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Remediation of Cassava Effluent Contaminated Soil Using Organic Soap Solution: Case Study of Soil Physical Properties and Plant Growth Performance

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Authors' contributions

This work was carried out in collaboration between all authors. Author OIA designed the study, wrote the protocol and wrote the first draft of the manuscript. Author HU performed the statistical analysis and managed the analyses of the study. Author DE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The remediation of cassava effluent contaminated soil, using organic soap solution was evaluated, in this research. Soil parameters and bean growth performance investigated were moisture content, pH, temperature, germination rate, leaf colour, number of leaves and seedling height. The research was carried out in natural environmental condition, with the research divided into two units, namely; Control Unit (CU) and Amendment Unit (AU). Under the AU, the cassava effluent contaminated soil was treated with organic soap solution; while under the CU, the contaminated soil was left untreated. From the results obtained, the organic soil solution was observed to improve the soil physical properties and bean growth performance. The results showed that there was appreciable level of degradation of the cassava effluent in the soil, arising from organic soap solution. The soil pH, temperature and moisture content in the CU were significantly better than in

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the AU. In terms of bean growth performance, the bean seeds planted in the AU performed better than those planted in the CU. *Iron* bean was found to be lesser tolerant to the effluent to the butter bean.

Keywords: Remediation; soil properties; bean seedlings; growth performance; cassava effluent.

1. INTRODUCTION

Cassava (*Manihot esculenta* crantz) is a staple food crop and one of the most important crops in Africa. It derives its importance from the fact that its starchy, thickened, tuberous roots are a valuable source of cheap calories, especially in developing countries where calorie deficiency and malnutrition are widespread. In many parts of Africa, the leaves and tender shoots of cassava are also consumed as vegetables [1]. Many traditional cassava-based food preparations of Asia and Latin America may be used alongside traditional African preparations. In addition, in many African countries home economists and nutritionists have developed a number of non-traditional foods by incorporating locally grown cassava into the recipe in place of exotic ingredients. Annual cassava production in Africa is about 160 million tonnes in 2016, with Nigeria accounting for about 58 million tonnes of the production [2].

Cassava tuber effluent contains cyanogenic glucosides (toxic substances), mainly linamarin (92-98%), which releases hydrogen cyanide after hydrolysis by an endogenous linamarase. The effluent from cassava tuber had the ability to inhibit vegetation growth and soil physical properties, thus reduces the entire soil fertility [3,4]. Almost all the wastes from cassava processing mills are discharged directly on the soils and in some places, pits are dug and the liquid are drained directly into them [5,6]. The mobility of cyanide compounds in soil depends on stability and dissociation characteristics of the compound, soil type, soil permeability, soil chemistry, and the presence of aerobic and anaerobic microorganisms [7]. Cyanide present at low concentrations in the soil can be decomposed to ammonia, carbon (iv) oxide, and nitrogen or nitrate under aerobic conditions, and to the ammonium ion, nitrogen, thiocyanate, and carbon dioxide under anaerobic conditions [8]. The mobility of copper, cobalt, zinc, and nickel-cyanide complexes in the soil are comparably higher than iron and manganese cyanide complexes [7].

Bean (*Phaseolus* spp) belong to one of several genera of the flowering plant family *Fabaceae*, which are used for human or animal food. Beans supply a significant amount of protein for a great part of the world population, especially in poor countries where the consumption of animal protein is relatively low [9]. Bean seeds and leaves are nutritious; having high protein, fibre, vitamins, and minerals contents, making them stable food in the world [10,11]. Among the plants families, legumes are the most utilised as alternative sources of protein; its human consumption of legumes has been increasing recently since the seeds are regarded as a source of beneficial nutrients and nutritional values. Legumes reduce the incidences of cardiovascular diseases and cancers; good sources of protein and minerals. Frequent intake of legumes may lower blood cholesterol concentration significantly [12,13].

