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Growth Performance and Nutrient Availability of Tomatoes (*Lycopersicum Esculentum*) Seedlings in Anaerobic Slurry Amended Soils

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ABSTRACT

To study the growth performance and nutrient availability of tomatoes (*lycopersicum esculentum*) seedlings in anaerobic slurry amended soils, a greenhouse trial was conducted at the faculty of agriculture, University of Benin. Four rates of the anaerobic slurry were used, namely 0, 200, 400, 600 cm^3/3kg soil in a completely randomized design in triplicate. Results from the pre- plant soils revealed that the application of the amendment enhanced the soil quality. Soil organic carbon, N, P, K, Ca, Na and % base saturation were significantly ($P < 0.05$), were higher than the control, while the soil pH remained in the acidic region and the soil exchangeable acidity reduced. Apart from, stem girth which showed no significant difference, plant height, number of leaves, leaf length, and total biomass yield by the plant were significantly ($p < 0.05$) better than the control, but in no particular order. Plant growth parameter suggest that the 600 cm^3 treatment performed better for plant height, leaves length and number of leaves while total biomass yield was better with the 400 cm^3/ treatment.

Keywords: Anaerobic Slurry, Growth, Nutrient, Tomatoes

INTRODUCTION

The intensive agricultural practices with poor agronomic management procedures in Nigeria, has led to soil nutrient depletion as well as other macro- and micronutrients such as Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn) and Zinc (Zn) from the soils. Therefore, to boost agricultural output, alternative nutrient is necessary for soil fertility enhancement. The application of synthetic fertilizer is the popular option to overcome soil nutrient depletion (Rahman and Tetteh, 2014) because it results to an immediate increase in crop production. However, they are out of reach for the low income rural farmers. Also the balanced macro and micro nutrient essential for plant growth may not be available in them because synthetic fertilizers are only able to provide specific soil nutrients. Furthermore, long term application creates crops that are prone to insect attacks, microbial pathogens, intrusive weeds and eventually low productivity (Kumar *et al.*, 2015). Now there is a drift from the use of synthetic fertilizers to bio-fertilizers due to the several benefits they possess.

Soil amendments with organic manure, compost, wastewaters and sewage sludge have been extensively studied. The results obtained are of the same opinion that they are environment friendly with improved and balanced nutrients supplies which include micro and macronutrients. They have increased soil microbial activity which enhances soil structure, root development, increased soil water availability and decomposition of harmful elements (Han *et al.*, 2016). Recent studies also reports that anaerobic slurries have similar soil fertility enhancement potentials.

Anaerobic slurry is a more viable option because it comes with the benefit of biogas (Sunarso *et al.*, 2012). Anaerobic slurry is the liquid effluent by-product at the end of anaerobic digestion that produces biogas. Research studies reveal that about 70-75% of the nutrient in the original feed stock is retained in the anaerobic slurries (Islam, 2016). Nitrogen from the slurry is readily available and increased absorption of other macro and micro nutrients such as P, Ca, Mg and Zinc (Delpino *et al.*, 2014). Anaerobic slurry application on soil is could also increase soil organic matter content which is a very important factor in maintaining soil fertility (Masclendaro and Ceccanti, 1999). However, this waste has not been given sufficient attention. Thus, this study investigates the growth performance and nutrient availability of tomatoes (*lycopersicum esculentum*) seedlings in anaerobic slurry amended soils.

Tomato (*Lycopersicum esculentum*) is one of the most important vegetables worldwide. It is a relatively short duration crop and gives a high yield. Tomatoes contribute to a healthy, well-balanced diet, as they are rich in minerals, vitamin A, B and C, iron, carotene, phosphorus and phytochemicals which enhance the protective properties of human health (Chaudhary *et al.*, 2018). And since in Nigeria, a lot of children suffer from vitamin A deficiency, regular eating of fruit and green leafy vegetables can reduce the nutritional problem (South Pacific Foods, 1995).

