length of the given fruit *i*; n = number of fruits measured.

The weight of the fruits is also weighed at each harvest of okra with the balance.

The mean fruit weight (w_m in g) is calculated as follows:

$$w_m = \frac{\sum_i^n w_i}{n}$$

With w_i= weight of the given fruit *i*; n=number of fruits weighed.

The total yield (Y) is the sum of the fruit weights harvested from all plants in each elementary plot per treatment, then extrapolated to the hectare (t. ha^{-1}). The total yield is expressed as follows:

$$Y = \sum_{i}^{n} r_i * \frac{S_{ha}}{\sum_{1}^{n} s_i}$$

With r_i = yield per elementary plot and per treatment; S_{ha} = Area per hectare; s_i = Area of the elementary plot *i*; n = total number of experimental plots corresponding to a treatment.

Statistical analysis of the data

Treatment effects on emergence rate, number of fruits, number of branches and flowering rate per week among treatments are compared using the Chi-Square-test. The effects of treatments on collar diameter, plant height, fruit diameter, fruit length, average fruit weight were compared using the Kruskal-Wallis-test. The distributions of these variables were not normal and the variances were not homogeneous. The Kruskal-Wallis-test, when significant, is followed by the Pairwise-test using Holm's method for p-value adjustment to compare the means two by two. The statistical tests were concluded at the α level of 0.05 and were realized using the R software version R i386 3. 6.1 (R Core Team, 2021).

RESULTS

Effects of treatments on growing okra

Emergence rate, number of branches and number of flowers per plant

The minimum emergence rate was 86.7±17% in treatment T_7, watered with water drained from ponds rearing Tilapia plus 75% of the recommended dose of mineral fertilizer and the maximum was 97.8±3.3% in treatments T_1 and T_5 watered with river water plus mineral fertilizer and water drained from ponds rearing Tilapia with 25% of the recommended dose of mineral fertilizer, respectively (Table 2). The emergence rates among treatments were independent of time ($p>0.05$).

The minimum number of branches recorded on okra plants is 2.7±1 in the T_0 treatment watered with river water. The maximum number of branches is recorded in the treatment (T_2) watered with river water plus poultry droppings with an average of 5.7±3 (Table 2). The time have significant effects on the number of branches in the treatments ($p<0.05$).

The mean number of flowers ranged from 2.2±1 in treatment T_0, to 5.5±3.6 in T_7 watered with water drained from ponds rearing Tilapia plus 75% of the recommended dose of mineral fertilizer (Table 2). These results show that the number of flowers when 100% flowering rate has been obtained on the 15 plants in the different treatments is significantly dependent on time ($p<0.05$).

Table 2: Averages of emergence rate, number of branches and flowers per okra plant according to the treatments

Treatments	Emergence rate (%)	Number of branches	Number of flowers
T0	89.6±13.4	2.7±1	2.2±1
T1	97.8±3.3	5.5±1.7	4.7±3.5
T2	93.3±10	5.7±3	3.4±2.3
T3	95.6±5.8	4.0±0.8	4.1±2.5
T4	89.6±19.2	4.4±1.7	3.4±2.2
T5	97.8±3.3	3.9±1.6	4.8±3.3
T6	88.1±23.3	5.1±2.3	4.0±3.4
T7	86.7±17	4.1±1.1	5.5±3.6
T8	89.6±16.4	4.6±1.2	3.0±1.8
T9	91.9±14.8	3.9±1.6	4.5±3.2
T10	88.9±15.3	5.1±2	4.3±2.5
T11	90.4±10.6	4.2±1.4	2.6±1.7
T12	89.6±21.4	3.1±1.3	3.5±1.8
T13	88.1±9.3	3.8± 1.6	2.4± 1.5

