



Screening of cassava effluent- a proposed weed biocontrol agent for its effect on soil nutrients and microbial population

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Abstract

Weed management in crop production has the objective of reducing plant nutrient competition with minimal effect on soil microbial load. Hence, it is important to investigate the effect of botanicals used for weed management in this regard. The effect of cassava effluent (CE) concentrations of 60, 120, 180 and 240 µg CN/kg (CN is a universal chemical symbol for cyanide) soil that were applied one, two, three and four times, was evaluated on soil nutrients and microbial load in a 4 x 4 factorial arrangement. Control treatment (without CE) was incorporated into the experiment in an incomplete factorial design. This was laid out in completely randomized design in the screen-house. Results showed that CE concentration and frequency of application altered the C, Ca, Mg, Na, K, Cu, Fe, Mn and Zn contents of the soil. CE concentration and frequency of application had significant interaction ($p < 0.05$) on all the plant nutrients analysed. CE concentration of 60 and 120 µg CN/kg soil applied one to four times had available P concentrations lesser than the control treatment. Contrarily, P increased by 45% when CE of 240 µg CN/kg soil was applied three times. Significant ($p < 0.05$) interaction between CE concentration and application frequency markedly decreased culturable bacterial population, while fungal population was increased by some interactions. The study concluded that application of CE for weed control has moderating effect on soil nutrients and microbial load. Hence, its adoption for weed control requires the understanding of its influence on chemical and biological properties of soil.

Keywords: Cassava effluent, soil nutrient, microbial load, weed control

Introduction

Screening of plant extracts as biocontrol agents for weed management goes beyond evaluation of herbistatic and herbicidal efficacies. It is important to investigate the effect of biocontrol agents on factors that affect crop growth as well. Weed management in crop production has the objective of reducing competition for soil nutrients and other limited growth factors. Previous studies showed that attenuating the negative effect of weeds improves crop yield (Aladesanwa and Ayodele, 2011; Akadiri *et al.*, 2017). However, it is important to ensure that the weed management strategy employed does not promote competition by adversely affecting soil nutrients and its biological component. The beneficial roles of soil microorganisms in nutrient cycling (Kumar *et al.*, 2015), solubilisation and absorption of plant nutrients (Kumar *et al.*, 2017) justify that weed management practices should not distress the soil microbial population.

The use of synthetic herbicides for weed control has generated concerns; as they negatively impact the soil

environment (Romano-Armada *et al.*, 2017). The associated hazards of herbicide application such as soil nutrient uptake interception (McLay and Robson, 1992), reduced activities of beneficial soil organisms (Gaupp-Berghausen *et al.*, 2015) and contamination of freshwater (Masiol *et al.*, 2018) have justified the quest for other effective weed management practices that are environment friendly.

Recently, attention is being given to the use of plants or plant products as alternative to synthetic herbicides for weed control (Arif *et al.*, 2015). The use of botanicals for weed control could be by direct application of allelopathic extracts or cultural means such as planting of allelopathic plant, intercropping with allelopathic plant, mulching and the use of cover crops (Bajwa *et al.*, 2015; Jabran *et al.*, 2015). In Central Tongu District of Ghana, the use of cassava effluent (CE) for weed control has been reported (Adabie, 2015). Also, studies conducted in Nigeria suggested that CE could be used for weed control based on its phytotoxicity (Nwakaudu *et al.*, 2012; Fayinminnu *et al.*, 2013; Eze and Onyilide, 2015).

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The phytotoxic nature of CE has been linked to the presence of cyanide (CN) that inhibits major plant processes such as respiration, CO₂ and nitrate assimilation, and photosynthetic electron transfer (Kremer and Souissi, 2001). However, cyanide concentration in cassava varies with respect to variety, age of cassava, and agro-ecological conditions of the area where it is cultivated (Agiriga and Iwe, 2016). Hence, it is important to evaluate CE for weed control in relation to CN applied through it, as against the quantity of CE applied.

Plant extracts end up in the soil when applied directly by chemigation or indirectly by foliar application. Thus, this study aimed at investigating the effect of CE concentration and frequency of application on soil nutrients and microorganisms.

