Utilization Potential of Kitchen Waste Sludge as Organic Fertilizer

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ABSTRACT

Aim: To investigate the possible conversion of kitchen waste sludge into organic fertilizer using a bio-treatment agent

Place and Duration of Study: The study was carried out at Afe Babalola University in the green house and the Kitchen waste sludge was obtained from the open drain behind Cafeteria 2 on Campus

Methodology: Microbial analyses of kitchen waste sludge were carried out using the pour plate method to isolate and identify bacteria and fungi. Treatment of kitchen waste sludge with OBD-plus a biotreatment/bioremediation agent was done and plant growth trials with maize carried out in the green house with both treated and untreated kitchen waste as biofertilizer. Physicochemical analyses were carried out on both the treated and untreated kitchen waste sludge.

Results: Six microorganisms were isolated. These included three bacteria; Bacillus sphaericus, Bacillus cereus and Bacillus anthracis while the fungi were Aspergillus niger, Aspergillus flavus and Penicillum citrinum. All these isolates grew on engine oil and vegetable oil agar as carbon source. Using the one-way Analysis of Variance at a level of 0.05(95%), the P value was ≤ 0.05 which showed that there is a statistical significant difference between the treated and untreated samples. The pH for the untreated kitchen waste (UKW) was 5.92 while for the treated kitchen waste (TKW), it was 5.60. The moisture content (%) for UKW was 44.60 and 23.22 for TKW. % dry matter for UKW=55.40 and TKW=76.78, % total nitrogen for UKW and TKW=18.48 and 23.04 respectively, total phosphorus for UKW=0.079% while TKW=0.222%. Potassium as K₂O for UKW=3.6% and TKW=6.3%, oil content for UKW=59.26%, TKW=21.54%, Zinc concentration in UKW=6.6ppm and TKW=0.85ppm, Lead concentration in the UKW=0.57ppm and TKW=0.33ppm. Subsequent plant growth trials on the untreated and treated kitchen waste were conducted in the Greenhouse using maize. Plant growth trials of maize using treated and untreated kitchen waste as bio-fertilizer and mixed with sand were carried out in the green house. Good growths of maize were observed in the soil with treated kitchen waste while the growths on the untreated waste dried up and died after some days.

Conclusion: The kitchen waste sludge treated with OBD-plus supported the growth of maize when compared to the untreated. There was also a reduction in the level toxic/heavy metals present while there was an increase in the level of some elements such as magnesium. This study shows that with biotreatment, kitchen waste can serve as biofertilizers. The limitation of this study is that the kitchen waste was not collected at random and is a representation of a specific case.

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Keywords: kitchen waste, biotreatment, biofertilizer, analyses

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1. INTRODUCTION

Kitchen waste is defined as left-over organic matter from restaurants, hotels and households [1]. Organic matter can be transformed into useful fertilizer and biofuel [2] and is a nutrient rich eutrophic environment containing high levels of carbohydrates, lipids, proteins, and other organic molecules which can support abundant populations of microorganisms [3].

Kitchen wastes are made up of several nutrient sources which could be explored for its utilization potential in the formulation of bio-fertilizers which can be used for the enhancement of plant growth and provision of essential nutrients for plant metabolism. Kitchen waste is usually acidic due to the action of acid fermentation bacteria such as lactic acid bacteria [1]. Since these wastes are largely composed of organic compounds and smaller proportions of some inorganic compounds, the kitchen wastes can be subjected to biological treatment for the liberation of the constituent elements which will be essential for the growth of plants. Oil is one of these biological compounds that could limit the water retention capacity of the soil when present due to its hydrophobic nature but with the potentials of microorganisms in utilizing the oil component as a source of carbon the oil components can be digested and the soil quality enhanced. This research investigates the possible liberation of the essential elements from the wastes through microbial digestion and with the aid of the Oso Biodegrader plus (OBD-plus) which is a patented consortium of microorganisms capable of this process.

Food waste has high energy content and it seems ideal to achieve dual benefits of energy production and waste stabilization [4]. Organic residue of plant or animal origins when applied has direct and indirect effects on the physical, chemical and biological properties of the soil. These materials affect the soil physical properties [5], soil faunal populations and the availability of soil nutrients [6]. The primary factor in treating food waste is the physico-chemical characteristics of substrate, including particle size and composition. According to [4], degradation of each component of food waste is affected by environmental conditions. Carbohydrate, cellulose, and protein have their own optimum pH and retention times for degradation [7]. This means that the degradation of food waste could be enhanced by adjusting the environmental conditions depending on the degradation.

