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WHAT IS THE EFFECT OF COMPOST ON THE CHARACTERISTICS OF A SANDY SOIL AFTER TWO SEASONS OF OKRA (ABELMOSCHUS ESCULENTUS) CULTIVATION IN THE NIAYES AREA OF SENEGAL?

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ABSTRACT

Soil is both a support and a nutrient source for the development of living organisms. Composts based on faecal sludge and vegetable wastes were tested on okra to see the proportion of organic matter and nutrients in the soil after two seasons. Thus the control, non-composted faecal sludge and chemical fertiliser were compared with the other treatments T0, T1 and T2. Physico-chemical parameters such as pH, electrical conductivity, organic matter, nutrients Carbon, Nitrogen, Potassium, Phosphorus and grain size were analysed. The results showed an increase in organic matter content from the beginning (As = 0.52%) with 1.72%, 1.9% and 1.4% for the soil samples that were amended with T0, T1 and T2 respectively. Thus the pH values are neutral for treatments T0, T1 and T2. The electrical conductivities are between 33-47µs/cm. Mineral elements such as A (0.08-0.1%), P (21.7-29.6%), K (0.02-0.03%), are satisfactory for T0, T1 and T2. The C/N ratio is between 9.5-10.4 and below 12.

Keywords: Compost, Sewage Sludge, Vegetable Waste, Abelmoschus Esculentus, Organic Matter .

1. INTRODUCTION

Soil is an essential component in the cycle of life, being the upper part of the earth's crust, it has the particularity of being loose and sheltering life (Djigal, 2003). Soil is both the support of plants and animals, and their interrelationships (Ouédraogo, 2015). Soil provides the food that living beings need because of its texture and structure (Calvet, 2003), it is endowed with fertilising and nutritive power through its organic matter content. It is provided with all the nutrients that plants need to grow, so it is essential for agriculture, which is the main source of income for more than a third of the world's population (Ciolos and Piebagls, 2013). Today, the overexploitation of these arable lands have led to its degradation (Houngbo, 2008), with the result that fertility has decreased (Ouandaogo, 2016) and yields are increasingly reduced (FAO, 2015).

This degradation is visible in the functioning of all soil-dependent beings. Indeed, soil depletion and degradation contribute to hunger and poverty in many regions (Lisan, 2014). Many nutrients and organic content are altered by natural and/or anthropogenic phenomena. It is essential to

ISSN: 2456-8643

restore these essential elements and to maintain them in the soil in the long term, it is appropriate to promote sustainable practices to maintain the cycles of life in the soil. The addition of organic matter promotes the functioning of the active microbial biomass of the soil. This improvement can be different in intensity and duration, depending on the type of organic matter used (Montaigne, 2018).

In our study on the valorisation of faecal sludge, the products of the composting process, which have shown an interesting agronomic value (Lô, 2015, Lô, 2019), are used on vegetable beds with local crops such as okra. Thus, we studied the effects of composts on soil properties in order to assess their added value compared to the inputs usually used

2. MATERIALS AND METHODS

2.1. Description of the study area

The experimental device was installed in the district of Sangalkam located in the department of Rufisque, about thirty kilometres from the capital Dakar. It is located in the Niayes area (GPS coordinates: 14°46' W and 17°13' N; Thiaw, 2017).

2.2. Experimental set-up

The composts based on faecal sludge and market garden waste were made with three (03) replications for each treatment (T0, T1 and T2). The proportions of faecal sludge and market garden waste were distributed as follows by volume:

T0: Control, sludge only (BV) ;

- T1: mixture of 2 volumes of BV + 1 volume of market garden waste (DM);
- T2: mixture of 1 volume BV + 1 volume DM.

Tables (1, 2 and 3) show the characteristics of the physico-chemical, parasitic and microbiological parameters of the composts.

Table 1 Agronomic value of the composts

Parameters	**Units**	**NCFS**	**T0**	**T1**	**T2**	Cofie (2009)
Physico-chemical						
pH (1 : 2,5)		6,03	6,4	6,5	6,2	7,6
EC (1 :10)	*µs/cm*	1690	985	1307	1243	$1,4\text{-}1,9.10^3$
Stability						
C	*%*	22,14	6,8	6,8	6,3	14-15
MO	*%*	38,2	12	12	11	20-21
C/N		10,6	11,1	11,1	11	13,1
AH	*%*	0,08	0,04	0,08	0,042	-
AF	*%*	0,5	0,6	0,82	0,58	-
AH/AF		0,2	0,1	0,1	0,1	-
Nutrients						
N	%	2,09	0,6	0,6	0,56	1,2-2,1
P	%	1,3	1,1	1,7	1,9	1,1-1,3

K	%	0,08	0,05	0,2	0,24	0,6-0,5

NCFS : non composted feacal sludge, T0 : composted faecal sludge (BV) alone T1 : composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2 : composts with a mixture of 1 volume BV + 1 volume DM.

The vegetable beds were cultivated twice with okra (Figure 1).

