

## Effects of the Digestate Produced by the Bio-Digester EB.06019.LHT-MWINDA on the pH of Kimwenzu-Mission Soil and the Growth of *Amaranthus cruentus*

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### Authors' contributions

This work was carried out in collaboration among all authors. Author PLL designed the study and wrote the protocol. Authors BKM and JMM performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Authors GLW and AI managed the analyses of the study. All authors read and approved the final manuscript.

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### ABSTRACT

The evaluation of the effects of the digestate produced by the reactor EB.06019.LHT-MWINDA on the pH of Kimwenzu soil and the growth of *Amaranthus cruentus* was conducted during the dry season (June-July 2019). Two treatments were used for the experiment: NPK (T1) and digestate (T2). The untreated soil was taken as a negative control(T0). The results obtained show that the digestate has a more neutralizing effect on the acidity of the Kimwenzu-mission soil than the mineral fertilizer: the pH increased from  $4.40 \pm 0.33$  to  $9.28 \pm 0.45$  for T2 versus  $5.19 \pm 0.59$  to  $7.71 \pm 0.29$  for T1. The plants treated with T2 gave leaves with relatively more weight ( $1.8 \pm 0.5g$ ) than those obtained with T1 ( $1.06 \pm 0.87g$ ). It was observed that plants treated with digestate were taller ( $10,4 \pm 1,1m$ ) than those with NPK ( $9,45 \pm 1,13m$ ). The average number of leaves obtained

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from plants was 7.06 ; 6.36 and 5.97 respectively for T2, T1 and T0. These results are an indication that the digestate produced by the reactor EB.06019.LHT-MWINDA could be used for the amendment of the acidic soil of Kimwenza-Mission and therefore contribute to reducing significantly the use of synthetic agro-chemicals, hence decreasing residual environmental and human health hazards.

**Keywords:** Digestate, fertilizer, soil, *Amaranthus cruentus*, kimwenza.

## 1. INTRODUCTION

Demographic experts revealed that the world's population is expected to increase by 2 billion people over the next thirty years, from 7.7 billion currently to 9.7 billion in 2050. It could reach a number closer to 11 billion around the year 2100. The population of sub-Saharan Africa, for example, is expected to double by 2050 [1-3]. In the Democratic Republic of Congo (DRC) as in many countries in the central africa, the population is increasing more faster compare to the quantity of foods [4]. According to a projection (2016) the population of metropolitan Kinshasa will increase significantly, to 35 million by 2050, 58 million by 2075 and 83 million by 2100, making it one of the largest metropolitan areas in the world [5]. This rapid increase of the populations has one big challenge: how to provide food in ever more abundant quantities. In fact, increasing agricultural production requires maintaining soil fertility subscribe to the idea of sustainable development which places growth in a long-term perspective and integrates ecological and social constraints into the economy [6]. To avoid the health problems caused by inorganic fertilizers, the use of organic fertilizers in farming is a healthy way to achieve sustainable development [7-9]. In fact, mineral fertilizers used for a long time, modifies certain physicochemical properties of the soil. In particular, nitrogenous mineral fertilizers are acidifying and can reduce nutrient availability and induce aluminum ( $Al^{3+}$ ) or manganate (Mn) toxicities causing lower yields [10,11].

Sys and colleagues revealed that the soils of Kinshasa were developed on sands called in pedology "Kalahari system" characterized by acidic pH values (<5.30), a texture according to the textural triangle of USDA predominantly sandy (> 90%) yellow ocher in color with clay content generally <20%, low organic matter content and degree of saturation of the adsorbent complex, low cation exchange capacity (CEC) (<5 cmol (+).  $Kg^{-1}$ ) indicating that these soils have limited nutrient storage capacity. As a result, the low fertility of this soil [12]. In

addition, the limited soil productivity and traditional agricultural practise of slash-and burn are a problem for increasing the agricultural productivity in the DRC [13].