The use of biological treatment methods, such as composting and fermentation, to turn organic waste into a valuable resource is expanding rapidly in many developed countries, as landfill space becomes scarce and expensive, and as people become more aware of the impacts they have on the environment. Utilizing organic waste by these methods is a big part of the plan to minimize waste overall and to divert these wastes from landfill and from incineration as well [8].

The aim of this study was to convert kitchen waste sludge into organic fertilizer using a biotreatment agent (OBD-plus) and the objectives were to isolate and identify microorganism from the kitchen waste sludge, carry out the physicochemical analyses of the treated and untreated kitchen waste sludge and conduct growth trails on maize using both treated and untreated waste sludge.

2. MATERIALS AND METHODS

2.1 Sample Collection and preparation

Kitchen waste sludge samples were collected on March 29, 2016 from an open drain also containing sewage at Afe Babalola University Ado-Ekiti Cafeteria 2 in clean polyethylene bag. The kitchen waste sludge was sun dried in plastic bowls in the green house.
2.2 Isolation of bacteria and fungi from the sludge

Ten grams of the wet kitchen waste sludge sample were weighed into sterile 90ml conical flask containing sterile water. This was shaken intermittently for 30 minutes after which 1ml was taken from the stock supernatant using a sterile pipette into a test tube containing 9mls of sterile water to make $10^{-1}$ diluent. This was also mixed thoroughly and the process was repeated until $10^{-4}$ diluents factor was reached [9]. One millilitre each was taken from the $10^{-2}$ and $10^{-3}$ diluents and transferred into sterile Petri dishes and molten sterile agar was poured on it and the agar plate swirled to allow even distribution of microorganisms using the pour plate method [10]. The plates were incubated at room temperature for 24 hours after which they were observed for bacterial growth.

2.3 Identification of isolates.

Macroscopic and microscopic examinations using cotton blue in lactophenol staining were carried out on the fungal isolates for identification according to the method of [11] by observing the morphology of the isolates under x100 magnification of a compound microscope and the cultural characteristics of the isolates. For bacteria, pure cultures were obtained and biochemical tests were carried out according to the methods of [12] and identified following the Bergey’s Manual of Determinative Bacteriology according to [13].

2.4 Oil utilization by bacteria and fungi

Nutrient and potato dextrose agar media were used for isolation of bacteria and fungi respectively. Oil agar medium was prepared using engine oil and vegetable oil separately. The oil agar medium consisted of basal (mineral salt) medium; 1.8g $K_2$HPO$_4$, 1.2g KH$_2$PO$_4$, 4.0g NH$_4$Cl, 2.0g MgSO$_4$.7H$_2$O, 0.2g yeast extract, 0.05g FeCl$_2$, trace elements which are 0.1g H$_3$BO$_3$, 0.1g ZnSO$_4$, 0.4g MnSO$_4$.H$_2$O and 4g agar-agar. Sub culturing of bacteria was done by streaking the bacteria colonies on sterile nutrient agar containing nystatin to prevent fungal growth. Fungi were cultured on potato dextrose agar medium containing streptomycin to prevent bacteria [14].

2.5 Bio-treatment of kitchen waste sludge

The kitchen waste sludge was collected and poured in two different bowls. The sample in one of the bowls was treated with OBD-plus which is a bio-treatment agent in proportion of 3:1 by volume of the dry kitchen waste and OBD-plus. The sample in the other bowl was untreated. The samples were sun dried in the greenhouse for 2 weeks. OBD-plus (Oso Bio degrader-plus) is a consortium of microorganisms invented and patented in Nigeria by Prof. B.A. Oso for pollution control and environmental management.

2.6 Physico-chemical analysis of the sludge

Physicochemical analyses of the treated kitchen waste (TKW) and untreated kitchen waste (UKW) were carried out on the first day. The method according to [15] was used to determine the nitrogen, phosphorus calcium, sodium, potassium contents, heavy metals, organic matter analysis and percentage oil content.

2.7 Test for odor of kitchen waste sludge

This test was carried out by smelling or perceiving the untreated and treated (with addition of OBD-plus) kitchen waste.

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2.8 Plant growth trials

Plant growth trials were conducted to study the effects of both the treated and untreated kitchen waste sludge on the germination and growth of maize [16].