Previous researches results on the effect of cassava effluent on soil properties and plant growth, shown significant changes. Olorunfemi [14] reported that cassava effluent inhibited cereal seed germination and seedling growth at lower concentration, while higher concentration resulted in withering. In the work of [15], soil sample pH decreased from 6.96 to 3.89, after treatment with cassava effluent, indicating that the effluent imparted acidic properties to the soil. Furthermore, Ehiagbonare [16] investigated the effect of cassava effluent on the environment and found out that the effluent had a negative effect on plants, domestic animals, soil and water. There is, therefore, a need to develop efficient processes for degradation of cassava effluent such that it can be safely discharged to the environment, but most methods currently in use are expensive and have several disadvantages. For instance, alkaline chlorination process is not effective in the case of cyanide species complexed with metals such as nickel, silver, etc. due to slow reaction rates [17]; while some increased the soil's alkalinity. Soil biodegradation occurred into two steps; first step is the oxidative breakdown of cyanides, and subsequent sorption and precipitation of free metals into the biofilm. Cyanide and thiocyanate are then converted to ammonia, carbonate and sulfate [18]. Even some works had been done on the bioaugmentation of cassava effluent contaminated soils; however, there's not much literature on the remediation effect of organic soap solution on cassava effluent contaminated soils, in regards to soil physical properties and plant growth performances. Therefore the aim of this study is to investigate soil treatment by using locally formatted soap (organic soap) solution, with the following objectives:

i. To establish a remediation impact of organic soap solution on the growth performance of two bean cultivars, namely *butter* bean and *iron* bean, planted on cassava effluent contaminated soil.
ii. To evaluate the remediation impact of organic soap solution on the physical properties of cassava effluent contaminated soil samples.

2. MATERIALS AND METHODS

2.1 Study Setting

The study was carried out in research farm of Agricultural and Bio-Environmental Engineering Technology Department, Delta State Polytechnic, Ozoro, Nigeria. Ozoro has the coordinates of 5°32′18″N and 6°12′58″E, with elevation of 68 meters, mean annual rainfall of 2400 – 2600 mm pa, experiences significant seasonal variation, with a temperature of 28 ± 5°C, according to data from the Delta State polytechnic metrological station. Delta state benefits from a tropical-type climate, somewhat influenced by the Atlantic regime [19].

2.2 Organic Soap Preparation

Oil palm bunch waste was collected from the oil mill of Delta State polytechnic, Ozoro, Nigeria. The waste was sundried before they were burnt into ashes; and the ashes were dissolved in distill water to obtain a heterogeneous solution. The filtrate obtained was evaporated and used to prepare the organic soap [20].

2.2.1 Analytical analysis of the organic soap solution

The pH and electrical conductivity of the prepared organic soap solution were determined with a digital conductivity meter (EMCEE Model 1152, India).

2.3 Bean Growth Experimentation

Ten identical seed beds were prepared for the research work. The beds were ponded daily with cassava effluent for fourteen days, after which they were divided into two lots; Amendment Unit (AU), and Control Unit (CU). In each of the seed bed, one hundred bean seeds from two bean (*Phaseolus vulgaris* L) cultivars namely; *iron* and *butter* beans were planted (50 seeds from each cultivar). The Amendment Unit was treated with one knapsack sprayer (16 L) of organic soap solution per bed at two days interval. Equal volume (16 L) of tap water was added to the Control Unit to keep the soil cup moist, to avoid withering of the bean seedlings. The growth performance rates of the seedlings were carefully monitored daily for 15 days after sowing.

2.3.1 Data collection

The bean seedlings were examined daily to determine the germination rate, number of leaves per plant, and seedling height. The bean seedlings height was measured with the aid a rope and a digital Vernier caliper. In addition, the seedlings were examined daily for diseases infection, in order to remove affected seedlings to avoid contamination of other seedlings.

2.4 Soil Samples Preparation

Hundred plastic cups were filled with 5 Kg sieved top soil, and kept in a shade. The soil was collected from six inches deep top soil, from the same horizon in the experimental site. All the cups were ponded with 1 L of fresh cassava effluent daily for two weeks to obtain a stabilisation point. After stabilisation, the cups were divided into two experimental lots, namely; Control Unit (CU) and Amendment Unit (AU). The Amendment Unit was treated with 0.5 L of organic soap solution for another seven days, and the Control Unit was left untreated.