Organic fertilizers has been used in farming due to their high availability of NPK content which are capable to enhance soil fertility and act as a substrate for soil microorganisms which lead to increase microbial activity, where of increasing the rat of organic material decomposing and releasing nutrient for plant uptake. In addition, organic fertilizers improve the physical properties of the soil as well [14-16].

Groupe de Génies Congolais (GGC), which is part of the Bioenergy laboratory of the Faculty of Science and Technology of Université Loyola du Congo(ULC), has been conducting research on the manufacture of organic fertilizers from anaerobic digestion since 2014 [17]. A prototype of a reactor named EB.06019.LHT-MWINDA was set up for the production of organic fertilizers (Fig. 1).



**Fig. 1. The EB.06019.LHT-MWINDA biodigester**

The aim of this study was to assess the effects of the Bio-digestate (BDG) produced by the Digester EB.06019.LHT-MWINDA on the pH of Kimwenza-Mission soil and the growth of *Amaranthus cruentus*. In fact, because of its basic pH values, the BDG produced by GGC could neutralize the acidity of Kimwenza soil and improve its physical properties.

## 1.1 Experimental Site

The experimental site is located in Kinshasa, precisely in the region of Kimwenza Mission (Fig. 2).

The climate of the Kimwenza-Mission is tropical humid type AW4 according to the Koppen classification, with 4 months of the dry season from May to September and 8 months of rainy season from October to month of April, interspersed by a short dry season from mid-January to mid-February, with temperatures varying between maximums of 32.2 ° C and minimums of 24.8 ° C. The average annual precipitation is 1300 mm of water [18]. The experimentation took place during the dry season (June-July 2019).

## 2. MATERIALS AND METHODS

### 2.1 Materials

During the experiment, the following materials were used:

- The reactor EB.06019.LHT
- The pH meter : (Oakton benchtop pH / conductivity / TDS meter with probes, 110/220 VAC).
- Analytical balance : (A & D Company Limited brand precision balance (FX-2000i; Max 2200g d = 0.01).
- The BDG obtained from the reactor
- NPK fertilizer 17-17-17

## 2.2 Experimental Disposition

For 28 days (June 17<sup>th</sup> to July 15<sup>th</sup> 2019) on unexploited soil, fifteen (15) pockets of 0.35 m x 0.30 m x 0.20 m were divided into three groups corresponding to three treatments, namely: the untreated soil as negatif control (T0), treatment with NPK mineral fertilizer 17-17-17 (T1) and treatment with BDG (T2). Each treatment was repeated five (5) times. The allocation of treatments to the experimental units was carried out according to a complete randomized block arrangement shown in Fig. 3[19].

## 2.3 Reactor and Digestate

The EB.06019.LHT- Mwindia biodigester is designed and manufactured by GGC®. It is a reactor which operates in a mesophilic regime and is fed in batch mode [20]. During the anaerobic digestion, the digestate is partly removed in order to conserve the bacterial flora and the process can start again with the entry of a new substrate (Fig. 4). The substrates or slurry introduced into the reactor are mainly: kitchen waste, gras, goat droppings and chicken droppings. In fact, goat manure is an excellent raw material for anaerobic digestion because of its high total nitrogen content and fermentation stability. The total nitrogen contents of fresh Goat manure (1.01%) and chicken manure (1.03%) are significantly higher than those of dairy manure (0.35%) and swine manure (0.24%). The range of liquid manure from goat manure varies from 25% to 35% and, from chicken manure, from 3%–12% dry matter content [21-23].