2.8.1 Preparation of soil for growth trials

The method according to [16] was employed. The kitchen waste was collected in clean polythene bags and brought to the greenhouse where they were poured into a large plastic bowl and weighed into a smaller bowl, and 1 kg of OBD-plus added to it for treatment. The kitchen waste and OBD-plus were thoroughly mixed in the bowl. Two kg of kitchen waste were also weighed into a second bowl without addition of OBD-plus. The kitchen waste samples were left on the platform in the greenhouse and turned daily for two weeks.

2.8.2 Germination and growth trials with maize seeds

After 2 weeks, dry forms of the kitchen waste sludge samples (treated and untreated) were obtained. Seed germination and plant growth trials were conducted to evaluate the application of kitchen waste sludge as an organic fertilizer in combination with sand. The dried kitchen waste sludge samples were mixed with sand in the proportion of 1 kg of the sludge to 3 kg sand respectively. These were transferred into 4 seed bags and 4 maize seeds were planted in each with 3 replicates per treatment, and watered with tap water every day in the greenhouse. Growths were then observed [16].

Statistical analysis: Data analyses obtained were subjected to one-way analysis of variance (ANOVA). Significant difference was accepted at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

Morphological and biochemical characteristics of bacterial isolates

Three bacterial and fungal isolates each were obtained from the kitchen waste sludge. They included *Bacillus sphaericus*, *B. cereus* and *B. anthracis*. All were Gram positive rods with endospore. *B. sphaericus* had swollen cell and did not hydrolyse starch while *B. cereus* and *B. anthracis* hydrolysed starch and their cells were not swollen (Table 1). Morphological characteristics of fungal isolates

The fungal isolates were identified via macroscopic and microscopic examination and were identified as *Aspergillus niger*, *Aspergillus flavus* and *Penicillium citrinum* (Table 2).

<table>
<thead>
<tr>
<th>Table 1: Morphological and biochemical tests of bacterial isolates</th>
</tr>
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<tbody>
<tr>
<td>Gram stain</td>
</tr>
<tr>
<td>------------</td>
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<tr>
<td>+ve</td>
</tr>
</tbody>
</table>

E-mail address: xyz@abc.com.
Table 2: Morphological characteristics of fungal isolates

<table>
<thead>
<tr>
<th>Description of isolates</th>
<th>Probable organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>fluffy appearance, black spores and light cream from the reverse. The conidiophores were distinct, terminated by a swollen vesicle. The hyphae were septate White hyphae developing with yellowish green conidia formation arranged radially with septate hyphae. Colony in grey shades, chains of single celled conidia produced in basipetal succession from a branched metulae with septate hypae</td>
<td><em>Aspergillus niger</em></td>
</tr>
<tr>
<td></td>
<td><em>Aspergillus flavus</em></td>
</tr>
<tr>
<td></td>
<td><em>Penicillium citrinum</em></td>
</tr>
</tbody>
</table>

Growth of bacterial and fungal isolates on Oil agar

The identified bacterial and fungal isolates were studied for their ability to utilize oil as a carbon source. The isolates all grew on engine oil and vegetable oil as sole sources of carbon being able to degrade oil (Table 3).

Physico-chemical analysis of treated and untreated dry kitchen waste

The results of the physical and nutrient analyses of the treated and untreated dry kitchen waste samples are presented in Table 4. At $P=0.05$ statistical significant difference was found between the treated and untreated kitchen waste samples. The pH of the sun dried treated kitchen waste was (5.6±0.007) and untreated kitchen was (5.92±0.007), using the one-way Analysis Variance to compare between one variable, the $P$ value deducted from the test showed a $P$ value less than 0.05 at a confidence interval of 95% which interprets that there

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is a significant difference as the application of the OBD-plus treatment has a significant impact on the pH of the kitchen waste although maize plants require a pH from moderate acidity to neutral. The percentage moisture content of the treated kitchen waste (TKW) was less than the untreated kitchen waste (UKW), but an increase in the dry matter percentage to 76.78 in TKW from 55.4% in UKW. The values were statistically significant at P<.05. Furthermore, the potassium content in the TKW when compared with the UKW from 3.6% to 6.3%, showing the efficacy of the OBD-plus. The same was also observed for magnesium with an increase in the TKW of 2947.5mg/kg compared to the UKW of 389.25mg/kg. The percentage of the total phosphorus showed a significant difference as there was an increase in the TKW of 0.222% compared to 0.079% in UKW. Also, the percentage of total nitrogen, showed a significant difference of 18.48% for UKW and 23.04% for TKW. The percentage oil content in the treated kitchen waste showed a decline to 21.54% in the TKW when compared to the untreated kitchen waste UKW of 59.26%.