2.4.1 Data collection

At an interval of three days after the treatment, both samples (CU and AU) were taken to the laboratory in dark plastic bags for the following physical parameters; soil moisture content and soil pH analysis. The soil temperature was directly measured in the field.

2.5 Analytical Procedures

2.5.1 Moisture content

The soil moisture content was determined gravimetrically following the procedures of Nwakaudu et al. [21], and calculated with equation 1.

$$\text{Moisture content} = \frac{\text{Weight of wet sample} - \text{weight of dry sample}}{\text{Weight of wet sample}} X100 \quad (1)$$

2.5.2 Soil pH

2 g of the dried soil sample was put inside a 50 ml beaker, 20 ml of distilled water was added and the mixture stirred for 30 minutes with a glass rod. The pH meter was standardised and calibrated with buffer solution of pH 4.10 and 9.20. The electrodes of the pH meter were immersed into the partly settled suspension and the readings taken. The electrodes were rinse with deionised water and wiped dry with clean filter paper after each sample reading [21].

2.5.3 Soil temperature

The soil temperature was measured with a digital soil thermometer. The thermometer probe was inserted 5 inches below the soil surface, and held for about five minutes with a stable reading appeared on the thermometer screen (Fig. 1). Readings were taken from ten cups from each experimental lot and the average value recorded.

Fig. 1. Soil temperature reading

2.6 Statistical Analysis

The data obtained from this research were statistically analysed using the Statistical Package for Social Statistics (SPSS version 20.0), and the means were separated using The Duncan's New Multiple Range (DNMR) Test ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

Physico-chemical properties of the soil sample before ponding with cassava effluent are presented in Table 1. The organic soap pH and electrical conductively were 9.8 and 1330 µS/cm/g respectively. From the results in Table 1, it can be seen that the cassava obviously caused some changes in soil samples collected. Similar alterations of soil physical properties, by cassava effluent were observed by Osakwe [15], Nwakaudu et al. [21], who recorded increased in soil moisture content and decreased soil pH, after contamination with cassava effluent.

Table 1. Physical properties of the soil sample before and after ponding with cassava effluent

Parameter	Value	
	Before ponding	**After ponding**
Soil pH	7.31	4.13
Soil moisture content (% wb)	23.48	30.65
Soil temperature (^{0}C)	29.12	40.62

The Analysis of Variance (ANOVA) of the treatment period and organic soap treatment are presented in Table 2. From Table 2, treatment period and soil treatment had significant ($P \leq 0.05$) effect on all the parameters investigated. In addition, from the ANOVA Table, it can be seen that the interaction of treatment period and treatment had significantly ($P \leq 0.05$) influenced all the parameters investigated.

3.1 Impact of the Organic Soap Solution on the Contaminated Soil Moisture Content

In referenced to the experimental results, the organic soap solution significantly influenced the moisture condition of the contaminated soil samples. As shown in Fig. 2, the untreated soil samples had higher moisture content throughout the experimental period, than the treated soil samples. The higher moisture content in the controlled soil samples could be attributed to the decreased in the soil porosity of the soil samples caused by the starch content of the cassava effluent, thereby increasing the water holding capacity of the soil [21].

Table 2. ANOVA of effect of treatment and treatment period on the physical properties of soil samples

Source of variation	df	Soil pH	Soil temperature	Soil moisture
P	3	4.12E-13*	1.60E-14*	6.82E-30*
T	1	1.18E-28*	2.89E-33*	2.38E-25*
P x T	3	3.49E-13*	1.56E-13*	1.22E-19*

*P = Treatment period; T = treatment; * =Significant at (P ≤0.05); ns= non-significant*

