Nigerian Journal of Ecology (2022) 18(2): 7-16
©Ecological Society of Nigeria 2022.
ISSN: 1116-753X (Print); E-ISSN: 2955-084X (Online)

Biochar-enhanced Remediation of Artisanal Refining-impacted Mangrove Site on Some Growth Parameters of *Rhizophora racemosa* G. Meyer

Yabrade[1], M., Tanee[2], F.B.G. and Obute[3], G.
[1]Department of Marine Environment and Pollution Control, Faculty of Marine Environmental Management, Nigeria Maritime University Okerenkoko, Delta State, Nigeria.

[2]Department of Plant Science and Biotechnology, Faculty of Sciences, University of Port Harcourt, Port Harcourt, Nigeria.

[3]Department of Plant Science and Biotechnology, Faculty of Sciences, University of Port Harcourt, Port Harcourt, Nigeria.

(Accepted 13 November, 2022)

ABSTRACT

Biochar-Enhanced remediation of artisanal refining mangrove-impacted vegetation for the growth of *Rhizophora racemosa* G. Mey, was carried out in Gbaramatu Kingdom, Delta State, Nigeria. A designated area of 12.5 m x 6.25 m was mapped out, demarcated into four treatment Plots-A (4000g Biochar), B(12000g Biochar), C(No Treatment), and D (8000g Biochar), with a Double Control Plot-E (non-polluted site) located 4km away. After treatment, the plots were left for 30 days to allow for remediation to take place, before propagules of *Rhizophora racemosa* were planted. Vegetative parameters such as leaf number, leaf length, leaf width, plant height, plant girth, leaf length/width ratio, leaf area, leaf area ratio, plant dry weight, shoot dry weight and root dry weight were observed after 25, 50, 75 and 100 days after treatment. The double control Plot-E performed better than the remediated plots in plant growth parameters. The remediated plots also experienced increased growth in vegetative parameters with time with the best performance in treatment option D (8000g biochar). While the non-remediated plots recorded the least growth performance in plant vegetative parameters with time. This indicates that appropriate quantities of Biochar obtained from *Rhizophora racemosa* plant, is capable of remediating artisanal refining mangrove-impacted sites for the growth of *Rhizophora racemosa* seedlings. Hence this is an eco-friendly and cost effective remediation technique that could be utilized in mangrove revegetation in the Niger Delta.

Key words: Biochar, *Rhizophora racemosa*, Remediation, Artisanal refining, Mangrove vegetation, Pollution.

INTRODUCTION

Mangrove habitats are one of the most sensitive shore-line habitat to oil and difficult to clean. Mangroves are slow growing plants; that usually grow in low energy environments where oil can persist for years (Duke *et al*., 1997). Oil impacts in mangrove community varies, depending on the type of oil, the amount of oil, and the duration of weathering (Tanee, and Kinako, 2008). As a result, mangrove areas should receive the highest protection priority from a spill. Efforts should be made to minimize the amount of oil that is allowed to enter a mangrove area, without causing greater harm (Social Action, 2018), while local remediation techniques, such as biochar obtained from pyrolysis of resident materials should also be used to remediate the environment for the sustainability of mangrove plants.

Crude oil and heavy refined products such as tar and other unconfirmed substrates and derivatives from human activities such as artisanal refining can affect the mangrove environment. Artisanal refining is a small-scale or subsistent distillation of crude oil over a specific range of boiling points with the aid of locally constructed metal plates/drums to produce useable products such as kerosene, diesel and petrol (SDN 2012). It involves traditional skills with little high end technology and uses stolen crude as the primary raw material. In recent years artisanal refining has become wide spread and prevalent in the coastal environments of the Niger Delta and is associated with severe environmental pollution and fire outbreaks that have led to loss of lives and properties (Yabrade and Tanee, 2016). Waste products from artisanal activities can coat the partially submerged prop roots and pneumatophores of mangrove plants, thereby reducing the ability of the plants to exchange gases because mangroves are more vulnerable to oil (Duke *et al*., 1997). These heavy oils will have long term persistence, especially with heavy accumulations which may cause leaf loss and possibly death to heavily oiled mangrove trees (Mensah *et al*., 2013). This has contributed to drastic depletion of the mangrove population in the Niger delta.