Growth performance of maize plant

Plant growth trials were carried out in the greenhouse using maize seeds, which were sown on the mixtures of treated and untreated dry kitchen waste and sand to evaluate the quality and growth promoting ability of the treated kitchen waste carried out. The physical features of the maize plants planted with the mixture of treated and untreated dry kitchen waste and sand are shown in Plate1 below. The maize plant that germinated on the treated mixture showed good growth, while that of the untreated mixture dried and eventually died. The good growth observed in the plant, is as a result of its high water retention property which is important to the soil for the release of humidity to the plants as needed. However the maize plant that germinated on the untreated mixture dried and died eventually due to the high oil content in the untreated mixture, which resulted to its low water retention property.

Table 3: Growth of Bacterial and Fungal isolates on Oil agar

<table>
<thead>
<tr>
<th>Isolates</th>
<th>Engine oil agar</th>
<th>Vegetable oil agar</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus sphaericus</em></td>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td><em>Bacillus anthracis</em></td>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td><em>Aspergillus niger</em></td>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td><em>Aspergillus flavus</em></td>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td><em>Penicillium citrinum</em></td>
<td>+ve</td>
<td>+ve</td>
</tr>
</tbody>
</table>

Key:

+ve: Growth

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TABLE 4: Physical and mineral analyses of untreated kitchen waste (UKW) and treated kitchen waste (TKW) samples.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>UKW</th>
<th>TKW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>pH</td>
<td>5.92±0.007&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.60±0.007&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sodium (mg/kg)</td>
<td>13.90±0.007&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.10±0.007&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lead</td>
<td>0.57±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.330±0.005&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Zinc</td>
<td>6.60±0.007&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.850±0.000&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Copper</td>
<td>1.772±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.260±0.000&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Manganese</td>
<td>15.50±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.31±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.048±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.168±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Iron</td>
<td>289.50±0.007&lt;sup&gt;b&lt;/sup&gt;</td>
<td>43.00±0.000&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.017±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.005±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Calcium</td>
<td>135.50±0.025&lt;sup&gt;b&lt;/sup&gt;</td>
<td>181.00±0.057&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.352±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.004±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Serilium</td>
<td>2.14±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.490±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Magnesium</td>
<td>389.25±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2947.5±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Keys: Superscripts a and b indicate difference in mean across the row at P=.05
UKW: Untreated kitchen waste
TKW: Treated kitchen waste

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Figure 1: Physicochemical parameters of untreated and treated kitchen wastes.
Bacteria and fungi were isolated from kitchen waste sludge to determine the microorganisms present in the sludge. The isolates were identified as *Bacillus sphaericus*, *B. cereus* and *B. anthracis*. The fungal isolates included *Aspergillus niger*, *Penicillium citrinum* and *A. flavus*. However, *A. niger* isolated in this study was also reported in the work of [16], on the conversion of food waste to organic fertilizer.

Physicochemical analysis was carried out on both the sun dried treated and untreated kitchen wastes. The utilization potential of the kitchen waste as organic fertilizer for plant growth was also carried out. Significant differences in the physicochemical parameters were found between the treated and untreated kitchen waste samples showing improvements as a result of the treatment with OBD-plus. The percentage moisture content of the treated kitchen waste (TKW) was less than the untreated kitchen waste (UKW). The addition of the OBD-plus treatment played a significant role in the reduction of its moisture content. Previous work by [8] on Brewery waste water sludge (BWS) also demonstrated that the %moisture content in the BWS of 10.70 was less in comparison to the municipal waste of 13.20% and farm waste of 15.83% used.

Furthermore, the potassium content was determined, and the results showed an increase in the potassium content in the TKW when compared with the UKW. The increase showed the efficacy of the OBD-plus. Potash (Potassium, K) is the nutrient required in the greatest
amount by maize. Potassium has a number of diverse roles in plants. It plays an important role in regulating the water content of the plant and with an adequate supply of K, plants can survive drought stress more easily. It is essential for the transport of sugar from the leaves to the storage organs where the sugar is converted to starch. It plays a major role in maintaining the turgor (i.e. rigidity) of plant tissue. Leaves need to be turgid to remain fully extended to maximise the surface exposed to sunlight that provides the energy to convert carbon dioxide in the atmosphere to sugars in the leaves. Plants well supplied with K also seem to be less susceptible to fungal and pest attacks. In a study carried out by [17], combined treatment with two Bacillus spps-\textit{B. megaterium var phosphaticum} and \textit{B. mucilaginosis} increased available phosphorus and potassium in the soil thus increasing their uptake and plant growths of pepper and cucumber. These were different from the Bacillus spps isolated from the kitchen waste. However, the same was also observed for magnesium, as there was also an increase in the magnesium content in the TKW of 2947.5mg/kg compared to the UKW of 389.25mg/kg. Previous work by [18] also demonstrated a significant correlation. This explains that the OBD-plus has a significant impact on the kitchen waste as magnesium (Mg) is an essential element in chlorophyll and hence for photosynthesis.