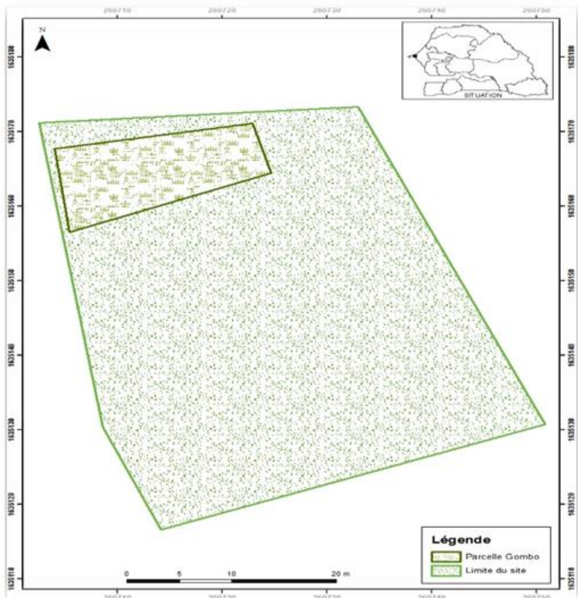


Figure 1: Location map of the Sangalkam site

Composts based on sewage sludge and vegetable wastes were used as organic amendments to the plots reserved for the experiments where other treatments such as chemical fertilizer (EN), non-composted sewage sludge (NCFS) and the no-input control were tested in parallel. Thus, a replication of three (03) vegetable plots of 10 m2 per unit was reserved for each treatment.

2.3. Methods

2.3.1. Soil sampling

Soil samples were taken with an auger from a depth of 0 to 20 cm in 3 locations on each vegetable bed before cultivation and after harvesting in the second season. In the laboratory, the collected samples were air-dried before being sieved on a sieve with a mesh size of 2 mm and 0.2 mm in diameter according to the needs of the analyses.

2.3.2. Analysis of soil physico-chemical parameters

Physico-chemical parameters such as pH, electrical conductivity (EC), carbon (C), nitrogen (N), phosphorus (P), potassium (K), grain size (clay, silt, fine sand, coarse sand) were measured.

The pH and electrical conductivity (EC) were measured directly with a Crison GLP 21 pH meter and conductivity meter fitted with a glass electrode in solutions obtained by suspending the compost in distilled water. For pH, 20 g of compost was diluted in 50 ml of distilled water and for electrical conductivity, the 20 g of compost was diluted in 200 ml of distilled water. For pH, 20 g of compost was diluted in 50 ml of distilled water and for electrical conductivity, the 20 g of compost was diluted in 200 ml of distilled water. K+ ions were analysed by photometry (Bocoum, 2004). Carbon was analysed using the modified Walkley and Black method and nitrogen was analysed using the Kjeldahl method (Bocoum, 2004). The C/N ratio was calculated from the results of separate analyses of carbon and nitrogen. Phosphorus was determined by the colorimetric determination method (Milin, 2012). Granulometry was determined from the soil analysis method (Bocoum, 2004

Irrigation Water Sampling and Analysis

The water used for irrigation was taken from well 1 and well 2. The physico-chemical parameters (pH, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, CO^{3+} and HCO^{3-}) were analysed in the laboratory (Bocoum, 2004)

2.3.4. Data processing and statistical analysis

The collected data were processed with the Excel spreadsheet for the results of the physico-chemical analyses. These were subjected to statistical analysis on R software version 3.1.2 (201-10-31) for principal component analysis (PCA) based on the relationship between soil fertility indicators. Diagram and Piper diagram software were used for processing the data of the irrigation water samples.

3.RESULTS

Water during the field test phase is essential to ensure the relationship of the plant and the soil structure. It is therefore essential to analyse certain physico-chemical parameters of the water used for the irrigation of okra plants. In fact, two wells (well 1 and well 2), about 100 m apart, supplied water to the market garden beds during the two okra growing seasons. The pH and EC of the water were analysed after sampling from the wells used for crop irrigation. Chemical parameters such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, CO^{3+} and HCO^{3-}were analysed. Figure 2 shows the EC of the well water used for irrigation during the cropping seasons.

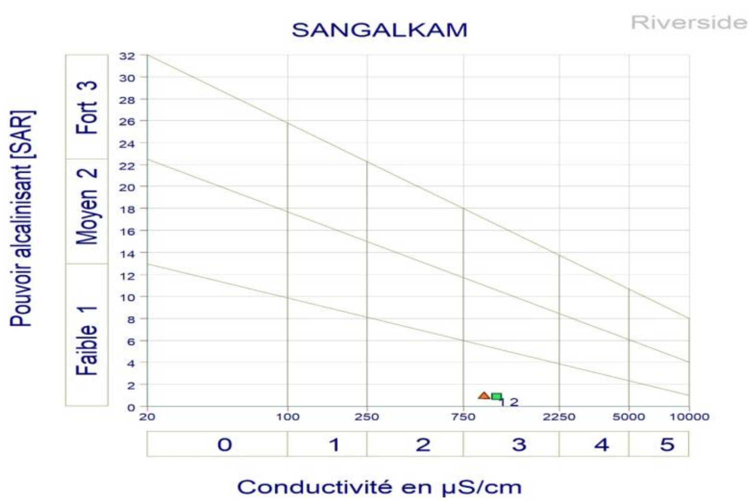


Figure 2 Electrical conductivity of irrigation water

ISSN: 2456-8643

According to this figure 2, the well water has EC levels between 953-1093 µs/cm. Figure 3 shows the salinity of the water used for irrigation during the cropping seasons.