There is therefore need to remediate such site for mangrove revegetation. One of such materials that can be used is biochar. Biochar refers to solid products derived from the pyrolysis of waste biomass residues from agricultural and forestry materials (Koul and Taak, 2018). Biochar could also be described as charred organic matter under high heat and low oxygen conditions that occur in natural fires and modern pyrolysis systems (Liu *et al*., 2011). The end products maybe in powdery form or in granules (Xu *et al*., 2013). Biochars have various properties that enhance remediation of polluted soils and also induce negative charge and large surface area (Koul and Taak, 2018). Biochar has excellent potential to adsorb inorganic contaminants from soil and make them unavailable to organisms (Beesley *et al*., 2011, Mohan *et al*. 2012). Also biochars have been observed to remove pollutants from soil and sediments through sequestration (Guo *et al*., 2017). The addition of biochar to soil serve as an effective treatment for the removal of toxicants from polluted soils due to its various properties such as; high water retention capacity; reduction of bioavailability, prevention of microbes from predators, prevention of stress induced by toxin to plants and microorganisms (Koul and Taak, 2018). Biochar also facilitate the immobilization of pollutants for further degradation by microbes (Oh *et al*., 2012). Due to the high aromatic nature, high surface area, micropore volume and the presence of abundance of polar functional groups in biochar, it has been found to be very effective in the uptake of a variety of organic chemicals including pesticides, PAHs and emerging contaminants such as steroids hormones (Kookana *et al*., 2011). Biochar amended soil can help absorb a variety of organic contaminants, thereby reducing their uptake by plants, thereby showing the fact that biochars are good eco-friendly remediation materials that could be applied in a variety of polluted soils (Zhang *et al*., 2013).

Hence the aim of the study, is to carryout Biochar-Enhanced remediation of artisanal refining impacted-mangrove site for the revegetation and growth of *Rhizophora racemosa* plants. This is a local, eco-friendly remediation technique, that will enable local indigenes clean up their environment easily, which will go a long way in commiserating the mangrove restoration efforts in the Niger Delta.

MATERIALS AND METHODS

Description of Study Area

The study was carried out, at an abandoned artisanal refining (polluted) site in the mangrove forests of Ikpokpo community and the non-polluted site was located some 4 km away at the neighbouring Tebujor community, along Escravos River, Warri South-West LGA, Delta State, Nigeria. The abandoned artisanal refining site is located at Latitude 5.5933N, Longitude 5.2259E, while the non-polluted site is located at Latitude 5.5988N and Longitude 5.2350E (Fig 1). The area is a salt water coastal environment, dominated by mangrove forest, with red mangrove (*Rhizophora racemosa and Rhizophora mangle*) being the prevalent plant species located in the area. Other plant species such as grasses- *Paspalum viginatum* and ferns-*Achrostichum aureum*, palm trees-*Elaeis guineensis*, were also found in the area. The area experiences unidirectional flooding inundation during high tides and receding during low tides. The tidal changes alternate every twelve (12) hours. The climate of the area is basically that of equatorial rainfall, with two alternate seasons of dry (November-March) and rainy (April-September). The soil type is mainly peaty clay or “chikoko”, which is dark in colour and has a sticky feel, containing debris, root fibres and leaf parts.