Materials and Methods

Experimental site

The experiment was conducted in the screen-house of the Institute of Agricultural Research and Training, Ibadan (7°31'N 3°45'E), located in the forest-savanna transition agro-ecological zone of Nigeria. The temperature and the relative humidity in the screen-house fluctuated between 24-33°C and 52-79%, respectively, during the experiment.

Materials

Fresh CE was obtained from the Cassava Processing Section of International Institute of Tropical Agriculture (IITA) Ibadan. The CE was extracted from cassava tubers that were processed within a day. The extraction involved peeling, grinding and pressing of the cassava tuber. The CE was collected on the day of processing and application; hence, it was not stored. The physicochemical properties of the CE were determined and are presented in Table 1.

The nitrogen (N) content of the CE was determined using modified micro-kjeldahl digestion method (Nelson and Sommers, 1973). The phosphorus (P) was analysed using a H₂SO₄-HNO₃ acid digestion procedure and the digest was analysed for ortho P using a colorimetric assay (Murphy and Riley, 1962). Potassium (K) and sodium (Na) of the effluent were determined by flame photometry (Black, 1965). The calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), and zinc (Zn) concentrations were analysed using Agilent Atomic Absorption Spectrometer model 280Z AA. The total suspended solids (TSS) and the total dissolved solids (TDS) were measured by the method 2540B of the American Public Health Association (APHA, 1995) and the pH was determined with Hanna pH 211 instrument.

The CE was analysed for CN using Ninhydrin-based spectrophotometric method (Surleva *et al.*, 2013). Hence, the equivalent amount of CE with the desired CN concentration required as experimental treatment was determined. Different volumes of CE with corresponding CN concentrations needed as experimental treatment were diluted with water and made up to same volume to facilitate equal spread when applied to the soil. This standardization was repeated weekly; at each time of CE application, maintaining same concentration levels.

Topsoil was collected from arable crop farmland within the premises of the Institute of Agricultural Research and Training, Ibadan where agro chemicals were not applied for the past five years. The soil collected is clay loam containing 378 g kg⁻¹ sand, 239 g kg⁻¹ silt and 383 g kg⁻¹ clay. This was air dried, sieved and homogenized.

Experimental treatments and design

The experimental treatments were four levels of CE concentration (60, 120, 180, and 240 µg CN /kg soil) in factorial combination with four levels of application frequency (one, two, three and four times). Control treatment where CE was not applied was also included. These were laid out in three replications in completely randomized design.

Application of CE to potted soil

The pot used for this experiment is 16.5 and 13.5 cm in length and breadth, respectively. Sixty pots were filled with the prepared soil at 5 kg per pot and these were arranged in the screen-house. The potted soil was watered every other day for five weeks to facilitate natural weed emergence and growth. Cassava effluent was not applied to twelve pots throughout the experiment. From the sixth week, standardized CE concentrations were applied to the soil in the remaining pots by drenching. Application of the same standardized CE concentration that was initially applied to the potted soil at the sixth week was repeated weekly till the ninth week. However, the application ceased at sixth, seventh, eighth and ninth week in some pots to achieve frequency of application of the standardized CE concentrations that is one to four times.

Data collection

Soil chemical properties

Soil sample was taken from each pot for chemical analysis immediately after the weed sampling at the end of the twelfth week into the experiment. Soil pH was determined at a soil to water ratio of 1: 2 (IITA, 1979). Soil organic carbon (SOC) was determined by the method of



Table 1: Physicochemical analysis of cassava effluent

N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (mg L ⁻¹)	Mn (mg L ⁻¹)
0.05	0.02	0.44	0.06	0.03	20.79	1.83
Fe (mg L ⁻¹)	Cu (mg L ⁻¹)	Zn (mg L ⁻¹)	CN (mg L ⁻¹)	pH	TSS (mg L ⁻¹)	TDS (mg L ⁻¹)
11.90	1.33	2.32	12.70	3.90	1.53	6300