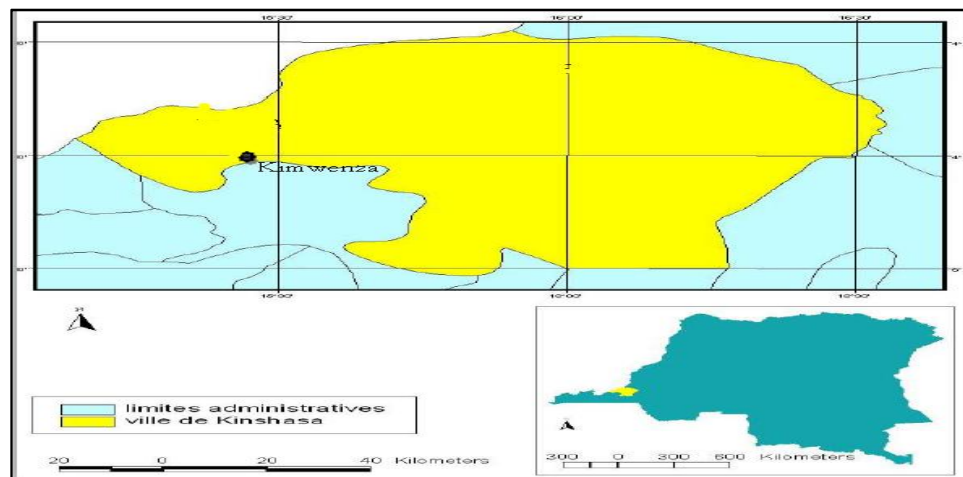


Fig. 2. Localisation of the experimental site

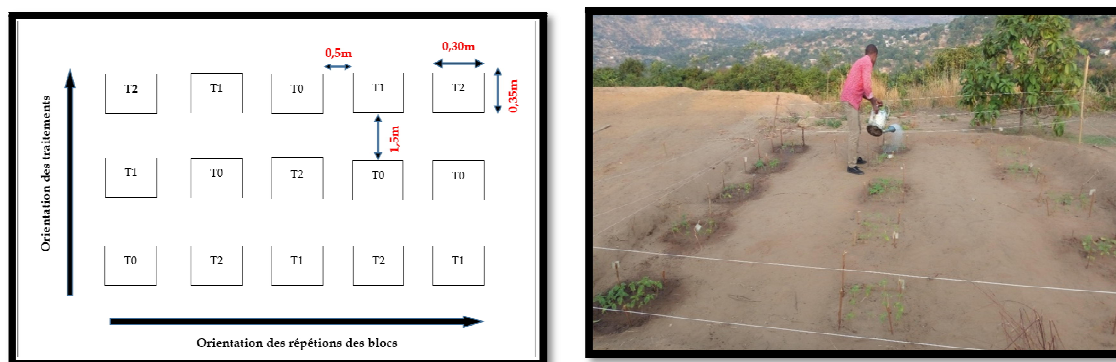


Fig. 3. Complete randomized block system with *Amaranthus cruentus*



Fig. 4. Removal of the digestate from the reactor

The reactor is fed weekly (after 7 days). With a capacity of 1000 mL, the Biodigester produces 200 L of biogas per day and generated 100 L of BDG a week.

The liquid fraction is assumed to have a high ammoniacal nitrogen content and is used as a liquid fertilizer with an immediate fertilizing effect [24]. To balance the quantity of minerals in the BDG, organic wastes are selected according to their chemical composition. According to the nutrient content data provided by Njoroge [25], 1 t of mulch from elephant grass would contain 15 kg N, 2.6 kg P and 35 kg K. Goat manure contains 6.1% of N, 5.2% of  $P_2O_5$  and of 12%  $K_2O$  while chicken droppings contain approximately 39.5% of N, 37.8% of  $P_2O_5$  and of 25.7%  $K_2O$  [26].

#### 2.4 The Crop : *Amaranthus cruentus*

The culture of *Amaranthus cruentus* (Fig. 5) was chosen for this experiment because of two major reasons. Firstly, *Amaranthus cruentus* leaves (locally called *bitekuteku* or *Ndunda*) are very

well appreciated by the population of Kinshasa. The leaves are rich in Vitamin C, Pro-Vitamin A, Zinc, Iron and Calcium [27]. Secondly, *bitekuteku* grow on poor soils and are resistant to drought, pests and diseases. Its cultivation requires less time [28-30]. Based on the complete randomized block arrangement described in section 2.2, nine plants of fourteen (14) days old amaranth seedlings were planted in the pockets containing the treatments (T0, T1 and T2).