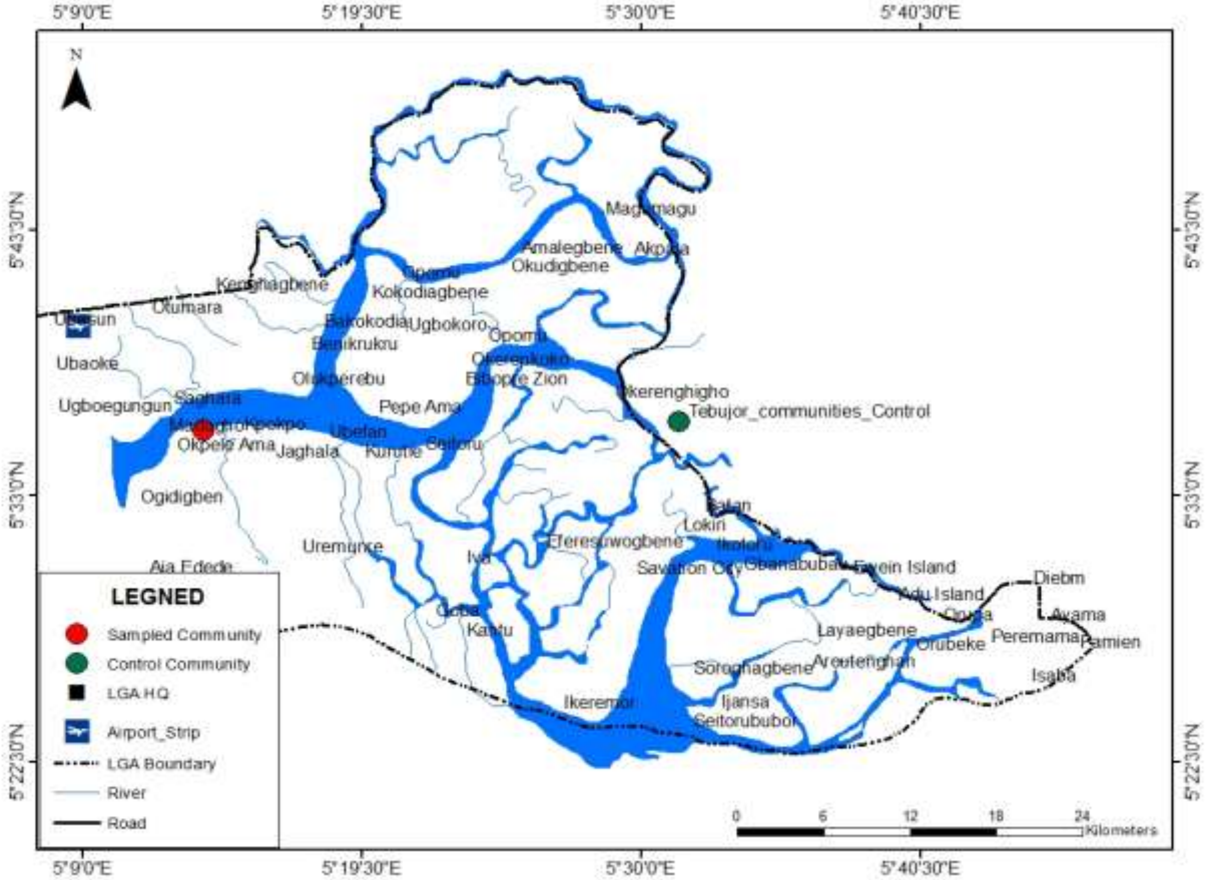

Fig. 1: Map of the Study Area

Land Preparation

An abandoned artisanal refining site was identified and an area of 12.5 m x 6.25 m was mapped out from the site. The site was cleared of debris and dead standing trees and then demarcated into four treatment plots (A, B, C and D) of 6.25 m x 3.13 m. The demarcation was carried out with stakes and water proof tarpaulin (thick Polyethylene material), lined/nailed to the stakes. The tarpaulins were dug deep to a depth of about 2 m below the soil surface and thoroughly arranged to minimize fluid movement from one treatment plot to another and from outside into the treatment plots. The control plot E, also followed same process of preparation with only one plot (Okoro, 2009, Hammond *et al.*, 2013).

Remediation Materials/Treatment

Dead mature *Rhizophora racemosa* plants were collected from local non-contaminated mangrove forest in the research area. These were then cut into smaller pieces with the aid of an axe and passed through intense heating (pyrolysis) in a controlled heat chamber (oven) above temperatures of 470°C and the residues crushed into powder to produce biochars. The biochars were then weighed and applied on the different polluted treatment sites as follows: Plot A was treated with 4000g of Biochar; Plot B, 12000g; Plot C was left untreated (No treatment), while Plot D was treated with 8000g Biochar and the Double Control Plot-E in the non-polluted site was also left untreated. The treatment plots were left for 30 days before planting of the test plant (Beesley *et al*., 2011, Bian *et al*., 2014).

Planting of Propagules of *Rhizophora racemosa*

Rhizophora racemosa seedlings (propagules) were obtained from the wild close to the double control site. Care was taken to obtain fresh propagules without injuries and contamination. The propagules were then taken to the treatment plots for planting. About 20 plants propagules were planted one meter (1m) apart in each treatment plot, using a zig-zag method, following the natural growth pattern of mangrove vegetation in the wild (Zabbey and Tanee, 2016). Propagules of almost same length and size were planted in all the treatment plots for easy monitoring. The hole for planting was dug wide enough to avoid injuries to the propagules while planting (Chindah *et al*., 2007).