Table 2: Effect of CE concentration on soil mineral elements

CE (µg CN/ kg)	SOC g/kg	T.N g/kg	P mg/kg	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na cmol/kg	Mn mg/kg	Cu mg/kg	Fe mg/kg	Zn mg/kg	pH (H ₂ O)
60	16.9a	1.5	7.68e	0.89d	1.89b	2.34b	1.82c	13.94d	2.48c	205.92c	0.89bc	6.98b
120	15.6b	1.4	10.14d	1.29c	2.00a	2.60a	1.92bc	14.79c	2.86b	234.67b	1.00a	7.11ab
180	16.1ab	1.2	11.76b	1.39b	1.64d	2.28b	1.97b	14.97b	2.73bc	232.16b	0.99a	7.15ab
240	14.5c	1.3	14.49a	1.84a	1.61e	2.32b	2.14a	18.94a	3.30a	291.16a	0.91b	7.29a
Control	16.2ab	1.2	11.33c	0.74e	1.70c	2.33b	1.50d	7.95e	1.97d	120.67d	0.81c	6.75c

Means in a column followed by the same letter are not significantly different according to DMRT ($p = 0.05$).

Walkley and Black (1934). Micro-kjeldahl digestion method was used to determine the total nitrogen (Kjeldahl, 1983). Available phosphorus (P) was determined by Bray and Kurtz (1945) No.1 method. Exchangeable bases were extracted with neutral ammonium acetate (1M NH₄OAc, pH 7.0). Potassium (K) and sodium (Na) in the extract were determined by flame photometry (Black, 1965). Versenate EDTA titration method was used to determine calcium (Ca) and magnesium (Mg) (Jackson, 1962). Trace elements in the soils (Fe, Mn, Cu, and Zn) were extracted by digesting the samples with mixture of concentrated nitric acid (HNO₃) and hydrogen chloride (HCl) and determined by Atomic Absorption Spectrophotometry (AAS) method (Soylak *et al.*, 2003).

Soil microbial data

Part of the soil sample taken from each pot at the twelfth week was used for microbial enumeration. Nutrient agar (NA) was used for the enumeration of total heterotrophic bacteria by the pour plate method. Incubation was done at 30°C for 24-48 h. Isolates from this were characterized based on cultural characteristics, staining reactions and biochemical reactions and identification was done with reference to Bergey's manual of systemic bacteriology. Potato dextrose agar (PDA) was used for enumeration of fungi. Inoculation was done and placed at 25°C for 48 h. The fungal isolates were characterized as described by Barnett and Hunter (1972).

Data analysis

Data were subjected to analysis of variance. Treatment means were separated by using DMRT at $p < 0.05$. These were performed using IBM SPSS Statistics 23 software (George and Mallery, 2016).

Results

Effect of CE concentration on soil mineral elements

The CE concentration applied to the soil had significant effect on soil C, Mg, Na, K, P, Mn, Cu, Fe and Zn (Table 2). In contrast, CE concentration did not significantly influence the total soil N. Cassava effluent concentration did not significantly increase soil organic carbon (SOC) rather CE of 240 µg CN/kg soil resulted in significantly reduced SOC of 10% compared to the control treatment. Potted soil treated with 60 µg CN/kg soil had the highest SOC while those treated with 240 µg CN/kg soil had the least.

Potted soil treated with CE of 60 and 120 µg CN/kg soil had Ca concentrations that were significantly higher ($p < 0.05$) than the control treatment by 11% and 18%, respectively, while those of 180 and 240 µg CN/kg soil were significantly lesser by 4% and 5%, respectively. Cassava effluent concentration of 120 µg CN/kg soil resulted in the highest concentration of soil Mg. It had Mg concentration that was 12% more than the control treatment and that was significantly higher ($p < 0.05$) than all other treatments.

The concentrations of soil Na, K and Mn increased significantly ($p < 0.05$) with increasing concentration of CE. Hence, soil treated with 240 µg CN/kg soil had the highest concentration of these mineral elements. The treatment resulted in soil Na, K and Mn that were 42%, 135% and 138% higher than the control treatment, respectively. Similarly, 240 µg CN/kg soil had the highest concentration of P with 28% increase over the control treatment while 60 µg CN/kg soil had the least with 32% decrease. These treatments were significantly different ($p < 0.05$) from the control treatment.