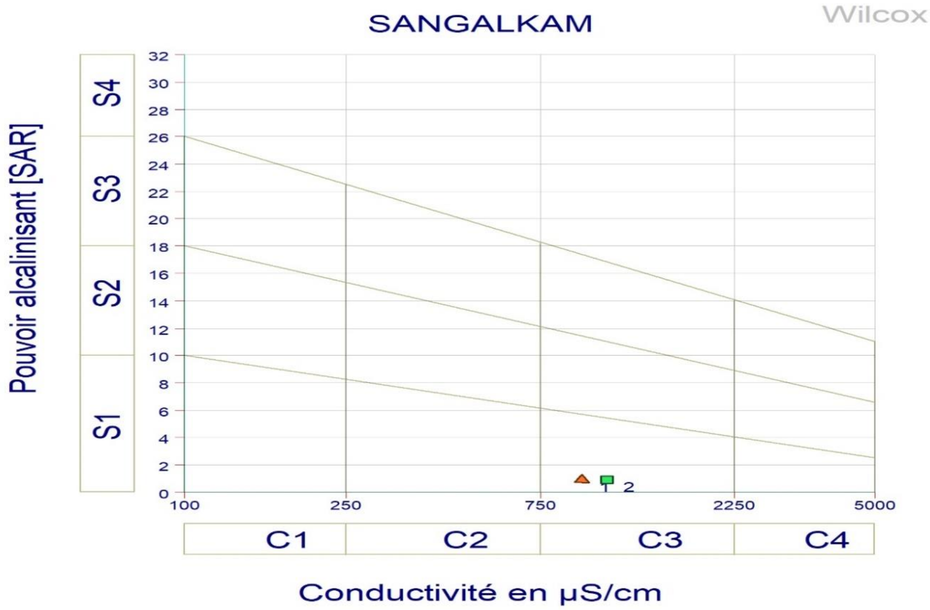


Figure 3 Salinity of irrigation water

The two (02) well water samples are between C2 and C3. Then the chemical parameters of the water used in irrigation are shown in Figure 4 4 (Bocoum, 2004).

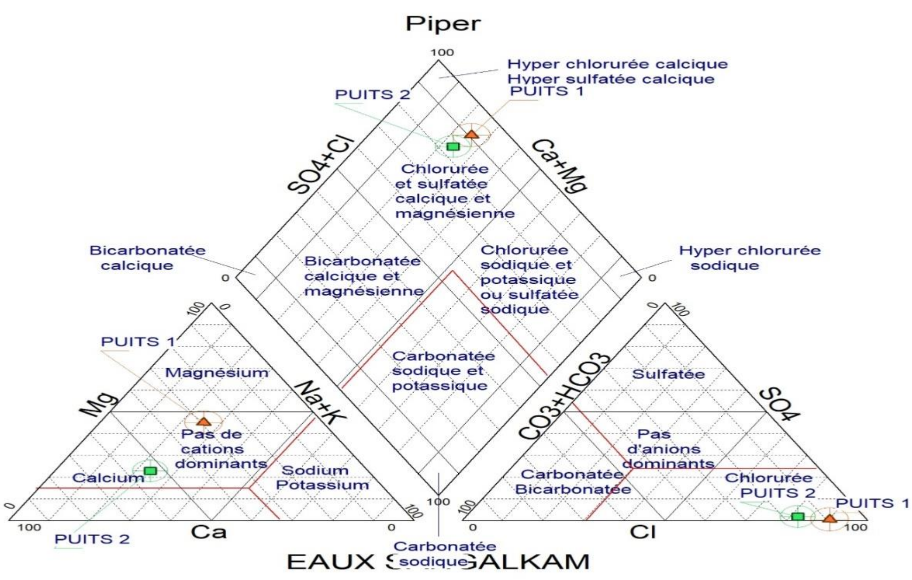


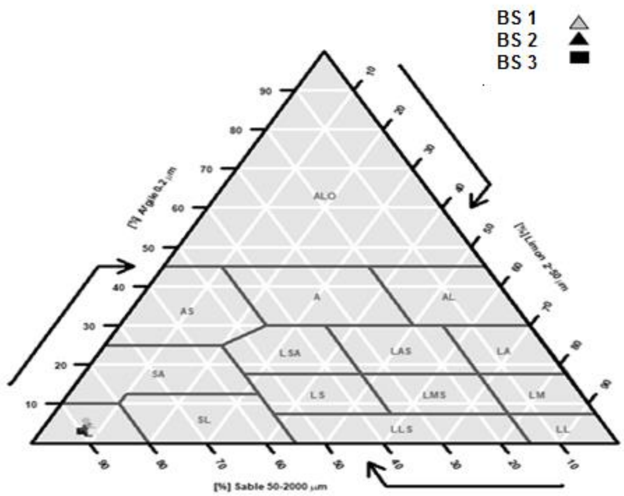
Figure 4 Hydrochemical classification of irrigation water in the experimental area (Sangalkam)

According to the texture triangle, the results of the particle size analysis of the studied soil indicate that the soil in the study area (Sangalkam/Dakar) has a sandy texture with a dominance

Vol. 07, No. 03; 2022

ISSN: 2456-8643

of sands. Indeed, before cultivation, the soil samples were analysed for grain size and the results are shown in Figure 5