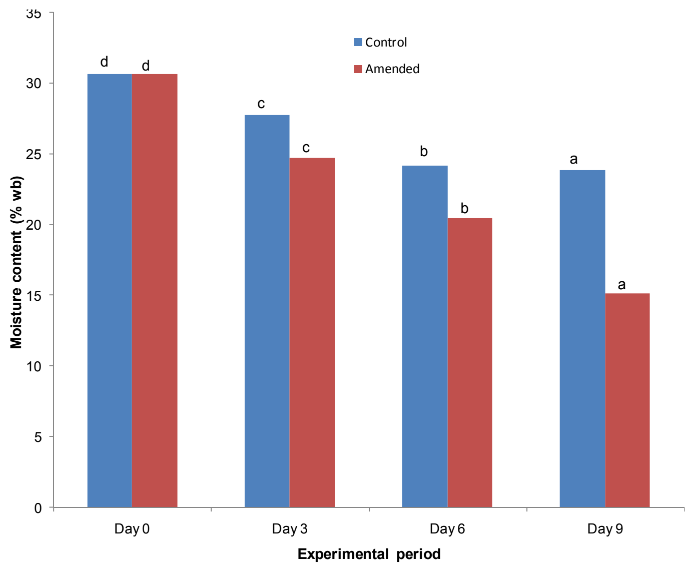

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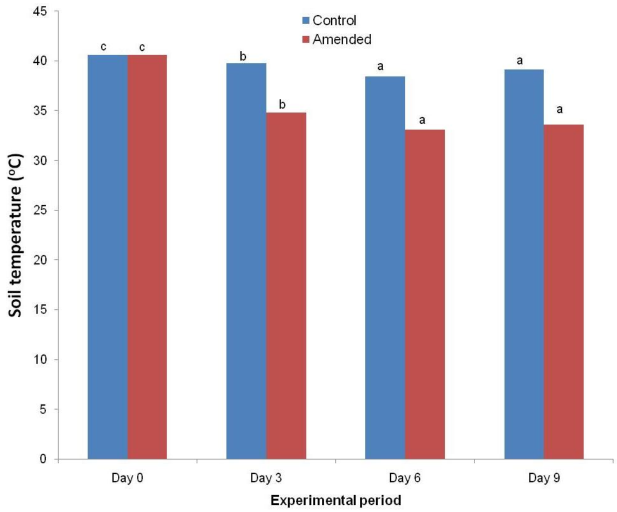
Fig. 2. Effect of organic soap solution on the contaminated soil moisture content

3.2 Impact of the Organic Soap Solution on the Contaminated Soil Temperature

Results obtained from the research shown that organic soap solution had significant effect on the soil temperature within the treatment period (Fig. 3). The higher soil temperature of the controlled soil samples could be attributed to the increased microbial activities associated with decaying of cassava effluent [22]. Soil temperature is a factor that drives germination of seeds, and directly affected the plant growth. Most soil organisms function best at an optimum soil temperature. Soil temperature impacts the rate of nitrification, influences soil moisture content, aeration and availability of plant nutrients [23]. Low and high soil temperatures have been shown to influence water viscosity and metabolic activities in plant roots through changes in membrane lipids or enzyme activities associated with nutrient uptake e.g. H^+ -ATPase [24].

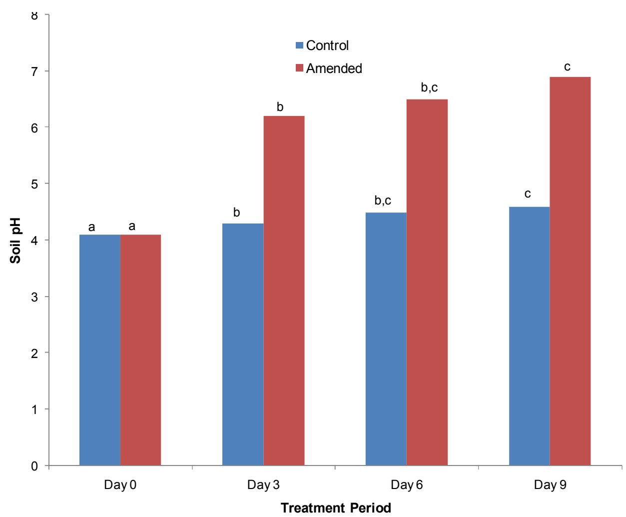
3.3 Impacts of Organic Soap Solution on the Contaminated Soil pH