Concentrations of Cu and Fe increased significantly ($p < 0.05$) in soil treated with CE of 60, 120, 180 or 240 $\mu\text{g CN/kg}$ compared to the control treatment. Soil treated with 240 $\mu\text{g CN/kg}$ soil had the highest concentration of these mineral elements. The Cu and Fe concentrations in this treatment increased by 23% and 141%, respectively, over the control treatment. Cassava effluent concentration did not significantly reduce soil Zn compared to the control treatment rather potted soil treated with 120, 180 or 240 $\mu\text{g CN/kg}$ soil had significantly increased Zn by 12-23%.

Potted soil treated with CE concentrations of 60, 120, 180 or 240 $\mu\text{g CN/kg}$ soil had significantly increased soil pH compared to the control treatment. The soil pH increased by 0.23-8% with increasing CE concentration.

Effect of frequency of CE application on soil mineral elements

Frequency of CE application had significant effect on all (C, N, Ca, Mg, Na, K, Cu, Fe, Mn and Zn) the mineral elements analysed (Table 3). There seemed to be no clear trend of SOC response to the frequency of CE application. However, four applications of CE significantly increased SOC by 8% while two applications of CE reduced SOC by 9% compared to the control treatment. Similarly, four applications of CE resulted in soil N that was significantly higher than those that had lesser frequency of CE application and the control treatment. It had soil N that was 33% more than the control treatment. Frequency of CE application lesser than four resulted in soil N that was comparable to the control treatment.

Table 3: Effect of frequency of CE application on soil mineral elements

Frequency	SOC g/kg	T.N g/kg	P mg/kg	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na cmol/kg	Mn mg/kg	Cu mg/kg	Fe mg/kg	Zn mg/kg	pH (H ₂ O)
1	15.0c	1.3b	11.18b	1.17c	1.74c	2.48a	1.71c	13.70d	2.43c	221.75d	0.67c	7.14ab
2	14.8c	1.3b	10.77c	1.35b	1.82b	2.49a	1.95b	14.55c	2.98b	233.08c	1.07a	7.28a
3	15.8bc	1.2b	11.29a	1.37b	1.59e	2.34b	2.11a	15.07b	2.48c	243.75b	1.03a	7.11ab
4	17.5a	1.6a	10.84c	1.53a	1.99a	2.24c	2.08a	19.33a	3.48a	265.33a	1.04a	7.00b
Control	16.2b	1.2b	11.33a	0.74d	1.70d	2.33b	1.50d	7.95e	1.97d	120.67e	0.82b	6.75c

Means in a column followed by the same letter are not significantly different according to DMRT ($p = 0.05$)

Table 4: Interaction effect between CE concentration and frequency of application on soil mineral elements