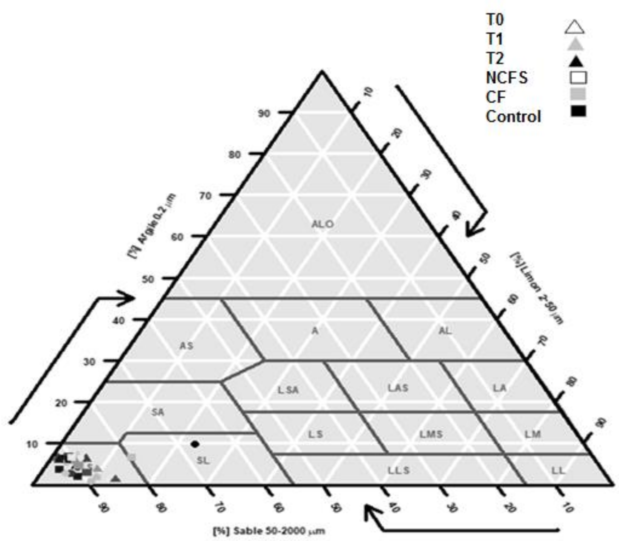


BS : before sowing

Figure 5 Soil textural triangle before amendment

The soils are specifically sandy and being in the Niayes areas (Ndiaye et al, 2012).

The results of the particle size analysis of the soil samples that received the okra speculation are recorded in Figure 6.

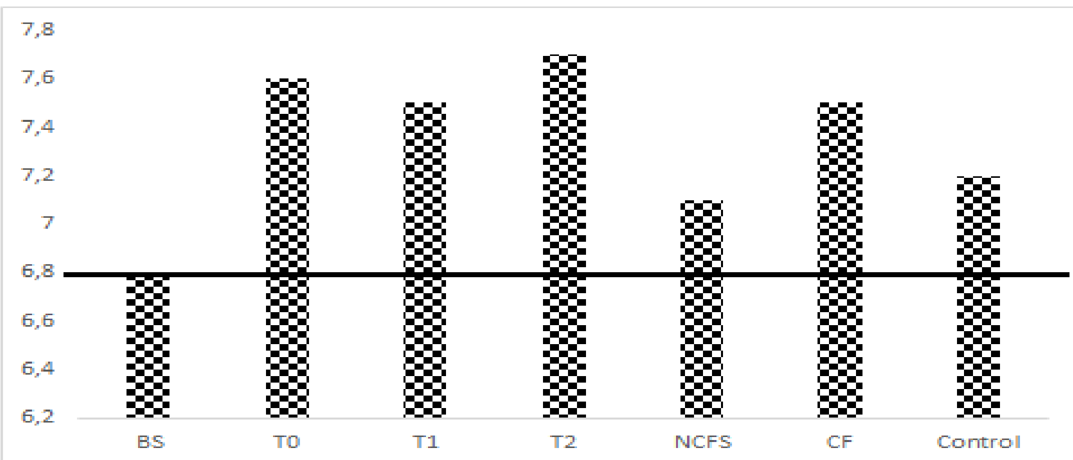


BS: before sowing, T0: composted feacal sludge (BV) alone, T1: composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2: composts with a mixture of 1 volume of BV + 1 volume of DM, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Sample : without organic input.

Figure 6 Textural triangle of market garden beds used for growing okra

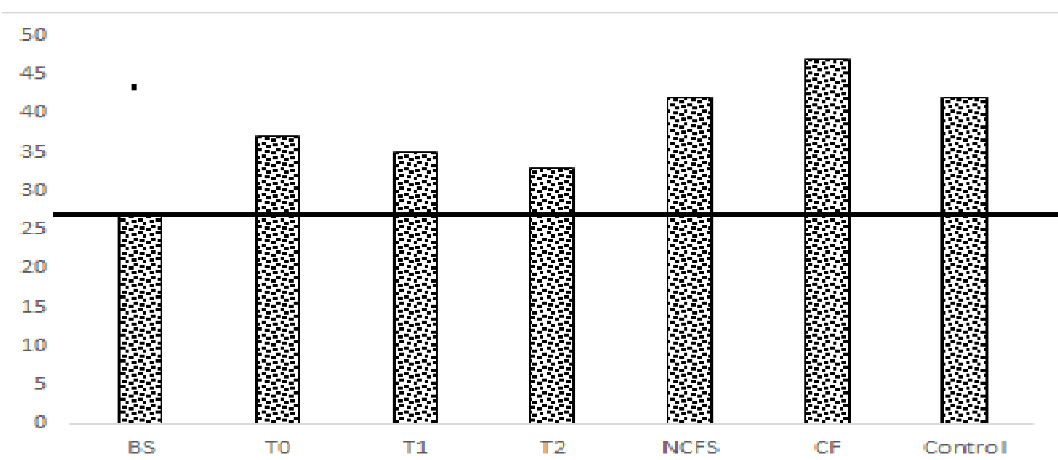
The texture of the soil, compared to that of the soil samples before cultivation (As), is unchanged and predominantly sandy.

The pH and EC were analysed for the soil samples before and after cultivation. Figures 7 and 8 show the pH and EC of the soil before sowing (As) of okra and after harvesting of the second cropping season.



BS : before sowing, T0 : sewage sludge (SS) composted alone, T1: composts with a mixture of 2 volumes of SS + 1 volume of market garden waste (MW), T2: composts with a mixture of 1 volume of SS + 1 volume MW, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Sample : without organic input.