Collar diameter of plants

The smallest mean collar diameter is noted in the treatment (T_0) with 1.0±0.5 cm corresponding to the treatment irrigated with river water. The highest value was 2.3±0.9 cm observed in the T_1 treatment watered with river water plus 100% RD-NPK (Figure 3). The mean collar diameter was 1.8±0.8 cm for T_2, 1.5±0.7 cm for T_3 and 1.5±0.6 cm for T_4. The collar diameter of plants shows significant differences between treatments ($p<0.05$). These differences were observed between the collar diameter of T_0 and all other treatments. All treatments with NPK at a dose supper than or equal to 50% of the recommended dose had mean collar diameters significantly different than T_4 treated with water drained from ponds rearing Tilapia. In contrast, the mean collar diameter of T_4 is comparable to that of the poultry droppings (T_2) or cow dung (T_3) treatments.

Height of okra plants

Mean plant height of okra is ranged from 24.5±13.8 cm for the T_0 treatment watered with river water to 61.6±32 cm for T_1 watered with river water added the recommended dose of mineral fertilizer (Figure 4). The average plant height was 45±24.7 cm, 42±25.4 cm and 44±26.4 cm for treatments T_2, T_3 and T_4, respectively. For treatment T_7, watered with water drained from ponds rearing Tilapia plus 75% of the recommended dose of mineral fertilizer, the average plant height was 52.6±32 cm. Mean plants heights were statistically different between the T_0 treatment and the other treatments ($p<0.05$). The value of T_1 was also different from T_4. However, the mean height of the plants in treatment T_4 was not significantly different from that obtained in treatments T_5, T_6, T_7 with 25%, 50% and 75% of RD- NPK, respectively, T_2 with 100% of the recommended dose of poultry droppings and T_3 with 100% of the recommended dose of cow dung ($p>0.05$).

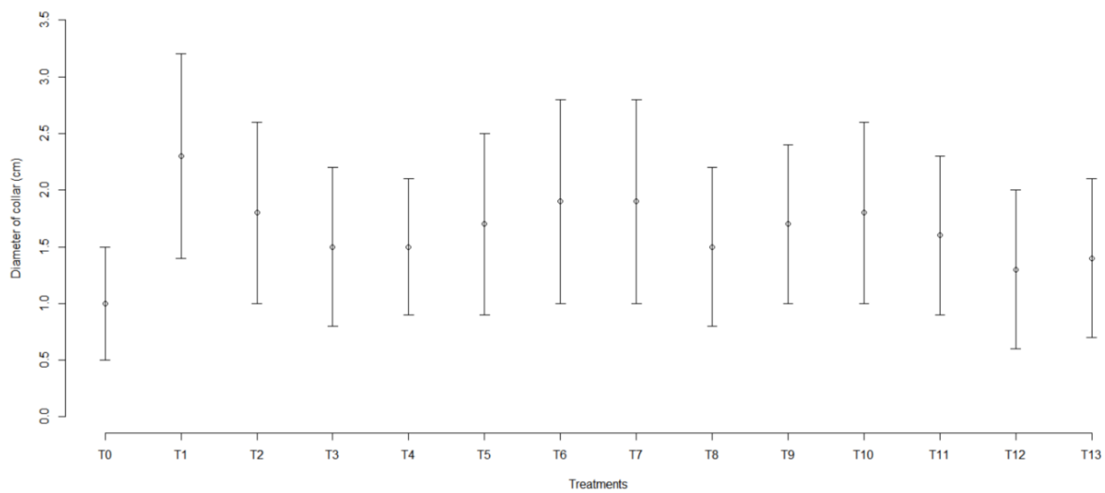

Figure 3: Variation in mean collar diameter of okra plants according to the treatments