CE ($\mu\text{g CN/kg}$)	Freq	SOC g/kg	T.N g/kg	P mg/kg	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na cmol/kg	Mn mg/kg	Cu mg/kg	Fe mg/kg	Zn mg/kg	pH (H ₂ O)
60	1	18.3a	2.2a	6.00m	0.95f	2.30a	2.24ef	1.82ef	18.19d	3.10cd	257e	1.11a-d	7.03b-d
60	2	16.9ab	1.4b	9.62k	0.95f	1.7e	2.36b-f	1.96de	14.69g	2.3f-h	198j	0.90fg	6.91cd
60	3	15.5bc	1.2b	5.93m	0.97f	1.85c	2.36b-f	1.81ef	11.80m	2.3f-h	210i	0.93e-g	7.09b-d
60	4	17.0ab	1.1b	9.19l	0.73g	1.7e	2.37b-f	1.70f	11.10n	2.20f-h	158m	0.62i	6.9cd
120	1	16.8ab	1.4b	10.13j	1.50cd	1.85c	2.44b-d	2.00c-e	18.59c	3.50c	249f	1.00d-f	6.88cd
120	2	16.9ab	1.3b	10.12j	1.43d	1.7e	2.46bc	2.14b-d	14.10h	2.5e-g	212i	1.16a-c	7.18a-c
120	3	12.4ef	1.2b	9.74k	1.07ef	2.15b	2.71a	1.74f	13.69i	2.60ef	256e	1.13a-d	7.40ab
120	4	16.0bc	1.7b	10.57i	1.19e	2.30a	2.80a	1.81ef	12.80k	2.83de	221h	0.71hi	6.97b-d
180	1	18.2a	1.5b	12.54e	1.62bc	1.5h	1.98g	2.07b-d	18.09d	2.6ef	218h	0.93e-g	6.97b-d
180	2	13.3de	1.1b	11.37g	1.41d	1.6g	2.44b-d	2.14b-d	15.89e	2.83de	288b	1.25a	7.17a-d
180	3	16.9ab	1.2b	11.01h	1.38d	1.8d	2.50b	2.00c-e	13.20j	2.90de	193k	1.19ab	7.35ab
180	4	15.8bc	1.1b	12.13f	1.16e	1.65f	2.23f	1.66fg	12.69k	2.60ef	229g	0.63i	7.11b-d
240	1	16.6ab	1.4b	14.69b	2.06a	2.30a	2.28d-f	2.44a	22.46a	4.70a	336a	1.10b-d	7.12b-d
240	2	16.1bc	1.1b	14.05c	1.72b	1.35i	2.08g	2.18bc	15.59f	2.30f-h	277cd	0.82gh	7.18a-d
240	3	14.5cd	1.5b	16.38a	1.99a	1.5h	2.4b-e	2.25b	19.50b	4.10b	273d	1.03c-e	7.29a-c
240	4	11.1f	1.3b	12.84d	1.60bc	1.3j	2.52b	1.67fg	18.19d	2.1gh	278c	0.71hi	7.58a
Control		16.2b	1.2b	11.33g	0.74g	1.7e	2.33c-f	1.50g	7.95o	1.97h	120n	0.81gh	6.75d

Means in a column followed by the same letter are not significantly different according to DMRT ($p = 0.05$)



Frequency of CE application to the soil significantly increased soil Ca by 2-17% when applied once, twice or four times compared to the control treatment. In contrast, three applications of CE significantly reduced soil Ca by 6% compared to the control treatment. Two applications of CE to the soil significantly increased soil Mg by 7% compared to the control treatment while four applications of CE significantly reduced soil Mg by 4%.

The application of CE to the potted soil at one to four times significantly increased the soil Na, K, Cu, Fe and Mn compared to the control treatment. Soil Fe and Mn increased with increasing frequency of CE application. In contrast, the response of soil Na, K and Cu to increasing frequency of CE application had no clear trend.

Two to four applications of CE to the soil significantly increased soil Zn by 26-30% while application of CE once resulted in significant reduction of 23% compared to the control treatment. The soil pH increased significantly ($p < 0.05$) when CE was applied one to four times by 4-8% compared to the control treatment. However, the response of soil pH to increasing frequency of CE application had no clear trend.

Interaction between CE concentration and frequency of application on soil mineral elements

The interaction between CE concentration and frequency of application was significant on all the soil mineral elements analysed (Table 4). However, the concentrations of SOC, N, Na, K, Mn, Cu and Fe were not significantly reduced by the interaction between CE concentration and frequency of application compared to the control treatment. Cassava effluent concentration of 240 µg CN/kg soil applied once had no mineral element that was significantly reduced compared to the control treatment. In contrast, other interactions of CE concentration and frequency of application significantly reduced the concentration of one or more mineral elements.

Cassava effluent concentration of 180 or 240 µg CN/kg soil applied twice or four times significantly reduced soil Ca. Similarly, 240 µg CN/kg soil applied thrice also did the same. Four-time application of 240 µg CN/kg soil had the least soil Ca. It was 24% lesser than the control treatment. The concentration of Mg was significantly lesser in potted soil treated twice with 240 µg CN/kg soil and 180 µg CN/kg soil applied once compared to the control treatment. The highest Mg reduction resulted from 180 µg CN/kg soil applied once (1.98 cmol/kg). It was 15% lesser compared to the control treatment (2.33 cmol/kg).