Figure 7 pH of soil samples (okra) at 0-20cm



Vol. 07, No. 03; 2022

ISSN: 2456-8643

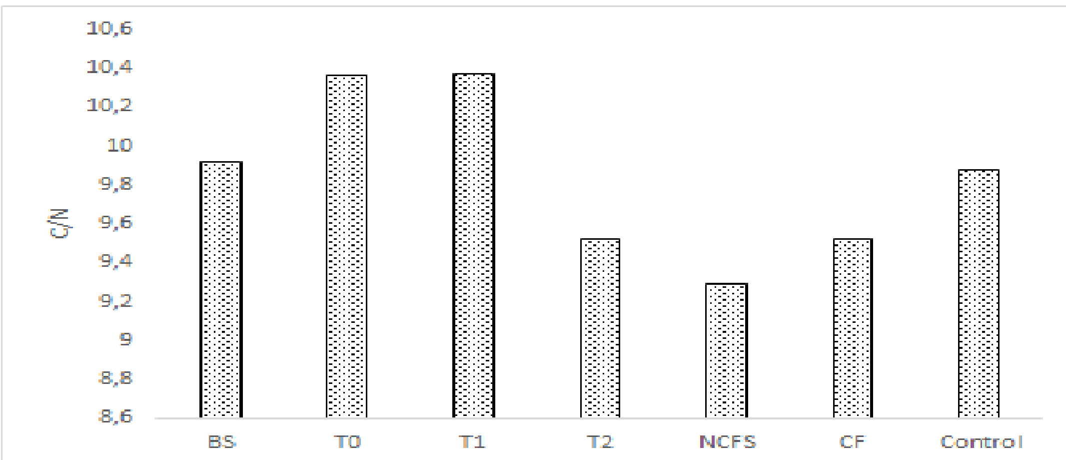
BS: before sowing, T0: feacal sludge (BV) composted alone, T1: composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2: composts with a mixture of 1 volume of BV + 1 volume DM, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Sample: without organic input.

Figure 8 EC (µs/cm) of soil samples (okra) at 0-20cm

The pH values are similar for samples taken at a depth of 0-20cm from the soil. To classify the pH and EC of the soil samples the classification tables of pH and EC values of UNDP-FAO (2014) and Durand (1983) were used.

Based on these scales, the soil type chosen for the experiments is neutral, i.e. between 6.8 and 7 for the depths 0-20 cm. Table 5 reporting the EC parameter, placed the soil samples in the category of non-saline soils.

The C/N ratio of the different treatments is shown in Figure 9.



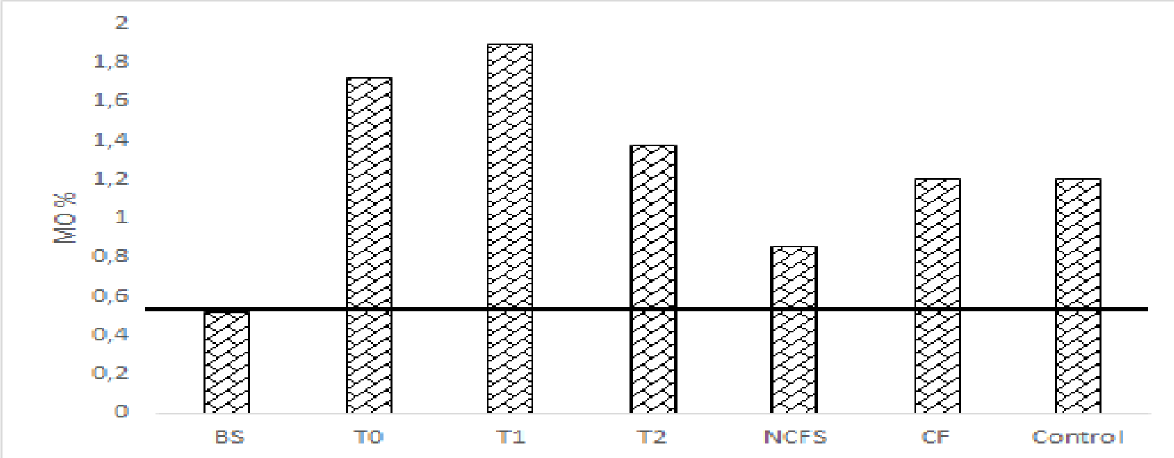
BS: before sowing, T0: feacal sludge (BV) composted alone, T1: composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2: composts with a mixture of 1 volume of BV + 1 volume DM, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Smple : without organic input.

Figure 9 C/N of soil samples (okra) at 0-20cm

Figure 10 represents the quantities of organic matter before cultivation and at the end of the harvest of the second crop year.

Vol. 07, No. 03; 2022

ISSN: 2456-8643



BS: before sowing, T0: feacal sludge (BV) composted alone, T1: composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2: composts with a mixture of 1 volume of BV + 1 volume DM, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Sample : without organic input.