MATERIALS AND METHODS

The anaerobic slurry was obtained by anaerobic digestion of rubber processing effluent (RPE) using cow dung inoculum at 1:1 effluent to inocolum (E:I) ratio in a closed anaerobic digester at 80% organic loading rate (OLR), using the mesophilic technique (Vavilin *et al.,* 2008). The physiochemical properties the anaerobic slurry determined using standard methods (Ademoroti, 1996; APHA, 1999; Rebecca, 2004).

Thereafter, composite soil samples were collected at a depth of 0 – 30cm from an uncultivated land behind the Faculty of Agriculture University of Benin, Benin City, Nigeria. The samples were air-dried, sieved through 2mm stainless steel sieve and thoroughly mixed to ensure uniformity and then stored in polythene bags at room temperature.

Three kilograms (3kg) each of soil samples were separately treated with 0 cm^3, 200 cm^3, 400 cm^3, and 600 cm^3 of the anaerobic slurry. The effluents applied were thoroughly mixed with the soil, watered, and left for eight weeks to allow for adequate mineralization and equilibration before transplanting of the seedlings.

Thereafter, three weeks old uniform seedlings of tomato (*Lycopersicum esculentum*) obtained from the Department of Crop Science, Faculty of Agriculture, University of Benin, were selected and transplanted at two plants per pot. These pots were arranged in a completely randomized design in triplicate. Weeding was carried out regularly. The experiment was monitored for a period of 4 weeks during which the seedlings were watered regularly. Plant growth parameters in terms of plant heights, stem girth, leaf length and number of leaves were determined on a weekly basis. Plant analyses in terms of nutrient uptake and total biomass yield were also determined using standard methods. The total biomass yield was determined by weighing the plant samples immediately after harvest from the green house. The plant samples were then wrapped in aluminium foil and dried in an oven at 105°C to attain a constant weight. The dried weight obtained was noted and recorded as the total biomass yield. The nutrient uptake of the plants was calculated by multiplying the mean dry weight (g) of each plant by the plant nutrient content (%) (Pal, 1991).

STATISTICAL ANALYSIS

One way analysis of variance (ANOVA) was carried out to assess the significant differences in the data obtained. The mean of the data was compared using SPSS (Statistical package for Social Scientist).

RESULTS AND DISCUSSIONS

Table 1 shows the physicochemical properties of the anaerobic slurry. From the results obtained, the effluent had pH of 7.60 which suggested that the effluent was slightly acidic though within the regulatory discharge limits (Ma, 2000; Ahmed *et al.,* 2003). The effluent contained appreciable amount of calcium, magnesium and potassium. Values of Total solid (1,650.00± 2.00) and Suspended solid (1,540.00± 2.00) were also high, indicating it can be used as a soil amendment.

Table 1: Physicochemical Properties of the Anaerobic slurry

PROPERTIES	OKOMU DIGESTATE mean ± SD
pH	7.60± 0.01
Organic carbon%	0.78 ±0.01
COD (mg/l)	672.65±0.05
Total solids (mg/l)	1,650.00 ±2.00
Volatile solids (mg/l)	175.00 ±2.00
Suspended solids (mg/l)	1,540.00± 2.00
Oil & Grease (mg/l)	4.10 ±0.05
Calcium (mg/l)	155.00 ±1.00
Magnesium (mg/l)	48.60 ±0.10
Phosphate (mg/l)	21.00 ±0.02
Potassium (mg/l)	168.38 ±0.02
Sodium (mg/l)	23.45 ±0.010
Nitrate (mg/l)	1.07 ±0.150
Sulphate (mg/l)	10.00 ±0.04
Copper(mg/l)	12.60± 0.05
Manganese (mg/l)	14.28 ±0.01

Table 2(A & B) shows the results of the physiochemical analyses of the parent soil. From the results, it is observed that the soil was acidic, with medium organic matter and low percentage base saturation. The low percentage base saturation (which was less than 35%) suggested that it is an ultisoil (Orhue *et al.,* 2005). Available phosphorus (3.19 mg/g) and nitrogen (0.33 g/kg) indicate that the nutrient level of the soil is low and would not favour the growth of plant for high yield of crops.

Soil textural analysis shows that the soil is sandy and therefore needs soil nutrient enhancement.