Soil treated with CE concentration of 60 or 120 µg CN/kg soil in all the application frequencies had significantly lesser available P than the control treatment. Similarly, soil treated with 180 µg CN/kg soil thrice had significantly lesser available P compared to the control treatment. Three applications of 60 µg CN/kg soil had the highest P reduction (5.93 mg kg⁻¹). It was 48% lesser than the control treatment (11.33 mg kg⁻¹). Soil treated four times with CE of 60 or 180 µg CN/kg soil had Zn that was significantly lesser than the control treatment. Four applications of 60 µg CN/kg soil had the highest Zn reduction of 27% compared to the control treatment.

The interaction between CE concentration and frequency of application did not significantly reduce soil pH. In contrast, soil treated with CE of 120 µg CN/kg soil twice or thrice, 180 µg CN/kg soil applied thrice and 240 µg CN/kg soil applied thrice or four times resulted in soil pH (H₂O) that were significantly higher than the control treatment.

Soil treated once with CE of 60 µg CN/kg soil had the highest SOC (1.83%), total N (0.22%), and available Ca (2.30 cmol/kg) amongst the treatment interactions. These increased by 13%, 83% and 35% above that of the control treatment, respectively. Similarly, soil treated once with CE of 240 µg CN/kg soil had the highest Na, K, Mn, Cu and Fe which were 83%, 178%, 183%, 139%, and 180% above those of the control treatment, respectively. Four CE applications of 120 µg CN/kg soil resulted in the highest soil Mg (2.80 cmol/kg). It was 20% more than the control treatment. The highest available P resulted from soil treated thrice with CE of 240 µg CN/kg soil (16.38 mg kg⁻¹). It was 45% more than the control treatment. Two CE applications of 180 µg CN/kg soil resulted in soil with the highest Zn (1.25 mg kg⁻¹). It was 54% more than the control treatment.

Table 5: Effect of CE concentration on soil microorganisms

CE (µg CN/ kg)	Bacteria (NA-X10 ⁹ cfu/mg)	Fungi (PDA-X 10 ⁷ cfu/mg)
60	29.8c	6.0b
120	25.4c	30.9a
180	48.4b	27.2a
240	50.9b	27.9a
Control	125.7a	28.3a

Means in a column followed by the same letter are not significantly different according to DMRT ($P = 0.05$)

Effect of CE concentration and frequency of CE application on soil microorganisms

The bacteria identified in the control treatment are *Bacillus*, *Pseudomonas*, *Micrococcus*, *Citrobacter* and



Alcaligenes species while the fungi are *Aspergillus*, *Fusarium*, *Rhizopus* and *Trichoderma species*. Cassava effluent applied at all the concentrations to the soil resulted in significantly lesser number of bacteria compared to the untreated soil (Table 5). Soil treated with 120, 180 or 240 µg CN/kg soil had fungi counts that were not significantly different ($p < 0.05$) from each other and that were comparable to control treatment. However, CE application at 60 µg CN/kg soil had fungi count that was significantly lesser than other treatments.

All the frequencies of CE application significantly reduced ($p < 0.05$) soil bacterial count compared to the control treatment (Table 6). Soil treated two times had the least bacteria count (26.08×10^9 cfu/mg) while control experiment had the highest (125.67×10^9 cfu/mg). Frequency of CE application did not have significant effect on fungi population.

Table 6: Effect of frequency of CE application on soil microorganisms

Frequency	Bacteria (NA-X 10^9 cfu/mg)	Fungi (PDA-X 10^7 cfu/mg)
1	40.8c	21.9
2	26.1d	23.8
3	41.5bc	27.0
4	46.3b	19.3
Control	125.7a	28.3

Means in a column followed by the same letter are not significantly different according to DMRT ($P = 0.05$).

Interaction between CE concentration and frequency of application had significant influence ($p < 0.05$) on bacteria and fungi population (Table 7). Interaction between CE concentration and frequency of application significantly reduced ($p < 0.05$) soil bacterial count. Soil treated once with CE of 180 µg CN/kg soil had the least culturable bacteria (11.67×10^9 cfu/mg). The fungal count in soil treated twice with CE of 60 µg CN/kg soil and 180 µg CN/kg soil applied thrice increased significantly compared to the untreated soil. Contrarily, soil treated once with CE, irrespective of concentration, resulted in significantly reduced fungal population compared to the untreated soil. Also, 240 µg CN/kg soil applied thrice and 60 µg CN/kg soil applied four times resulted in reduced fungal count.