Figure 10 : Quantity of organic matter stored in soil samples from okra planting beds

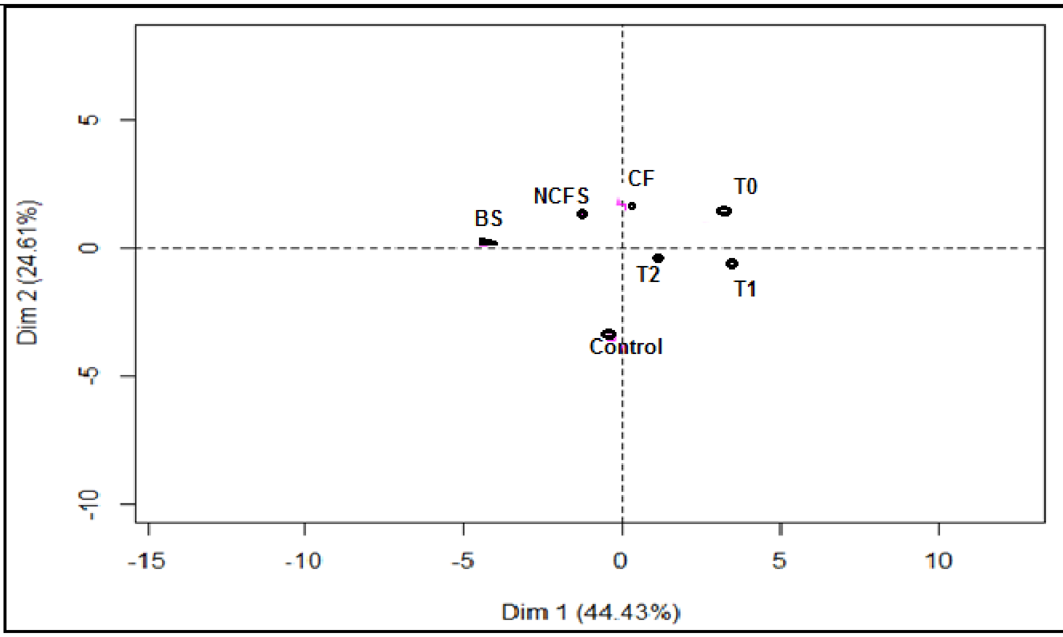
The physico-chemical parameters are recorded in table 2.

Table 2 : Physico-chemical parameters of soil samples from okra beds at 0-20cm

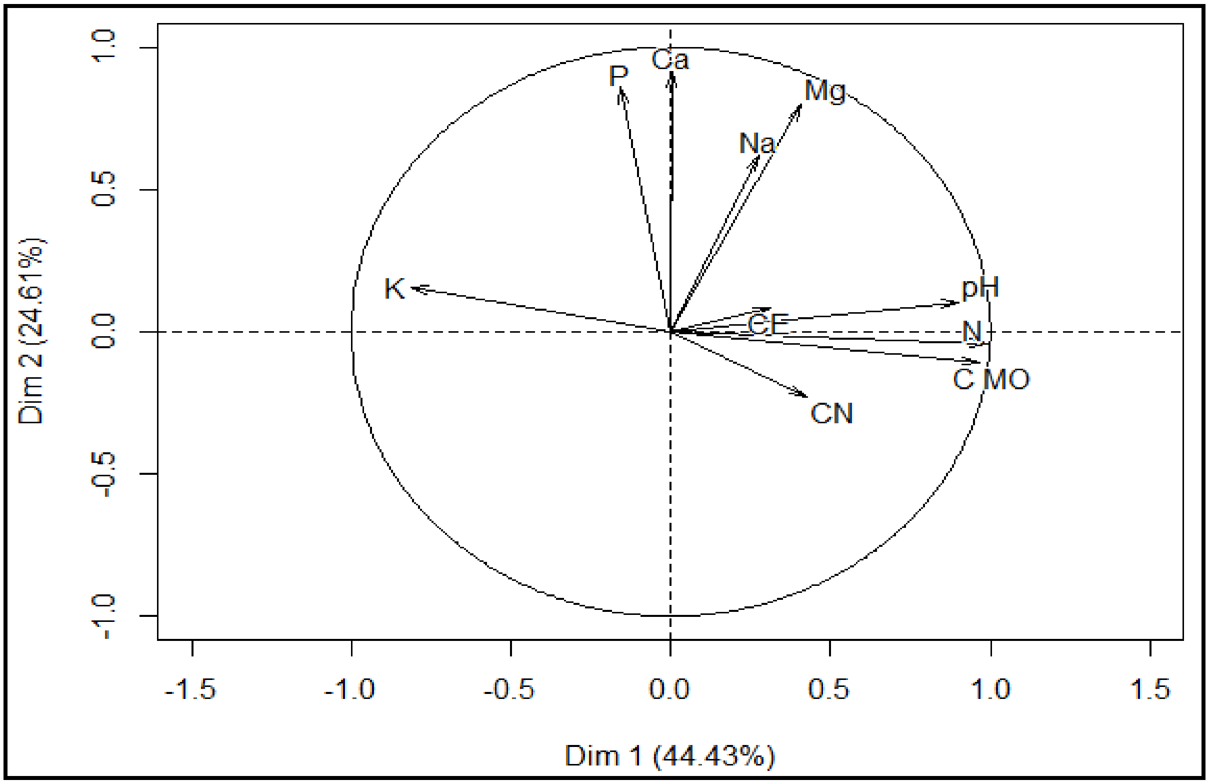
Traitements (Gombo)	Unité	N	K	P
BS	ppm	0,03	0,13	30,09
T0	ppm	0,1	0,03	27,66
T1	ppm	0,1	0,02	29,62
T2	ppm	0,08	0,03	21,71
NCFS	ppm	0,06	0,03	33,72
CF	ppm	0,07	0,03	34,34
Model	ppm	0,07	0,02	17,41

BS: before sowing, T0: feacal sludge (BV) composted alone, T1: composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2: composts with a mixture of 1 volume of BV + 1 volume DM, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Sample : without organic input.