The results showed that organic soap solution significantly lowered the soil acidity. At the end of the experimental period, the pH of the control samples were lower (more acidic) than those of the amendment samples (Fig. 4). Lower pH of cassava effluent contaminated soil samples could be attributed to the presence of hydrogen cyanide in the cassava effluent [21]. Soil pH influenced the occurrence of major macro nutrients concentration in the soils, since their availability is relatively dependent on the soil pH [15]. Other negative effects of low soil pH include increased risk of heavy metals absorption into the soil system, and the release of unsuspected anthropogenic related specimens adhering conveniently to soil sediments [25]. These results obtained in the Amendment Unit are better in crop production than in the Control Unit, as low soil pH and high moisture content and temperature have adverse effect on crop production.



Bars with the same common letters means that they are not significant different at (P ≤0.05)

Fig. 3. Effect of organic soap solution on the contaminated soil temperature



Bars with the same common letters means that they are not significant different at (P ≤0.05)

Fig. 4. Effect of organic soap solution on the contaminated soil pH

3.4 Impact of Organic Soap Solution bean Seedlings Leaves Colour

The influence of the organic soap solution on the growth performance of the two bean cultivars are presented in Table 3. As shown in Table 3, the organic soap amendment had a significant effect on bean seedlings leaves colour. It was observed from the results that *Butter* bean seedlings were more tolerant to the effluent than the *Iron* bean seedlings; and the two bean cultivars responded positively to the soil amendment. Previous researches shown that cassava effluent increased the zinc content of soil samples; therefore, the as stunted growth and chlorosis observed in the untreated bean seedlings could be attributed to Zn toxicity [20,26]. Nwakaudu et al. [21] reported stunted growth in maize planted in cassava effluent contaminated soil; while Okonokhua et al. [27] observed a reduction in the ear length of the maize plants planted in contaminated soils, likewise significant decrease ($P < 0.05$) in the grain yield of the crop plants between those grown in the control and contaminated soil. Similarly, a study by Olorunfemi et al. [14] showed that the germination and growth rates of *Zea mays*, *Sorghum bicolor* and *Pennisetum americanum,* decreased significantly with increase in cassava effluent concentrations (25, 50, 75 and 100%).

Table 3. The beans seedlings leaves colour over a period of 15 days

Time (Days)	Control		Amended	
	Iron	***Butter***	***Iron***	***Butter***
1	-	-	-	-
2	-	-	-	-
3	-	-	Green	Green
4	-	Green	Green	Green
5	Green	Green	Green	Green
6	Green	Green	Green	Green
7	Green	Green	Green	Green
8	Pale green	Green	Green	Green
9	Pale green	Green	Green	Green
10	Pale green	Pale green	Green	Green
11	Pale green	Pale green	Green	Green
12	Pale green	Pale green	Green	Green
13	Yellow	Pale green	Green	Green
14	Yellow	Pale green	Green	Green
15	Yellow	Yellow	Green	Green