#### 2.5 Preparation and Application of Treatments

For the application of the mineral fertilizer, we modified the protocol used by Palm and colleagues : the NPK 17-17-17 mineral fertilizer was applied to the soil by dissolving 1.5 grams of the fertilizer in 1 liter of water per pocket. It should be noted that soil sampling was carried out at a depth of 10 cm in order to reduce the effects of soil heterogeneity with respect to depth. The treatment based on pure organic biodigestat fertilizer was applied as follows: 1.5 liters per pocket [31].



**Fig. 5. The harvest of *Amaranthus cruentus* at GGC**



**Fig. 6. Determination of the collar by a digital caliper**

## 2.6 pH Measurement

Once a week, the pH was taken from all 15 pockets and the collection of soil samples was continuous for 4 weeks. For the determination of the soil pH, a 20g portion of soil was mixed with 50 mL of distilled water and the measurement was taken using the Oakton benchtop brand digital pH meter.

## 2.7 Evaluation of the growth of *Amaranthus cruentus*

The parameters taken in consideration for the evaluation of the growth of amaranthus were: the stem collar diameter (obtained using the digital caliper (Fig. 6), the height of the plants, the number of leaves and the weight of the fresh leaves.

Twice every day (morning and later in the afternoon), the crops were watered at cool hours of the day and the crops were treated with a insecticide commercially named CYGA, depending on the incidence of the pest.

## 2.8 Statistical Analyses

A one-way Analysis of variance ratio (ANOVA) was used to compare the means of various

growth parameters among the treatments. Treatment means were segregated using Least Significant Difference (LSD) and Duncan post hoc multiple comparison tests. Excel-2020 software was used to perform all of the calculations, statistical analysis and presentation of graphs in this experiment.

## 3. RESULTS AND DISCUSSION

### 3.1 Effects of Digestate on the pH of Kimwenza-mission Soil and the Growth of *Amaranthus cruentus*

#### 3.1.1 Evolution of the pH of the soil under treatment

The evolution of the pH of the soils collected from the pockets over 28 days is presented in Table 1.

The results from Table 1 above indicate that at the fourth week, the mean pHs were 9.28, 7.708, and 4.81, respectively for the pockets subjected to the T2, T1 and T0 treatments. The digestate have given a better result compare to the NPK. Analysis of variance revealed an highly significant differences between the three amendments. The results clearly show the neutralizing effect of NPK and BDG on the

Kimwenza soil which is slightly acidic (pH = 4.81 ± 0.74). Comparison of averages by LSD showed that the BGD amendment gave higher pH values, followed by the NPK amendment. On the other hand, the negative control gave lower values (Fig. 7).

**3.1.2 Stem collar diameter**

The mean values of the diameter at the collar of amaranths are presented in Table 2.

It emerges from Table 2 that the diameter at the collar were 4.53 mm, 3.90mm, and 3.29 mm respectively, for the fertilizers T2, T0 and T1.