Analyses of Vegetative Features

After planting of mangrove propagules on the treatment plots, the plants were then monitored and measurements taken and recorded after 25, 50, 75 and 100 days of planting. The plant parameters measured were; leaf number, counted manually, plant girth (cm), measured with the aid of a vernier calliper at a particular spot on the stem marked with a masking tape; plant height, leaf length and leaf width, measured in centimetres with the aid of measuring tape. Other parameters were leaf length/leaf width ratio (cm), obtained by dividing the leaf length with the leaf width; leaf area (cm^2), obtained by multiplying the figures obtained from the leaf length and leaf width with that of the leaf shape coefficient of 0.76, being the constant obtained for leaves whose area is less than 10 cm. Plant total fresh weight, plant dry weight and root dry weight were measured in grams, using a casio digital scale model number SF-400.The leaf area ratio (cm^2/g) was determined by dividing the leaf area of a particular plant with the dry weight of that plant.

Statistical Evaluation

Data generated from the study were analyzed using Statistical Package for Social Sciences (SPSS) version 2.0 by IBM Inc. Descriptive statistics such as mean and standard errors were summarized, while one-way analysis of variance (ANOVA) was used to check for the level of significance between the means at $P < 0.05$. Charts were created using Microsoft Excel 2015 by Microsoft Incorporated.

RESULTS

Fig. 2 showed leaf production in the remediated site and the double control. Results showed that, the double control Plot-E recorded the highest number of leaves after 100 days of planting with a significant difference at $P < 0.05$. This was followed in descending order by Plots D (8000 g biochar), B (12000 g biochar) and A (4000 g biochar), with Plot C (non-remediated) recording the least number of leaves after 100 days of planting (Fig.2).

The result of the leaf length (Fig. 3) and leaf width (Fig.4) have similar trend. The results showed that, the double control Plot-E, recorded the highest leaf length and leaf width which progress with time than other treatment plots, followed in descending order by Plots D (8000g Biochar), B (12000g Biochar) and Plot A (4000g Biochar) ($P < 0.05$). While Plot C with no remediation treatment, recorded the least performance in leaf length and leaf width which remained static from 25-50 days after planting and experienced further decrease from 50-100 days after planting.

Results presented in Fig. 5 showed that, there was progressive increase in plant height with time in the double control Plot-E and remediated Plot-D (8000g Biochar). While the other treatment Plots A (4000g Biochar), B (12000g Biochar) and C (No treatment) experienced stunted plant height with time. Fig. 5, clearly showed that plant girth development is a very slow process as all the treatment plots and the control experienced slow growth progression from 25-100 days after planting, with no significant difference @ P < 0.05. Highest girth value was observed by plants at plot of 8000g biochar (D) treatment.

Results of the leaf length/width ratio, leaf area and leaf area ratio are presented in Figs. 7, 8 and 9 respectively. It was observed that, the double control Plot-E, recorded the highest values for these leaf characteristics (length/width ratio, leaf area and leaf area ratio) with time (P < 0.05). Remediated Plots A (4000g Biochar), B (12000g Biochar) and D (8000g Biochar) recorded increase in leaf length/leaf width ratio from 25 to 50 days of planting. Plot-C recorded the least performance in terms of these leaf characteristics.

Fig. 10 showed that double control Plot-E and remediated Plot-D recorded the highest plant fresh weight at the end of the experiment. (P < 0.05). However, Plot C, with no treatment recorded the lowest value. Similar results were obtained for the total dry weight (Fig.11), root dry weight (Fig. 12) and shoot dry weight (Fig. 13).