Table 2(A): Soil Physiochemical properties before and after the experiment

Treatments	pH	T. Org. C g/Kg	Org. Mat. g/Kg	Ca cmol/kg	Mg cmol/kg	Av. P mg/g	K cmol/kg	Na cMol/kg	N g/Kg
BEFORE THE EXPERIMENT									
0 cm^3	5.14 ±0.010	6.410 ±0.01	11.070± 0.100	0.423 ±0.001	0.353 ±0.0200	3.189 ±0.100	0.145± 0.200	0.108 ±0.001	0.325± 0.010
AFTER THE EXPERIMENT									
0 cm^3	5.568 ±0.020 ^{c}	5.660 ±0.020 ^{a}	9.780 ±0.110^a	0.830 ±0.010 ^{d}	0.350 ±0.030^b	1.650 ± 0.500 ^{a}	0.170 ±0.020 ^{a}	0.120 ± 0.000^a	0.487 ± 0.011^a
200 cm^3	5.210±0.200^a	13.770± 0.020^c	23.710 ± 0.200 ^{c}	0.6200± 0.100^b	0.213± 0.010^a	6.417 ± 0.110^c	0.304 ± 0.010^d	0.1203 ± 0.00^a	0.487 ± 0.11^a
400 cm^3	5.200±0.001^a	13.770 ± 0.12 ^{c}	23.720± 0.200 ^{c}	0.541± 0.100^a	0.220± 0.000^a	6.417± 0.110^c	0.214 ± 0.085^b	0.1216±0.001^b	0.773± 0.022^c
600 cm^3	5.332±0.030^b	11.170± 0.100^b	19.270 ± 0100 ^{b}	0.810 ± 0.100 ^{c}	0.241± 0.200^a	5.471± 0.200 ^{b}	0.260^d± 0.020^c	0.131 ± 0.010^c	0.640± 0.010^b

Means with different alphabet remarks in the same column are significantly different at 5% probability level (P<0.05).

Table 2(B): Soil Physiochemical properties before and after the experiment

Treatments	EA cmol/kg	CEC cmol/kg	% BASE SAT.	SAND%	CLAY%	SILT %
BEFORE THE EXPERIMENT						
0 cm^3	1.856± 0.020	2.880± 0.010	31.94± 0.020	87.150± 0.110	6.320± 0.001	6.540± 0.120
AFTER THE EXPERIMENT						
0 cm^3	1.904 ± 0.100^c	3.360 ± 0.200^d	39.880 ± 0440^b	87.730±0.200^b	7.030±0.020^b	5.230 ± 0.110 ^{a}
200 cm^3	1.904 ± 0.100^c	2.590 ± 0.300^c	44.020± 0.200^c	86.870±0.100^b	6.130± 0.020^a	7.000 ± 0.110^b
400 cm^3	1.377 ± 0.220^b	2.470 ± 0.300^b	39.270± 0,110^a	86.770±0.200^b	6.130± 0.020 ^{a}	7.100 ± 0.050^b
600 cm^3	0.671 ± 0.200^a	2.110 ± 0.100^a	62.090±0.050^d	82.900±1.000^a	7.830±0.030 ^{c}	9.270 ± 0.200^c

Means with different alphabet remarks in the same column are significantly different at 5% probability level (P<0.05).

Effect of treatment on plant growth parameters is presented in Table 3 – 6. Plant heights (Table 3) suggest that effluent treatment of soils was better than the control. Plant height improved with increasing effluent applications with the 600 cm^3 treatment having the highest value (59.282±0.210[d]). This value was statistically different from the other values. Increase in plant height on soil amended with anaerobic slurry is similar to findings of Aziz *et al.*, (2010) who reported an increase in plant height due to the application of organic manure and Budhan *et al.*, (1991) who reported an increase in plant height on the application of cattle manure.