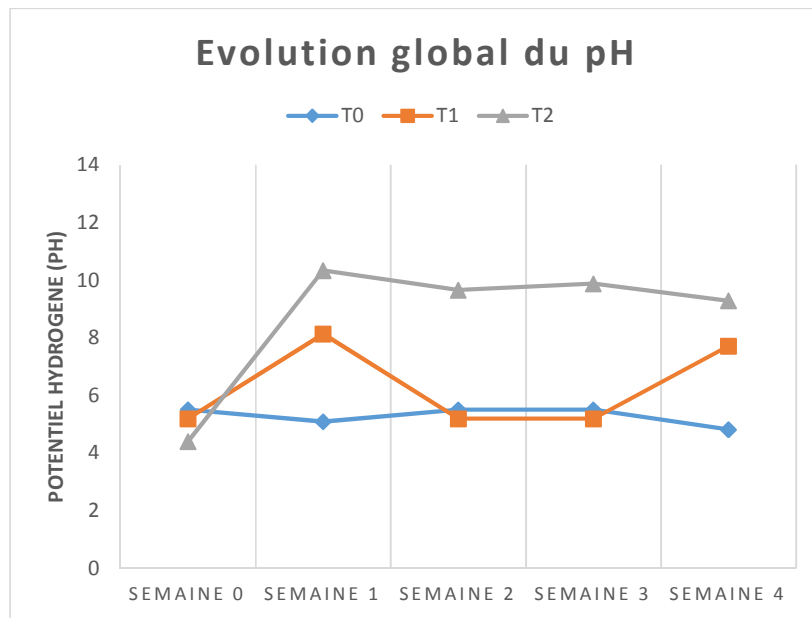
Although the analysis of variance did not show significant differences between the fertilizers, the comparison of the means by the LSD test allowed us to conclude that the fertilizer T2 gave plants with a diameter at collar superior to T0 and T1. It is very surprising to notice that T0 produced plants with a larger collar diameter than the T1 fertilizer. This observation needs further investigations.

**3.1.3 Effects of fertilizers on plant height(cm)**

The height of the plants subjected to two fertilizers for fourteen days is given in Table 3.

**Table 1. Evolution of the pH of the soil**

Treatment	pH values per week			
	1	2	3	4
Negative control(T0)	5.09±0.29	5.50±0.54	5.50±0.54	4.81±0.74
NPK (T1)	8.13±0.36	5.19±0.59	5.19±0.59	7.71±0.29
DIGESTATE (T2)	10.33±0.32	9.65±0.42	9.87±0.26	9.28±0.45



**Fig. 7. Evolution of the pH of the soil under treatment**

**Table 2. Effect of fertilizers on the diameter at the collar (mm)**

Treatment	Repetitions			
	1	2	3	4
Negative control(T0)	4.14±1.16	3.29±0.98	3.15±0.43	3.90±1.96
NPK (T1)	3.18±0.36	3.22±0.49	4.19±0.25	3.29±0.48
DIGESTATE (T2)	4.30±0.70	3.18±0.68	4.39±0.90	4.53±1.22

**Table 3. Effect of fertilizers on plant height(cm)**

Treatment	Height of plants			
	1	2	3	4
Negative control(T0)	8.58(±2.59)	7.94(±1.91)	8.44(±1.89)	8.76(±1.76)
NPK (T1)	8.76(±1.18)	11.11(±3.07)	8.67(±1.20)	9.28(±2.1)
DIGESTATE (T2)	11.60(±2.29)	9.06(±1.42)	10.97(±1.69)	10.17(±2.37)

**Table 4. Effect of fertilizers on the number of leaves of plants**

Treatment	Number of leaves per block			
	1	2	3	4
Negative control(T0)	6.22±0.83	5.67±1.73	5.44±1.59	6.56±1.59
NPK (T1)	7.78±1.09	5.0±1.50	5.67±1.32	7.0±1.2
DIGESTATE (T2)	7.78±1.72	5.89±0.4	6.89±1.96	7.67±2.4

**Table 5. Effect of fertilizers on weight of fresh leaves(g)**

Treatment	Weight of fresh leaves(g)			
	1	2	3	4
Negative control(T0)	0.65±0.17	0.63±0.39	0.55±0.42	1.08±0.81
NPK (T1)	2.33±1.5	0.42±0.26	0.61±0.3	0.89±0.46
DIGESTATE (T2)	2.40±1.82	1.12±1.3	1.62±1.2	2.04±1.35

It appears from this table that the average fresh weight was 2.04±1.35 g, 1.08±0.81 g, and 0.89±0.46 g, respectively, for the fertilizers T2, T0 and T1. The analysis of variance does not show significant differences between the fertilizers. Comparison of averages by the LSD test allowed us to state that the T2 ration yielded plants with the highest fresh weight than the T1 and T0 rations. And that the ration T1 and T0 do not differ significantly from the point of view of the fresh weight of the leaves.