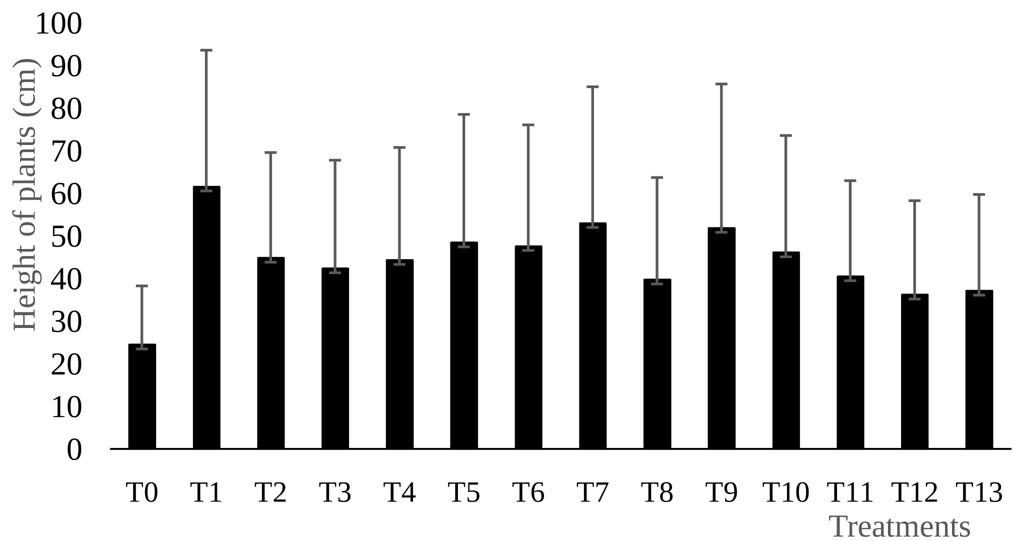

Figure 4: Variation of mean heights of the okra plant according to the treatments

Effects of treatments on okra yield parameters

Mean number, weight and length of fruits

The lowest mean number of fruits per plant was noted in T_0 treatment with 5.7±0.3 and the highest with 20.4±0.9 was obtained in the treatment T_7 watered with drained water plus 75% RD-NPK (Table 3). The mean number of fruits was 14±0.8 for T_2, 13.1±0.5 for T_3 and 9.2±0.4 for T_4. For treatment T_{10}, the number of fruits per plant was 19.7±1.1 for the treatment watered with water drained from ponds rearing Tilapia plus 75% RD-PD. The mean number of fruits per plant was significantly different between treatments ($p<0.05$).

Table 3: Variation in mean weight, number and length of okra fruits according to the treatments

Treatments	Number of fruits	Fruit weight (g)	Fruit length (cm)
T0	5.7±0.3	$7.1±3.5^{c}$	$6.6±2.0^{c}$
T1	19.4±1	$12.8±4.9^{ab}$	$8.3± 2.2^{ab}$
T2	14±0.8	$10.8±5.4^{b}$	$7.4±2.5^{ab}$
T3	13.1±0.5	$12.9±6.2^{ab}$	$8.1±2.7^{ab}$
T4	9.2±0.4	$11.1±6.4^{ab}$	$7.9±2.8^{abc}$
T5	17.2±0.9	$12.5±5.2^{ab}$	$7.9±2.4^{ab}$
T6	16.3±0.9	$10.8±4.8^{b}$	$7.3±2.2^{bc}$
T7	20.4±0.9	$13.9±5.7^{a}$	$8.6±2.5^{a}$
T8	13.7±0.6	$11.2 ±5.7^{ab}$	$7.5±2.7^{abc}$
T9	16±0.6	$13.0±7.0^{ab}$	$8.1±2.1^{ab}$
T10	19.7±1.1	$12.7±5.0^{ab}$	$7.8±2.1^{ab}$
T11	10.8±0.7	$11.4±4,5^{ab}$	$7.9±2.1^{abc}$
T12	12.2±0.5	$10.5±5.9^{b}$	$7.6±2.3^{abc}$
T13	8.3±0.4	$12.9±7.5^{ab}$	$7.7± 2.6^{abc}$

NB: Values with the same letter in the column are not significantly different from each other and those with different letters are statistically different from each other at $\alpha = 5\%$ threshold