An increase in the total phosphorus of the TKW of 0.222% was obtained when compared to the UKW of 0.079%. [17], in their work on the utilization of brewery waste water sludge (BWS) as organic fertilizer reported total phosphorus of BWS to be 3.3% and that of municipal waste MW, 0.6%. Phosphorus is involved in the metabolic processes responsible for transferring energy from one point to another in the plant. It is also critical in root development and flowering because phosphorus moves slowly through the soil, it is however important to work it into the soil, where it is needed by the roots.

Also, the percentage of total nitrogen, showed a significant difference between the amount (18.48%) obtained for UKW and 23.04% for TKW after treating with OBD-plus, previous work by [16] on brewery waste sludge as organic fertilizer also demonstrated a significant correlation in BWS of 4.5% compared to MW; 1.1% and FW; 1.6%. Nitrogen is known to promote plant growth as it is associated with leafy, vegetative growth. It is part of every protein in the plant, making it important for virtually every process- from growing new leaves to defending against pests. Nitrogen is part of the chlorophyll molecule, which gives plants their green colour and it is involved in the production of food for the plant through photosynthesis. Lack of nitrogen causes general yellowing (chlorosis) of the plant. More so, sodium and other micronutrients such as lead, zinc, copper, manganese, nickel, iron, cadmium, calcium, chromium and serillium were low in the treated kitchen waste (TKW) compared to the untreated kitchen waste. One of the major hiccups in the application of kitchen waste has been the presence of heavy metals and the resultant toxic effects on plants and soil. It also affects the quality of water and water bodies as a result of leaching. This is also in accordance with the previous work by [18] on the conversion of food waste to organic fertilizer.

The treated kitchen waste showed a decline in the percentage oil content compared to the untreated kitchen waste. There was also a progressive reduction in the percentage oil content in the treated kitchen waste sample over a period of a month. The TKW mixture was observed to have a high water retention property as a result of the reduction in oil content, compared to the UKW. The high water retention property of TKW is also in accordance with previous work by [19] on utilization of brewery waste water sludge for soil improvement. Water retention is important in soil for providing the necessary humidity to the plants as needed.

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Furthermore, seed germination and plant growth with maize seeds planted on OBD-plus treated and untreated kitchen waste mixed with river sand showed much better and healthier growth in the treated waste compared to the untreated which provided unhealthy, stunted plants that later withered.

The essential plant nutrients available in the soil, which were improved by the application of the treated kitchen waste, indicate that there will be sufficient nutrients for uptake of crops thus improving and increasing the outcome of yields.

4. CONCLUSION

The results presented in this work have shown that treated kitchen waste (TKW) can be a useful and valuable source of nutrients as organic fertilizer to plants. It also reveals that waste is not a waste in itself, as it can be re-used, reduced, recycled and diversified into wealth in such a way that develops the economy and improves the ecosystem and biodiversity as a whole in an environmentally friendly approach. There were improvements in some parameters and elements such as dry matter, total nitrogen, magnesium after treatment with OBD-plus and reduction in oil content, iron and lead. All these improved the quality of the kitchen waste for plant growth. The limitation of this study is that the kitchen waste was not collected at random and is a representation of a specific case.

CONSENT

It is not applicable.

ACKNOWLEDGEMENT

The authors will like to acknowledge the contribution of Mr Samson Mabayoje of the Department of Biological Sciences, Afe Babalola University Ado Ekiti for the preparation of the samples for growth trials in the greenhouse

ETHICAL APPROVAL

It is no applicable

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COMPETING INTERESTS

Authors have declared no competing interest exist.

AUTHORS’ CONTRIBUTIONS

This work was carried out in collaboration between all the authors. Authors BAO, TAO and COA designed the study and wrote the protocol while author COA performed the statistical analysis. Authors COA and TAO wrote the first draft of the manuscript, managed the analysis of the study and the literature searches. BAO, TAO and COA read and approved the final manuscript.

REFERENCES


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