Using the R software, the principal component analysis carried out enables the identification of groupings, oppositions and directional trends. Figure 11 shows the variability of the types of treatments and physico-chemical



a) Variability of treatment types by soil PCA at 0-20cm depth for okra



b) Variability of soil chemical properties at 0-20cm depth for okra

BS: before sowing, T0: feacal sludge (BV) composted alone, T1: composts with a mixture of 2 volumes of BV + 1 volume of market garden waste (DM), T2: composts with a mixture of 1

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volume of BV + 1 volume DM, NCFS : no composting feacal sludge, CF : Chemical fertilizer, Sample : without organic input.

Figure 11 : Graphical approach to PCA of soil physico-chemical parameters

4. DISCUSSIONS

The water used for the cultivation campaigns, is within the ranges established for water used for irrigation in sandy areas (Frenken and Gillet, 2012; Djegbe et al., 2018). According to the Piper diagram, both water samples are chlorinated. However, sample 1 from well 1 is devoid of dominant cations compared to sample 2 from well 2. In addition, the two samples from the two wells are chlorinated and sulphated, calcic and magnesian. According to Bocoum (2004), the well water is rich in nutrients.

Soil texture is defined by the relative proportions (%) of clayey, silty and sandy particles that make up the fine soil of the horizon (Calvet, 2003). Indeed, texture is an important soil characteristic, influencing several aspects of its functioning, such as the amount of water retained by the soil and its electrolyte and cation exchange capacities (Djigal, 2003). After the analysis of the results of the textural triangles, the soil texture is essentially dominated by sand (mineral particle of diameter 50-2000 µm) which represents 95% of the mineral particles of the soil (Diallo et al., 2015).

Although the difference at the beginning of cultivation and at the end of the second cropping season is small, it can be significant in the long term with regular application of the T0, T1 and T2 treatments used in this study. According to Djigal (2003), fine-textured soils have a lower capacity for infiltration but a higher capacity to store and deliver water than coarse-textured soils. In this study, all the soil samples from the okra beds fall into the coarse-textured category, but with closer observation, there is some tendency for an increase in the proportion of fines with a decrease in the coarse part. This leads us to deduce that the long-term application of composts with a certain more responsible technique can favour the water retention capacity of the soil while reducing the water infiltration rate.

The pH of the substrate is very important for the good development of the plants, as nutrients become available to the plants at different pH levels. According to M'sadak and Bembli (2018); Ballot et al. (2016), the optimum is about 5.5 for organic media and 6.5 for mineral media. These results are confirmed by those of Ramdani (2007) who states that soil pH values close to neutrality are favourable to the crop and when they move away from it, there is a blockage of nutritional exchanges. For the different treatments, i.e. T0, T1, T2, non-composted sewage sludge (BVNC), chemical fertiliser (EN) and control, the pH values are shown in Figure 7. The pH values are all neutral around 7 according to Table 4 on the acid-base status of the soils. Compared to the initial stage before the start of cultivation, the pH is increasing after the two cultivation seasons for okra.

After analysis of the soil samples before cultivation, the EC values (Figure 8) placed the soil samples in class I. According to Table 5, the soils in this class are non-saline, so the soil samples are suitable for agriculture (Bocoum, 2004).

Also EC's are increasing compared to the soil samples before the start of cultivation. The addition of inputs and the relationship of the plants with the soil favoured the increase of the EC, reflecting the activity in the plant-soil complex. Indeed, the composts increased the pH by 0.5 points. The evolution of pH from 0.1 to 0.5 in the vegetable beds amended with treatments T0, T1 and T2 is due to the addition of OH-. These ions tend to participate in the increase of the pH. With treatments T0, T1, T2, BVNC on okra crops, some of the OH^- ions are free and some are bound to the complex, so there is no participation in the increase of EC. The salinity compared to the soil samples of the okra planting beds is significant. Also on the same register, the work of Toundou (2016) collected increases in pH and EC after addition of the treatments on the cultivated soil.

According to the EC, the soils are non-saline even after the application of the different treatments. The values found are lower than those of the work of Nadjoua and Zahra (2016) which are around 447µs/cm at 25°C and declared as non-saline. However, given the levels recorded, the different doses of amendments applied do not significantly influence soil pHwater (Biaou, 2017).

The C/N ratios of the soil samples from the okra beds at 0-20 cm are shown in Figure 9. The C/N ratios are in the range described in the literature and they are lower than 12 for all treatments (T0, T1, T2, BVNC, chemical fertilizer (EN) and control for respectively, 8.79; 7.53; 8.46; 8.61; 8.36 and 8.89). These C/N values show a high mineralization (Diallo et al., 2015).

The proportion of P in the soil samples is high in all treatments compared to the beginning of the field experiments (Table 6). For N, the levels are increasing compared to the beginning of the field test. These results are satisfactory compared to the work of Nadjoua and Zahra (2016) which have lower N values than those found in our work. On the other hand, for potassium K (Table 6), the contents are decreasing compared to the soil samples before cultivation. The decrease in K may be due to the cultivation of the crop used in this study, i.e. okra, which is K-demanding, as this element is involved with P in the growth of the aerial parts of the plants.