The lowest mean fruit weight was noted in the treatment T_0 watered with river water with 7.1±3.5g and the maximum was 13.9±5.7g in the treatment T_7 watered with water drained from ponds rearing Tilapia plus 75% RD-NPK (Table 3). The average fruit weight was 12.8±4.9g for T_1, 10.9±5.5g for T_2, 12.8±6.2g for T_3 and 11.1±6.4g for T_4. The average weight of the fruits showed significant differences between T_0 and the other treatments ($p<0.05$). Likewise, significant differences were noted between T_7 on the one hand and on the other hand, T_2, T_6 and T_{12}. The mean values of treatments T_1, T_2, T_3 and T_4 were not statistically different ($p> 0.05$).

The mean length of okra fruits varied from 6.6±2.0 cm in the control treatment T_0 to 8.6±2.5 cm in the treatment T_7 watered with water drained from ponds rearing Tilapia plus 75% mineral fertilizer. The mean length of the fruit showed significant differences between treatments ($p< 0.05$). These differences were noted between T_0 and treatments T_1, T_3, T_5, T_9, T_{10}. Also, the mean length of plants in treatment T_7 was significantly different from that of T_6.

The mean length was 8.3±2.2 for T_1, 7.5±2.3 for T_2, 8.2±2.5 for T_3 and 7.9±2.8 for T_4. These values are statistically comparable ($p> 0.05$).

Diameter of okra fruits

The smallest mean of okra fruit diameter was 1.4±0.2 cm recorded in the control treatment (T_0) watered with river water. The highest mean fruit diameter was 1.7±0.4 and was recorded in treatments T_3, T_5, T_7, T_9, T_{10} and T_{13} (Figure 5). The mean fruit diameter was 1.6±0.3 cm for T_1, 1.6±0.3 cm for T_2, 1.7±0.3 cm for T_3 and 1.6±0.3 cm for T_4. The okra fruit diameter showed significant differences between treatments ($p< 0.05$). These differences were noted between T_0 and all other treatments, except T_6. This difference was also significant between T_6 and T_7. However, the values of T_1, T_2, T_3 and T_4 do not show significant differences between them ($p> 0.05$).

Okra fruit yield

The estimated mean yield per hectare was ranged from 4.1±2.1 t. ha^{-1} in the control treatment (T_0) to 12.7± 6.4 t. ha^{-1} in the treatments with water drained from ponds rearing Tilapia plus 50% RD-NPK (T_6) and water drained from ponds rearing Tilapia plus 50% RD-PD (T_9). The mean yield in the water drained from ponds rearing Tilapia treatments (T_4) was 11.0±5.5 t. ha^{-1} (Figure 6). It was 10.8±5.4 t. ha^{-1}, 5.7±2.9 t. ha^{-1} and 7.5±3.8 t. ha^{-1} for treatments T_1, T_2 and T_3, respectively. Yields show significant differences between treatments ($p<0.05$). The yield of T_4 was significantly different from T_2 but comparable to T_1 and T_3. The other differences were noted between T_0 and the other treatments, except, T_2, T_{11}, T_{13}.