Table 3: Effect of treatment on plant height

Treatment	Wk 1 (cm) mean ± SD	Wk 2 (cm) mean ± SD	Wk 3 (cm) mean ± SD	Wk4 (cm)mean ± SD
0 cm^3	36.670±0.300[a]	38.723±0.023 [a]	40.382±0.120 [a]	40.954±0.020 [a]
200 cm^3	43.853±1.000[b]	47.572±0.050[b]	51.951±0.500[b]	53.010±1.000[b]
400 cm^3	47.463±0.220[c]	51.162±0.020[c]	53.180±0.200 [c]	54.573±0.500 [c]
600 cm^3	49.391±0.201[d]	56.610±0.305[d]	57.042±1.000[d]	59.282±0.210[d]

Means with different alphabet remarks in the same column are significantly different at 5% probability level ($P<0.05$). Wk - Week

Table 4: Effect of treatment on stem girth

Treatments	Wk 1 (cm) mean ± SD	Wk 2 (cm) mean ± SD	Wk 3 (cm) mean ± SD	Wk4 (cm) mean ± SD
0 cm^3	2.472±0.022[a]	2.533±0.022 [a]	2.611±0.011	2.553±0.050 [a]
200 cm^3	2.233±0.262 [a]	2.333±0.200 [a]	2.433±0.200 [a]	2.537±0.210 [a]
400 cm^3	2.347±0.020 [a]	2.433±0.230 [a]	2.480±0.400 [a]	2.570±0.220 [a]
600 cm^3	2.457±0.500 [a]	2.600±0.500 [a]	2.533±0.203 [a]	2.633±0.110 [a]

Means with different alphabet remarks in the same column are significantly different at 5% probability level ($P<0.05$). Wk - Week

Table 5: Effect of treatment on leaf length

Treatments	Wk 1 (cm) mean ± SD	Wk 2 (cm) mean ± SD	Wk 3 (cm) mean ± SD	Wk4 (cm) mean ± SD
0 cm^3	5.861±0.201[a]	5.973±0.210 [a]	6.201±0.200 [a]	6.432±0.200 [a]
200 cm^3	5.740±0.020 [a]	5.987±0.010 [a]	6.373±0.120 [a]	6.643±0.120 [a]
400 cm^3	6.430±0.200[b]	6.643±0.200 [b]	6.733±0.200 [b]	6.850±0.126 [b]
600 cm^3	7.133±0.100 [c]	7.034±0.383 [c]	7.243±0.125 [c]	7.333±0.011[c]

Means with different alphabet remarks in the same column are significantly different at 5% probability level ($P<0.05$). Wk - Week

Table 6: Effect of treatment on number of leaves

Treatments	Wk 1 (cm) mean ± SD	Wk 2 (cm) mean ± SD	Wk 3 (cm) mean ± SD	Wk4 (cm) mean ± SD
0 cm^3	7.666±0.220[a]	14.400±0.115 [a]	21.682±0.301 [a]	25.332±0.168 [a]
200 cm^3	18.340±0.120 [c]	20.646±0.110[b]	31.782±0.301[b]	32.383±1.001[b]
400 cm^3	15.642±1.332[b]	23.463±1.000 [c]	41.633±0.320 [c]	54.650±0.120 [c]
600 cm^3	15.617±0.100[b]	24.000±0.500 [c]	42.591±0.200[d]	63.747±0.010[d]

Means with different alphabet remarks in the same column are significantly different at 5% probability level ($P<0.05$). Wk - Week

Plant girths (Table 4) were not statistically different in all the trials, however the 600 cm^3 treatment had the highest value (2.633±0.110 [a]). This study is not consistent with Osagbovo *et al.*, (2010) where stem girth increased in soils amended with fish pond effluent. The result from plant leaf length (Table 5) showed that the leaf length varied among the different treatments and was better than the control with the exception of the 200 cm^3 treatment which was not statistically different from the control. The highest leaf length was observed in the treatment that received the 600 cm^3 digestate (7.333±0.011[c] cm), followed by the 400 cm^3 treatment (6.850±0.126 [b] cm)

The effect of treatment on number of leaves (Table 6) was not in agreement with studies conducted by Orhue *et al.*, (2005) were no significant changes was observed in the number of leaves on plant sown on rubber effluent-amended soils. Results from this study suggested that the number of leaves varied among different treatment and increased with increasing treatment. Maximum value was observed in the treatment that received 600 cm^3 treatment (63.747±0.010[d]) followed by the 400 cm^3 treatment (54.650±0.120 [c]) This result is consistent with Kant and Kumar (1994) who reported that the application of organic manures to soil led to increased number of rice tiller.