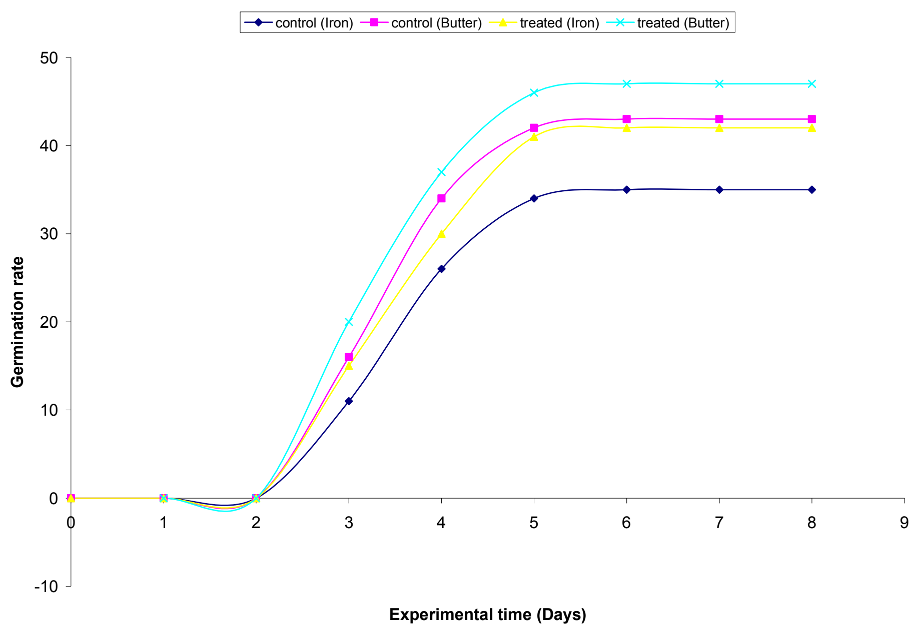


Fig. 5. Effect of organic soap solution on bean seeds germination rate in a contaminated soil

3.5 Impact of Organic Soap Solution Bean Seedlings Germination Rate and Height

The experimental results indicated that bean seeds planted in the remediated soil (Amendment Unit) grew well throughout the experimental period attaining heights that were significantly higher than seedlings growing in the control unit. Germination rate of the bean seeds followed the same pattern in spite of the slight differences the two cultivars used in the present study. Sam [28] reported that cassava effluent caused a significant reduction in germination percentage and growth performance of maize (*Zea mays*), which was attributed to the heavy metals poisoning. Germination inhibition of the bean seeds could be attributed to the acidity of the soil caused by the cassava effluent.

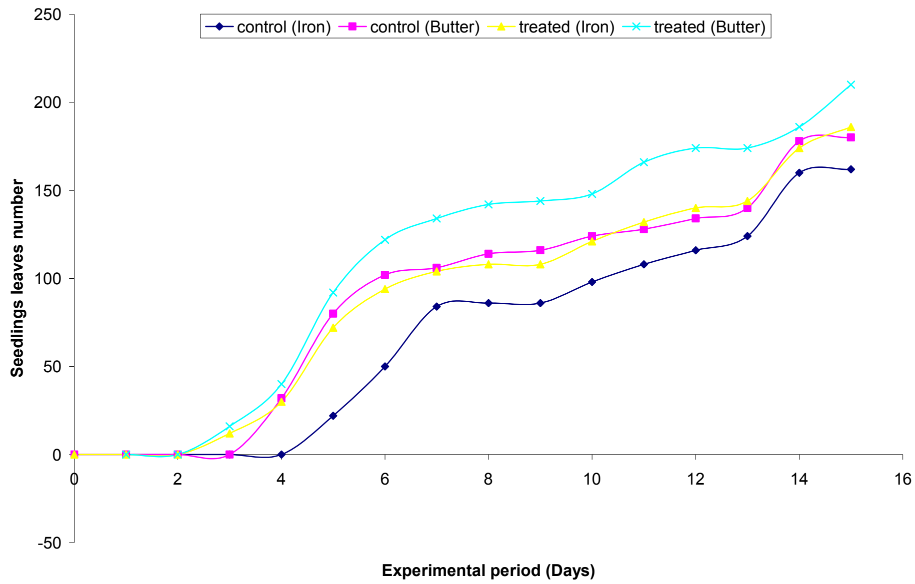


Fig. 6. Effect of organic soap solution on bean seedlings growth in a contaminated soil

Table 4. Regression equations of the effect of the organic soap treatment on the growth performance of the two bean cultivars

Parameter	Bean cultivar	Treatment	Linear equation	R^2	r	Sig of regression
Germination rate	*Iron*	Control	y = 5.45 x - 7.133	0.892	0.9449	1.22E-04*
		Treated	y = 6.733 x - 3.377	0.876	0.9361	2.97E-04*
	Butter	Control	y = 6.883 x - 2.977	0.862	0.9286	2.04E04*
		Treated	y = 7.785 x - 4.535	0.829	0.9285	2.99E-04*
Number of leaves	*Iron*	Control	y = 11.82 x - 20.53	0.895	0.9736	2.23E-10*
		Treated	y = 14.05 x - 12.24	0.928	0.9601	3.83E-09*
	Butter	Control	y = 14.51 x - 12.97	0.894	0.9769	8.77E-11*
		Treated	y = 18.65 x - 20.65	0.914	0.9541	3.10E-09*
Seedling height	*Iron*	Control	y = 1.176 x - 1.698	0.949	0.9742	1.86E-10*
		Treated	y = 1.263 x - 0.661	0.975	0.9846	7.49E-11*
	Butter	Control	y = 1.288 x - 1.161	0.969	0.9874	1.06E-11*
		Treated	y = 1.442 x - 0.942	0.982	0.9909	6.37E-14*