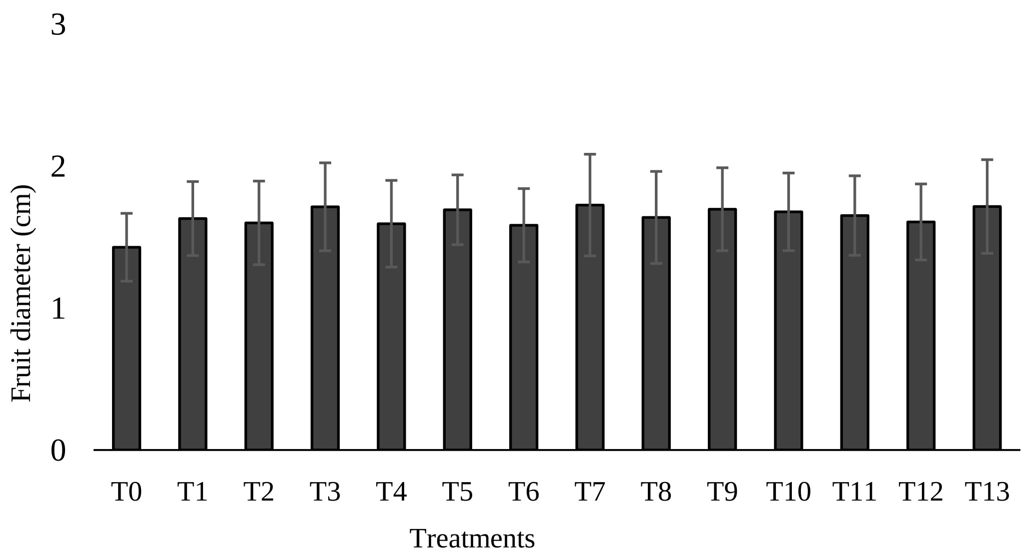

Figure 5: Variation in mean okra fruit diameters according to the treatments

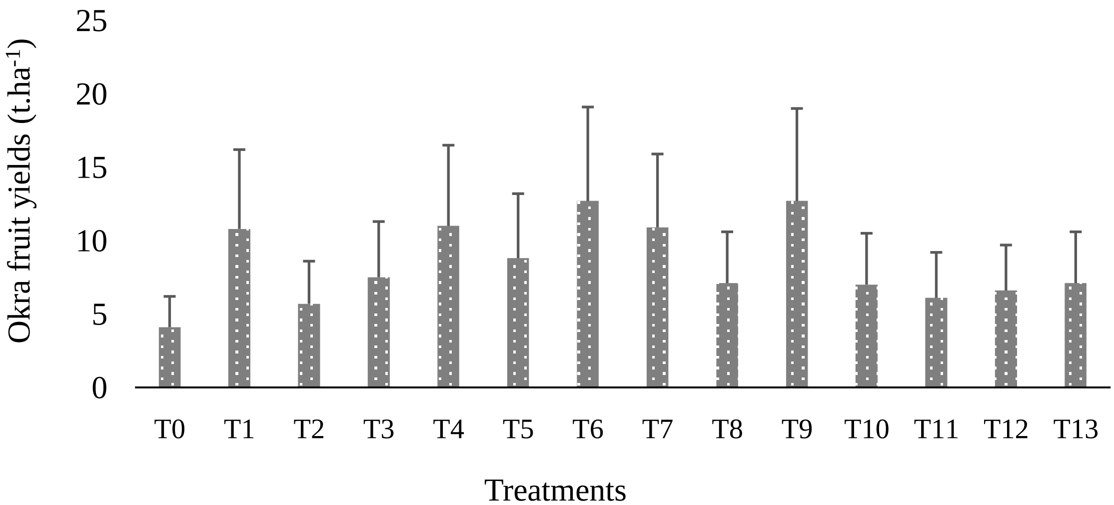

Figure 6: Variation in mean okra yield according to treatments

DISCUSSION

Effects of treatments on okra growing parameters

The rate of plant emergence was comparable between treatments. This result can be explained by the quality of the seeds used and the randomized total of experimental design guaranteeing the same pedo-climatic conditions in all treatments. These observations corroborate those of Dupriez et al. (1987) who indicated that the rate of plant emergence depends essentially on the reserves contained in the cotyledons, the physico-chemical and hydro-climatic conditions of the environment and not on the nutritive elements present in the soil.

For branching and flowering, the highest values were observed in treatments T_2 and T_7. Although mineral element measurements were not performed, these results indicate that poultry droppings promote rapid growth of okra. This could be explained by the nutrient richness and early release of mineral elements from this type of manure. These observations are consistent with those of Tine et al. (2022) who showed that poultry dropping was an important source of ammonia and phosphorus, which could be the reason for the higher number of branches and flowers obtained with treatments combining water drained from ponds rearing Tilapia and poultry dropping. According to Poirie et al. (2019) phosphorus and nitrogen have significant effects on growing parameters such as plant elongation, increased collar diameter and increased leaves size.