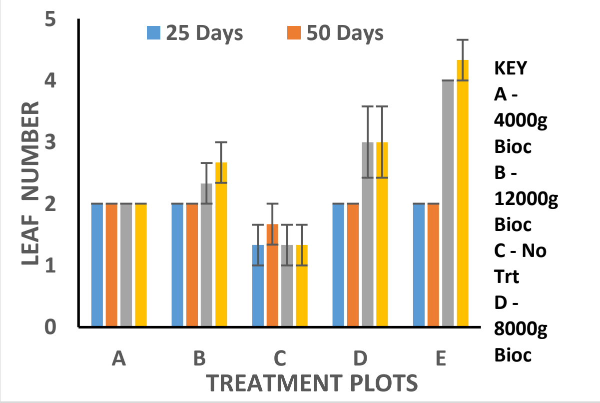

Fig. 2: Number of leaves in each treatment plot

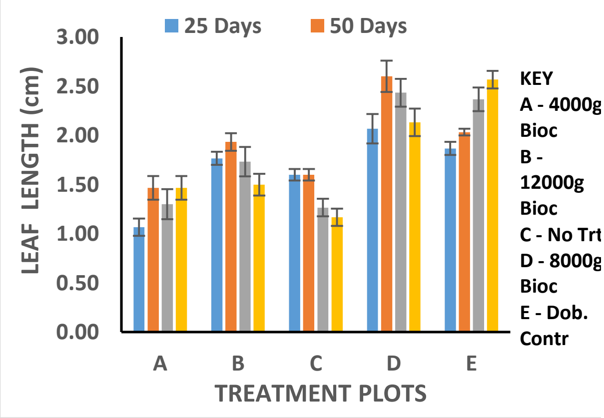

Fig. 3: Leaf length in the various treatment plots

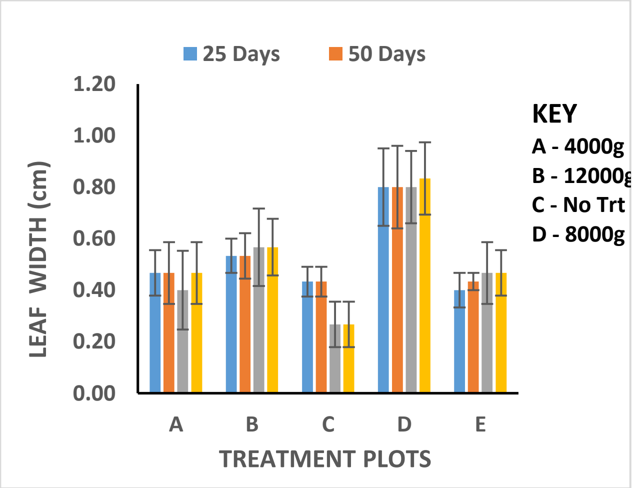

Fig. 4: Leaf width in the various treatment plots

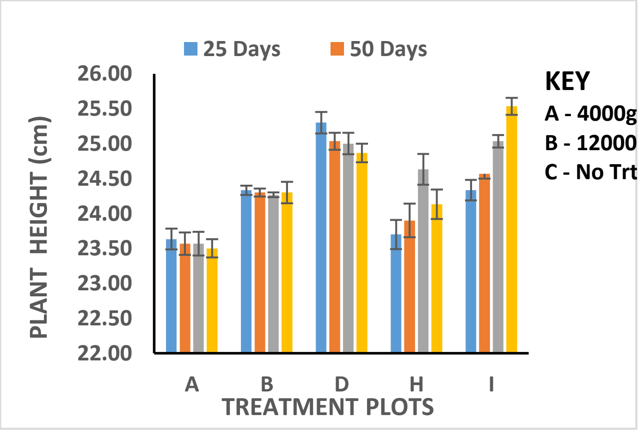

Fig. 5: Plant height in the various treatment plots

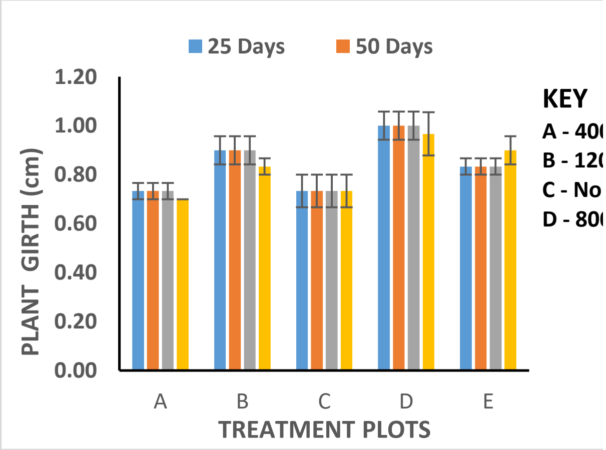