Discussion

Effect of CE chemigation on soil mineral elements

The change in the concentrations of SOC, Mg, Na, K, P, Mn, Cu, Fe and Zn in the soil upon the application of CE for weed control could be attributed to the presence of these

elements in CE and their resultant reaction in the soil. This corroborates earlier studies (Osakwe and Akpoveta, 2012; Orhue *et al.*, 2014) that reported the soil nutrient modifying ability of CE.

The total soil N, that was not significantly influenced by CE of 60, 120, 180 and 240 µg CN/kg soil, is an indication that these weed control concentrations are not good sources of N to the soil. The amount of N present in these CE concentrations was plausibly not consequential to influence the total soil N. This finding does not agree with the reports of Osakwe and Akpoveta (2012) and Nwakaudu *et al.* (2012) that CE added to the soil significantly altered the soil nitrogen concentration. Difference in the CE concentrations used in these studies may be responsible for this disparity.

Table 7: Interaction between CE concentration and frequency of application on soil microorganisms

CE (µg CN/kg)	Freq.	Bacteria (NA-X 10^9 cfu/mg)	Fungi (PDA-X 10^7 cfu/mg)
60	1	58.7d	4.7i
60	2	21.0h	55.0a
60	3	39.3ef	17.7e-i
60	4	44.0e	10.3f-i
120	1	28.7gh	7.3h-i
120	2	34.3fg	23.0c-g
120	3	21.0h	33.0cd
120	4	20.3h	31.7c-e
180	1	11.7i	3.3i
180	2	23.3h	24.0c-f
180	3	97.7c	48.0ab
180	4	33.3fg	32.7cd
240	1	20.3h	8.7g-i
240	2	23.0h	21.7d-h
240	3	35.7e-g	10.0f-i
240	4	106.0b	37.0bc
Control		125.7a	28.3c-e

Means in a column followed by the same letter are not significantly different according to DMRT ($P = 0.05$)

The decrease observed in SOC upon CE addition of 240 µg CN/kg soil could be a pointer to increase in decomposition activity of soil microbes, thus causing sorption of organic carbon into their cell, thereby reducing SOC. However, the reduced SOC from the addition of 240 µg CN/kg soil was still above the critical limit of SOC composition in tropical soils (Ravikumar and Somashekar,



2013). Hence, application of this CE concentration for weed control may not lead to serious SOC loss.

The reduction in available soil P upon CE addition of 60 and 120 µg CN/kg soil and its increase upon the addition of 180 and 240 µg CN/kg soil had a reverse trend with Ca with reference to the control treatment. This suggests that the concentrations of these mineral elements in the soil are inversely related upon the addition of CE concentration range used in this study. Increase in the concentration of Ca can cause free Ca to form complexes with P, thereby reducing its concentration (Stewart and Tiessen, 1987). It is opined that the Ca concentration in the soil that increased upon the application of 60 and 120 µg CN/kg soil may be due to the richness of this mineral element in the effluent while its reduction may be due to the displacement reaction by the increasing Na concentration.

The significant increase in soil Na, K and Mg with the addition of CE concentrations disagrees with the findings of Eze and Onyilide (2015) that reported that these mineral elements decreased when CE was applied to soil. The observed increase in the concentration of trace elements such as Mn, Cu, Fe, and Zn upon the addition of CE concentrations to the soil for weed control had also been reported in previous studies (Nwakaudu *et al.*, 2012; Osakwe and Akpoveta, 2012; Igbinosa and Igiehon, 2015). Hence, the adoption of CE concentrations used in this study for weed control is only safe where the permissible limits of these trace elements in the soil will not be exceeded.

The increase in the soil pH resulting from the addition of CE was an indication that the CE concentrations used in this study reduced the acidity level of the soil. Similarly, Chinyere *et al.* (2018) reported that dumpsite of CE had increased soil pH over control soil samples. However, this finding does not agree with some previous studies that reported that addition of CE to the soil decreased its pH (Osakwe and Akpoveta, 2012; Ehiagbonare *et al.*, 2009). The increase in soil pH that resulted from the addition of CE to soil in this study could be due to the associated increase in soil Na and K. The presence of base forming ions increases the pH of the soil (Mitra and Shanker, 1957; Lakshmi *et al.*, 2019).