The collar diameter of plants watered with water drained from ponds rearing Tilapia (T4) is comparable to that of the treatments with poultry dung (T2) and cow dung (T3). The best growth in collar diameter was obtained in treatments with at least 50% RD-NPK. The fact that drained water from ponds rearing Tilapia, *O. niloticus,* gives the same results on okra collar diameter as the 25% RD-NPK, poultry dropping and cow dung treatments indicates that this water drained from ponds rearing Tilapia contains sufficient nutrients, especially nitrogen, essential for plant growing (Tremblay et al., 2001). However, the content of these elements in the water drained from ponds rearing Tilapia can be lower than those of treatments with at least 50% RD-NPK. This could justify a higher collar diameter in the latter treatments.

For mean okra plant height, T_1 treatment gave better growth compared to T_4. On the other hand, T_4 gave the same plant growth performance as the treatments with poultry dropping (T_2) and cow dung (T_3) and those with lower doses of RD-NPK. These results obtained with the water drained from ponds rearing Tilapia will be due to the presence of nitrogenous materials, especially nitrates (NO^{3-}), resulting from the transformation process by bacteria of ammonia or ammonium in two steps: nitrosation followed by nitration. This ammonia or ammonium come in part from the decomposition in the rearing ponds of the uneaten artificial feed and the fecal matter resulting from the digestive metabolism of the reared fish. Nitrates are the main form of nitrogen available to plants. Nitrogenous materials influence plant growing by promoting plant growth, stimulating phosphorus utilization, influencing fruit diameter, and giving plants green color (Batamoussi et al., 2016).

Effects on okra yield parameters

For mean diameter, length and weight of okra fruit, treatments with RD-NPK (T_1), RD-PD (T_2), RD-CD (T_3) and DWT (T_4) gave comparable results. These results can be explained by the presence of suspended solids and plant-available nutrients such as nitrogen (N) and phosphorus (P) in the water drained from ponds rearing Tilapia (Boyd et al., 2000; Boyd, 2003; Tucker and Hargreaves, 2003). The content of these elements in the water from ponds rearing Tilapia makes it possible to satisfy the needs of the plant in the growth of the diameter, length and weight of okra fruit in the same way as conventional fertilizers used in agronomy such as NPK, poultry dropping and cow dung. These nutrients play important roles in the development of okra fruits (Muller et al., 1996). The combination of water drained from ponds rearing Tilapia plus 75% RD-NPK (T_7) gave the best results on production parameters such as fruit diameter, fruit number, length and average fruit weight. This can be explained by the complementary positive effects between the two types of fertilizers on the production parameters.

The treatment with DWT (T_4) achieved the same yield performance as T_1, T_3 and higher yield than T_2 treatment. In this study, the yield obtained with $T_4 = 11.0±5.5$ t. ha $^{-1}$was higher than that of 8 t. ha $^{-1}$obtained by Dieudonné (2018) by fertilizing okra with the mineral fertilizer. The yield in T4 can be explained by the dejecta produced in the rearing environment which, following its mineralization, releases mineral nutrients that can be assimilated by the plant into the rearing water. Yinhe (1995) showed that in rice-fish culture, the daily amount of excreta produced by a fish was estimated at 2 g, which corresponds to 450 kg. ha^{-1} for a density of 3,000 fish per hectare during a rearing period of 75 days. In addition, Xiao (1995) showed that the dejecta produced by fish is of good quality and contains 42% phosphorus and could have the positive effects on plant yield.

Our results showed that treatments combining drained water with different fertilizers such as NPK, poultry dropping or cow dung does not significantly improve yields compared to fertilizing with water drained from ponds rearing Tilapia only. These results are in agreement with those of a study conducted in South Asia on fruits and vegetables grown on land fertilized with poultry dropping and irrigated with fish farm water (FAO, 2020). The elementary plots watered with water from ponds rearing Tilapia with added 75% of the recommended dose of mineral fertilizer (NPK) or poultry dropping did not allow to obtain the best yields. This observation can be explained by a saturation related to excess of nutrient supply compared to the plants' needs for optimum yield.