Table 3 shows that the effects of the fertilizers on the height of the plants after fourteen days are such that the plants treated with the fertilizers T2, T1, and T0 reached 10.17 cm, 9.28 cm and 8.76 cm respectively. Analysis of variance did not show significant differences between fertilizers. However, the comparison of the means by the LSD test shows that the plants subjected to the T2 fertilizer gained more height. As for the fertilizers T1 and T0, the comparison of the means by the LSD test shows no significant differences.

### 3.1.4 Effect of fertilizers on the number of leaves in the plant

Table 4 shows the number of leaves of plants subjected to three fertilizers for fourteen days.

The results in Table 4 show that after cultivation, the average leaf number was 7.67, 7.00 and 6.56 respectively for the plants subjected to the T2, T1 and T0 rations.

The analysis of variance revealed significant differences between the three fertilizers.

Comparison of averages by LSD showed that the soil treated with the BGD fertilizer produced plants with the highest leaf number (7.67±2.4). While the NPK fertilizer (7.0±1.2) and the control (6.56±1.59) do not differ significantly from the point of view of the number of leaves per plant.

### 3.1.5 Effects of fertilizers on the weight of fresh leaves (g)

The average weight of fresh leaves of the plants after fourteen days of culture is presented in Table 5.

## 3.2 Discussion

The results above show clearly that there are significant differences in the evolution of pH of Kimwenza soil, stem collar diameter, growth rates, number of leaves and weight of the plantes depending on the treatments. T2 gave better results implying that organic fertilisers could improve soil fertility and enhance the growth parameters of *amaranthus cruentus*. These

results corroborate those of related studies [32-34].

The analysis of the above results underlines the assertion that goat and chicken droppings contain macronutrients, such as nitrogen(N), phosphorus(P) and potassium (K) which play a crucial role in the growth and development of *amaranthus cruentus* and reduce the acidity of soils. The digestate gave better results comparing to the mineral fertilizer NPK 17-17-17. This is a clear indication that organic fertilizers like the digestate produced by EB.06019.LHT-Mwinda reactor could suitably replace mineral fertilizers which are generally costly to farmers and destroy the environment due to their ability to increase the acidity(pH) of soils when uninterruptedly used. In fact, organic matter enhances soil buffering capacity [35,36].

The findings of this study support the global advocacy for organic farming and open a new door for further investigation: the production of bio-fertilizers from the BDG. This will be an essential contribution to increase the production in acidic soils like in Kimwenza and to reduce of the use of synthetic agro chemicals because of their associated environmental and human health hazards.

#### 4. CONCLUSION

This study evaluated certain agricultural parameters, namely the evolution of the acidity of the soil of Kimwenza and the comparison of the growth of amaranth when it is subjected to biodigestat as organic fertilizer on the one hand and mineral fertilizer, NPK 17-17-17 on the other hand. The results obtained after four weeks showed that biodigestate (pH=9.28 ± 0.45) had a more neutralizing effect than NPK (pH=7.71 ± 0.29) on soil acidity; Amaranths planted in pockets where biodigestate was applied were taller in size(10,4 ±1,1m vs 9,45 ±1,13m ) and their fresh leaves weighed(1.8 ± 0.5g) more than those planted in soils treated with NPK(1.06 ± 0.87g). Therefore, based on the results obtained, it can be underlined the fact that the biodigestate produced at GGC could replace the mineral fertilizer NPK for the production of amaranth and improving the acidity of Kimwenza Soil.

These results pave the way for further studies on the chemical composition of the biodigestate produced by the EB.06019.LHT-Mwinda reactor as well as on the manufacture of an organic

fertilizer that can help improve agricultural yields in Kinshasa.

#### DISCLAIMER

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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