Where y = the parameter, x = experimental period, R^2 = coefficient of determination, r = correlation,
** = significant at 95% confidence level*

Graphical representations of the effect of bioremediation on the bean germination rate, seedlings height and number of leaves are shown in Figs. 5, 6 and 7. The similarity of the three graphs indicated that organic soap solution had remarkably similar effect on all the soil samples which significantly improved the beans growth performance. From the results, the *Butter* bean seedlings were more tolerant to the contaminated soil treated for the first 15 days before planting (DAP); while germination of the *Iron* bean seeds were inhibited until the sixth (Fig. 5). The regression equations of the effect of the organic soap treatment on the growth performance of the two bean cultivars are presented in Table 4. Reference [14] reported that the height of the cereals and the coloration of the leaves were adversely affected by cassava effluent contaminated soil in their study.

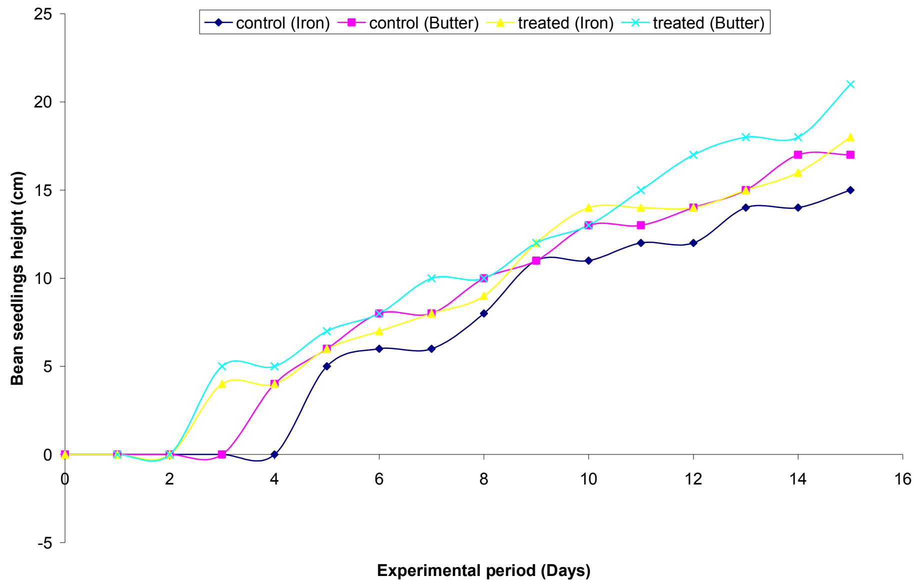


Fig. 7. Effect of organic soap solution on bean seedlings height in a contaminated soil

4. CONCLUSION

The present study has shown that for soil physical properties, the cassava effluent decreased the soil pH, but increased the soil moisture and temperature. Also, the results indicated that the cassava effluent adversely affected the bean seedlings growth performance. The results obtained showed that organic soap solution was able to mitigate alterations caused by the cassava effluent, as the soil pH increased from 4.13 to 6.9; the moisture content decreased from 30.65 to 15.15; while the soil temperature decreased from 40.62 to 33.57°C. These results obtained in the Amendment Unit are better in crop production than in the Control Unit, as low soil pH and high moisture content and temperature have adverse effect on crop production. As for the crop production, the results obtained from the research showed that the bean seedling performed better in the Amendment Unit than in the Control Unit. These results showed the importance of cassava effluent treatment before disposal, and the possibility of using organic soap solution as a detoxification agent. This study had unveiled the potentials of organic soap solution in degrading cassava effluent contaminated soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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