In sum, water drained from ponds rearing Tilapia gave the same growth performances as recommended dose of poultry droppings, recommended dose of cow dung and all treatments containing at least 50% recommended dose of NPK. Globally, fertilization with the best growth performance was that with water drained from Tilapia breeding 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 Tilapia 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. Water drained from ponds rearing Tilapia is a good fertilizer for okra production.

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Conflict interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Allison EH, Perry AL, Badjeck MC, Adger WN, Brown K, Conway D, Halls AS, Pilling GM, Reynolds JD, Andrew NL and Dulvy NK (2009). Vulnerability of national economies to the impacts of climate change on fisheries. Fish Fisheries, 10: 173–196.

Argote L, Ingram P, Levine JM and Moreland RL (2000). Knowledge transfer in organizations: Learning from the experience of others. Organizational behavior and human decision processes, 82(1): 1-8.

Bassène C, Mansaly N, Mballo R, Camara A, Mbaye M and Kandioura N (2018). Structure et caractéristiques de la flore adventice de la ferme agricole de l'Université Gaston Berger deSaint-Louis(Sénégal). European Scientific Journal, 14 (24) : 229-244

Batamoussi MH, Tovihoudji PG, Tokore SBJ, Boulga J and Essegnon MI (2016). Effet des engrais organiques sur la croissance et le rendement de deux variétés de tomates (*Lycopersicon esculentum*) dans la commune de Parakou (Nord du Bénin). International Journal of Innovation and Scientific Research, 24, n°1: 86-94.

Boyd CE (2003). Guidelines for aquaculture effluent management at the farm-level. Aquaculture, 226: 101–112.

Boyd CE, Queiroz J, Lee JY, Rowan M, Whitis G and Gross A (2000). Environmental assessment of channel catfish *Ictalurus punctatus* farming in Alabama. Journal of the World Aquaculture Society, 31: 511–544.

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.

Diack M andRazakamananifidiny P (2012).Ferme agricole universitaire au cœur du développement régional : cas de l'Université Gaston Berger. Université Gaston Berger (Sénégal), Université du Québec à Trois Rivières (Canada), 41pages. http://docplayer.fr/10009001-Ferme-agricole-universitaire-au-coeur-du-developpement-regional-cas-de-l-universite-gaston-berger.html.

Diaité B, Diallo MD, Goalbaye T, Diédhiou S, Diallo A, Talla R andGuissé A (2020). Effet de l'application de différentes doses de fertilisants organiques sur la croissance et le rendement de la tomate (*Solanum lycopersicum*). Journal of Animal and Plant Sciences, 44(1): 7553-7566.

Dieudonné CMM (2018). Effets des doses croissantes d'azote sur le comportement du gombo (*Abelmoschus esculentus* var. *Clemson spineless*) dans les conditions edapho-climatique de Lubumbashi et ses environs. International Journal of Innovation and Applied Studies, 24 (3): 1252-1260.

Doney SC, Ruckelshaus MJ, Duffy JE, Barry JP, Chan F, English CA, Galindo HM, Grebmeier JM, Hollowed AB, Knowlton N, Polovina J, Rabalais NN, Sydeman WJ and Talley LD (2012). Climate Change Impacts on Marine Ecosystems. Annual Review of Marine Science, 4 : 11–37.

Dupriez H andLeener P (1987). Jardins et vergers d'Afrique, Terres et vie. Rue Laurent Delvaux, 13, 1400 Neville, Belgique, Harmattan, Paris, France, 354 pages.

FAO (2006). Situation de la pêche et de l'aquaculture mondiale. Rome Italie,148 pages.

FAO (2020). The State of Food and Agriculture 2020. Overcoming water challenges in agriculture. FAO, Rome, 28 pages.