In our study, the amounts of OM (Figure 10) before cultivation (As=0.52) are lower than the amounts of OM after harvest. In addition, the vegetable beds with treatments T0, T1 and T2 have high organic matter values of 1.72%, 1.9% and 1.4% respectively compared to the other treatments BVNC, EN and the control for 0.9%, 1.2% and 1.2% respectively. The share of organic matter added to the soil participates in the improvement of the soil structure with the increase of the water retention capacity and also an addition of the fine part in order to reinforce the adsorbent complex of the soil and thus favouring the availability of water for a longer time especially for sandy textured soils (Benzallat, 2012). According to Pizongo (2014) compost increases the performance of soil physicochemical characteristics. With the vegetable beds that received the composts (T0, T1 and T2) as organic amendment have an added OM value two (02) to three (03) times higher than the initial value (As : 0,52%). Thus, according to Toundou et al (2014), water deficit leads to an increase in EC in compost treatments on sandy soils and thus promotes OM mineralisation. Therefore, the addition of compost based on sewage sludge and vegetable waste contributes to the increase of OM in the soil and thus contributes to the increase of water retention capacity.

ISSN: 2456-8643

For Figure 11b representing the variability of physico-chemical parameters, axis 1 corresponds to the abscissa and axis 2 is considered the ordinate axis. Following the analysis of the graphs (figure 11a), organic matter (OM), carbon and nitrogen are positively correlated. Indeed, these three (03) parameters depend on each other. They can be placed on an increasing gradient from left to right to observe the mineralisation of the organic matter content of the different treatments. Two groups can be formed with group I composed of T0, T1, T2, EN which are well supplied with these elements and group II with BVNC, the control and As (soil sample before cultivation) which are compared to the previous ones less rich in these elements. These results are confirmed by the use of composts (T0, T1 and T2) which favour the increase of soil organisms and the maintenance of their activity, because according to Ouedraogo (2015), soils amended with compost combined with macrofauna lead to a significant increase in assimilable soil phosphorus. In addition, the sandy texture allowing the mobility of the macrofauna can favour its vertical movements (Diop, 2013).

5. CONCLUSION

The organic matter content in the 0-20cm depths, where the exchanges of the soil-plant system are the most marked, presents interesting values except for the T2 of the okra vegetable beds.

In the case of okra at a depth of 0-20cm, the pH values after analysis of the soil samples are around neutrality (7) for treatments T0, T1 and T2. The electrical conductivities are between 33-37µs/cm. Mineral elements such as N (0.08-0.1%), P (21.7-29.6ppm), K (0.02-0.03 meq/100g) are present in the vegetable beds amended with treatments T0, T1 and T2. The C/N ratio is between 9.5-10.4 and is below 12 thresholds established in the literature.

The soil samples from the okra beds had high organic matter values of 1.72%, 1.9% and 1.4% for T0, T1 and T2 respectively compared to the other treatments BVNC (uncomposted sewage sludge), EN (chemical fertiliser) and the control for 0.86%, 1.2% and 1.2% respectively. The proportion of organic matter added to the soil contributes to the improvement of the soil structure with the increase of the water retention capacity and also an addition of the fine part in order to strengthen the soil adsorbent complex. Thus, compost helps to increase the performance of the soil's physico-chemical characteristics.

The results compared with other similar studies were satisfactory in terms of mineral elements, but it is too early to give a definitive conclusion. As a follow-up to this study, further tests would seem to be appropriate to support the performance of the treatments used.

The authors would like to thank the laboratory of the National Institute of Pedology (INP) of Senegal and the laboratory of the National Office of sanitation of Senegal (ONAS) for their contributions to the analysis of the various parameters used to characterise the composts. The authors also thank ONAS for hosting the research team. The design and planning of the study were made possible by the support of the research team of the Laboratory for Environmental Studies of Urban and Rural Environments (LEEMUR) of the Institute of Environmental Sciences (ISE) of Cheikh Anta Diop University of Dakar (UCAD).

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Conflict Of Interest

The Authors Declare That They Have No Conflict Of Interest In This Article.

Authors' Contributions

All Authors Contributed To The Realization Of This Work And To The Writing Of The Manuscript.

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ACRONYMS AND ABBREVIATIONS

PCA: Principal Component Analysis
AS: before sowing or BS: before sowing
BV: Faecal sludgeBV :
BVNC: non-composted sewage sludge or NCFS: no composting feacal sludge
EC: Electrical conductivity
C/N: Carbon to nitrogen ratio
M: Market garden waste
EN Chemical fertilizer or CF
ENSA: Ecole Nationale Supérieure d'Agriculture (Senegal)
ISE: Institute of Environmental Sciences.
FAO : Food and Agriculture Organization of the United Nations
FST Faculty of Science and Technology
INP: National Institute of Pedology (Senegal)
K: Potassium
LEEMUR: Laboratory for Environmental Studies of Urban and Rural Environments
MO : Organic matter
N : Azote
ONAS : Office National de l'Assainissement du Sénégal
P : Potassium
pH : hydrogen potential
UNDP United Nations Development Programme
Témoin ou Control
UCAD: Cheikh Anta Diop University of Dakar (Senegal)
UT University of Thiès (Senegal)