Effect of frequency of CE chemigation on soil mineral elements

Findings from this study indicate that the frequency of CE application influenced soil nutrients. This could be of an advantage when the nutrients are improved. However, the significant reduction of some nutrient elements could be a concern if it can hinder the growth of crops when applied for weed control. For instance, reduction in SOC when CE was applied once or twice could be adduced to immobilization

caused by increased activities of microorganism (Xu *et al.*, 2018). CE applied thrice provided the organic carbon requirement of the associated microorganism. Hence, the resulted SOC was not significantly influenced compared to the control treatment. However, four applications of CE provided excess organic carbon that was more than what the associated microorganism required, hence this resulted in increase in the SOC. The implication of this is that CE applied once or twice for weed control may temporarily reduce SOC of the treated soil.

The total N content of the soil was not significantly influenced by CE applied once, twice or thrice indicating that these CE application frequencies for weed control does not have the additional advantage of improving the N content of the soil whereas CE applied four times does. The increase observed in soil total N with frequency of CE application in this study agrees with the report of Osakwe and Akpoveta (2012) who found CE capable of increasing soil N.

Increase in soil Na, K, Mn, Cu and Fe due to the frequency of CE application suggests that CE applied one to four times for weed control could enhance these elements in the soil. Hence, the use of these CE application frequencies for weed control should take the inherent concentration of these trace nutrients into consideration to avoid toxicity to crops.

The reduction in Ca concentration that resulted from CE applied thrice coincided with the peak concentration of Na. Therefore, it is opined that the increase in the Na concentration was responsible for the significant decrease in Ca concentration. The soil pH that increased significantly when CE was applied one to four times could be due to the increase in the Na and K content of the soil (Lakshmi *et al.*, 2019).

Interaction between CE concentration and frequency of chemigation on soil mineral elements

Cassava effluent of 240 µg CN/kg soil applied once may be ideal for weed control based on soil consideration since none of the mineral elements of this treatment was significantly reduced compared to the control treatment. However, the decrease in soil mineral elements by the interaction between CE concentration and frequency of application should not necessarily debar its adoption for weed control if the decrease is temporary and is not capable of nutrient deficiency in crop or growth retardation.

Effect of CE concentration and frequency of chemigation on soil microorganisms

Reduction in soil bacterial count due to concentration and frequency of application of CE found has also been reported by Igbinosa and Igiehon, (2015). This has



implication on soil nutrient immobilization and availability as it had been established that *Bacillus*, *Pseudomonas*, and *Alcaligenes* species contribute to soil nutrient availability (Ipek *et al.*, 2014; Meena *et al.*, 2016; Saha *et al.*, 2016).

The CE of 60 µg CN/kg soil, that had significantly lesser fungal count compared to other treatments, may be due to the significantly lesser P found in the treatment. This agrees with the report of del Mar Alguacil *et al.* (2010) that addition of low doses of P could increase the colonization of some fungi. However, fungal count that was not significantly different in the control treatment and the potted soil treated with CE one to four times may be due to the inability of CE to alter the soil pH range from neutral to acidic that is favorable for fungi (Abubakar *et al.*, 2013).

The interactions between CE concentration and frequency of application that altered fungal count both positively and negatively did not exhibit any distinct trend when compared with the soil chemical properties. Hence, it is opined that the differential response of fungi genera to the resulting soil chemical properties may be responsible for this (Sieverding and Howeler, 1985). The interaction effect between CE concentration and frequency of application that resulted in reduced fungal population may inhibit phosphate-solubilizing role of *Aspergillus* and *Rhizopus species* (Sharma *et al.*, 2013) and the biocontrol activities of *Trichoderma species* (Commatteo *et al.*, 2019).

Conclusion

The application of CE to the soil for weed control has a significant modifying effect on the soil nutrient levels and the population of microorganisms therein. Hence, its adoption for weed control requires the understanding of its influence on soil chemical and biological properties.

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