Hamon S and Charrier A (1997). Les gombos. *In*: Charrier A., Jacquot M. and HAMON S., Nicolas D. (eds.). L'amélioration des plantestropicales. Montpellier (FRA), Paris: CIRAD, ORSTOM, 313-333.

Henchion M, Yayes M, Mullen AM, Fenelon M and Tiwari B (2017). Future protein supply and demand: strategies and factors influencing a sustainable equilibrium. Foods, 6-53.

Kestemont P (1996). Production alevins de *Tilapia nilotica*. FAO/ADCP/REP/89/46,123p.

Lazard J. (2009). La pisciculture des tilapias. Cahiers Agricultures, 18(2-3) : 393–401.

Legba EC, Ahlincou RG, Atchanhouin LR, Aglinglo LA, Francisco RA, Hotègni NVF and Achigan-Dako EG (2021). Fiche technique synthétique pour la production de gombo (*Abelmoschus esculentus* L.). Laboratory of Genetics Horticulture and Seed Science (GBioS), Technical Report,6p : dépôt légal N° 10669 du 06/09/18 Bibliothèque Nationale du Bénin, 3ième trimestre septembre, 2018.

LiB, Pattenden SG, Lee D, Gutiérrez J, Chen J, Seidel C and Workman JL (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(51): 18385-18390.

Mangin P (2014). La coopérationagricole :produisonsl'avenir. Géoéconomie, (3) : 23-37.

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 (5) : 389 – 392.

Muller O, Naud O andCedra C (1996). New rules for optimizing fuel savings for agricultural tractor. IFAC Proceedings, 29(4): 119-122.

Nzikou JM, Mvoula T, Matouba E, Ouamba JM, Kapseu C, Parmentier M and Desobry S (2006). A study on gumbo seed grown in Congo Brazzaville for its food and industrial applications. African Journal of Biotechnology, 5(24): 2469-2475.

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.

Poirie C and Lemaire E (2019). Quel rôle ont le phosphore et l'azote sur la croissance des fines herbes ? Institut Québécois du Développement de l'Horticulture Ornementale (IQDHO), Saint-Hyacinthe, Canada, https://www.agrireseau.net/documents/Document_100483.pdf.

R Core Team (2021). R. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, https://www.R-project.org/.

Siemonsma JS and Hamon S (2004). *Abelmoschus esculentus* (L.) Moench : Ressources Végétales de l'Afrique Tropicale. Fondation PROTA, Wageningen-Pays-Bas: 25-30.

Tine M, WadeS andSembene M (2022). Integration of Fish and Poultry Farming into Cropping Systems to Improve Production Yields. Open Journal of Applied Sciences, 12(12): 2037-2054.

Tremblay N, Scharpf HC, Weier U, Laurence H and Owen J (2001). Régie de l'azote chez les cultures maraîchères : Guide pour une fertilisation raisonnée. Agriculture et Agroalimentaire Canada, Québec, 70 pages.

Tucker CS and Hargreaves JA(2003). Management of effluents from channel catfish (*Ictalurus punctatus*) embankment ponds in the southeastern United States. Aquaculture, 226: 5–21.

Worm B, Hilborn R, Baum JK, Branch TA, Collie JS., Costello C, Fogarty MJ, Fulton EA, Hutchings S, Jennings S, Jensen OP, Lotze HK, Mace PM, McClanahan TR, Minto C, Palumbi SR, Parma AM, Ricard D, Rosenberg AA, Watson R and Zeller D (2009). Rebuilding global fisheries. Science, 325: 578–585.

Xiao F (1995). Fish culture in Rice fields: Rice-Fish Symbiosis. *In*: MacKay, K.T. (ed.), Rice-fish culture in China. International Development Research Centre, 183-188.

Zouakh DE, Ferhane D andBounouni A (2016). Intégration de la pisciculture àl'agriculture en Algérie : Cas de la Wilaya de Ouargla. Revue des bioressources, 6(1) : 66-82.