Table 7: Effect of treatment on nutrient uptake of tomatoes (lycopersicum esculentum) seedlings

Treatments	N (mg/kg) mean ± SD	P (mg/kg) mean ± SD	K (mg/kg) mean ± SD	Ca (mg/kg) mean ± SD	Mg (mg/kg) mean ± SD	Na (mg/kg) mean ± SD
0 cm^3	1.510±0.010	103.030±1.000	8295.00±5.000	300.300±30.100	180.100±0.100	400.300±20.200
200 cm^3	1.268±0.022	100.400±1.200	17080.00±10.00	360.300±0.150	170.300±0.200	530.300±0.300
400 cm^3	0.760±0.200	112.30±0.300	12250.00±0.430	400.200±15.100	145.300±1.200	435.200±2.200
600 cm^3	0.314±0.011	77.630±0.020	11708.00±2.00	360.100±0.100	145.400±1.100	405.300±1.300

Means with different alphabet remarks in the same column are significantly different at 5% probability level ($P<0.05$).

There was no general pattern with regards to nutrient uptake in the trials (Table 7). However, the result revealed that sodium (Na), potassium (K) and calcium (Ca) nutrient levels were higher in plants grown in the treated soils while phosphorus with exception of the 400 cm^3 treatment, nitrogen (N) and magnesium (Mg) were lower. Nitrogen uptake was significantly different ($P < 0.05$) in the trials, with the control having the highest uptake while the lowest was obtained from the 600 cm^3 treatment. Also, phosphorus uptake was significantly different ($P < 0.05$) with the 400 cm^3 treatment having the highest uptake while with the 600 cm^3 POME treatment having the lowest. Potassium uptake at 200 cm^3 treatment was significantly different ($P < 0.05$) with 200 cm^3 treatment having the highest uptake while the control had the lowest. Also, calcium uptake was significantly different ($P < 0.05$) with at 400 cm^3 having the highest uptake while the control had the lowest. The 400 cm^3 and 600 cm^3 treatment were not significantly different ($P < 0.05$) in the uptake of magnesium but lower than the other treatments. In sodium uptake, 200 cm^3 soil treatment was the highest while the control was the lowest.

Table 8: Effect of treatment on total biomass yield

0 cm^3 mean ± SD	200 cm^3 mean ± SD	400 cm^3 mean ± SD	600 cm^3 mean ± SD
BEFORE DRYING (g)			
15.437±0.117^a	33.543±0.018^d	31.354±0.150^c	22.554±0.110^b
AFTER DRYING (g)			
2.453±0.013^a	3.151±0.026^b	4.732±0.052^d	3.432±0.200^c

Means with different alphabet remarks in the same row are significantly different at 5% probability level ($P<0.05$).

Result from Table 8 revealed that individual plant weight varied among different treatments and were better than the control. The highest plant weight was obtained in the treatment that received 400 cm^3 treatment while control had the lowest. The higher yields from the digestate amended soils could be attributed to the fact that the digestate is nutrient rich as anaerobic digestion of organic materials has very little to no effect on the amount of nutrients after digestion (Bonten *et al.*, 2014), and in completely mineralized form. The lower yield from the control could be attributed to the effect of poor nutrient status of the sandy soil, which is less effective in providing the plant with the necessary nutrients. In a similar report, Salakinlop and Hunshal (2008) reported increase in biomass yield of wheat on domestic sewage amended soil. The increase in biomass yield could be attributed to increase in potassium, phosphorus and other nutrient content in the amended soils.

CONCLUSION

The anaerobic digestion was a successful biological treatment. The 1:1 E:I showed the highest biogas yield of 690cm^3, at a 40– day retention time, which led to a COD reduction of about 60%. There was evidence that the treatments using the digestate altered the soil properties better than the control. Plant growth parameters also suggested that effluent treatment of soil was better than the control. Plant growth parameter suggested that the 600 cm^3 slurry treatment performed better for plant height, number of leaves and leaves length while total biomass yield was better in the 400 cm^3 treatment

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