Fig. 6: Plant girth in the various treatment plots

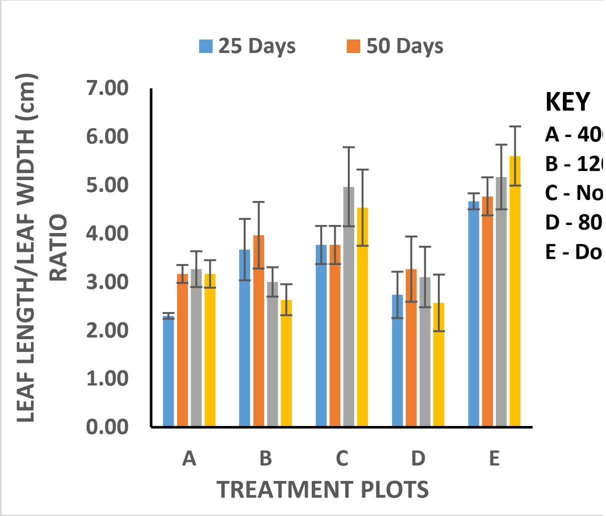

Fig. 7: Leaf length/width ratio in the various treatment plots

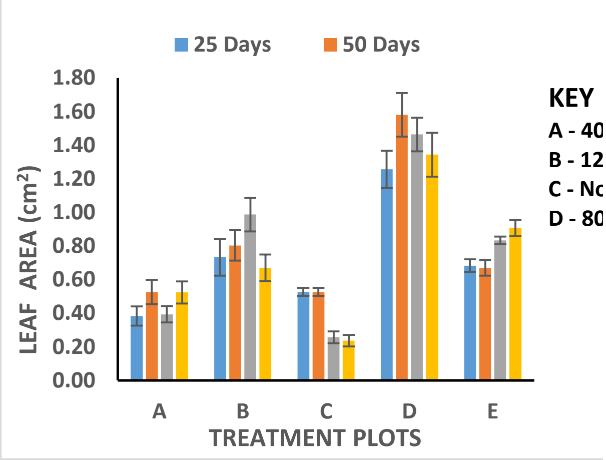

Fig. 8: Leaf area in the various treatment plots

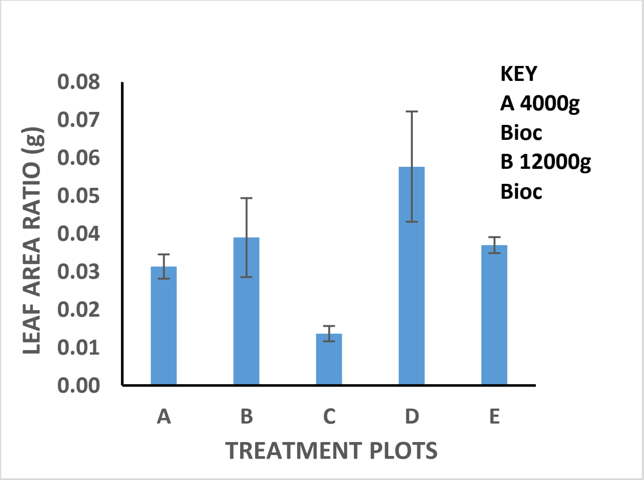

Fig. 9: Leaf area ratio in the various treatment plots

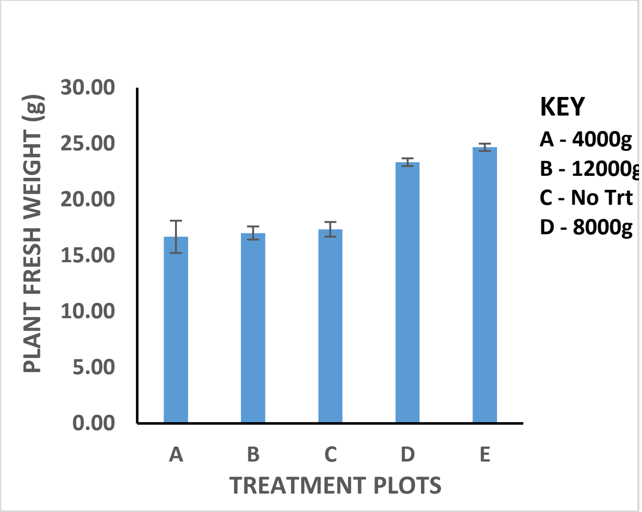

Fig. 10: Plant fresh weight in the various treatment plots

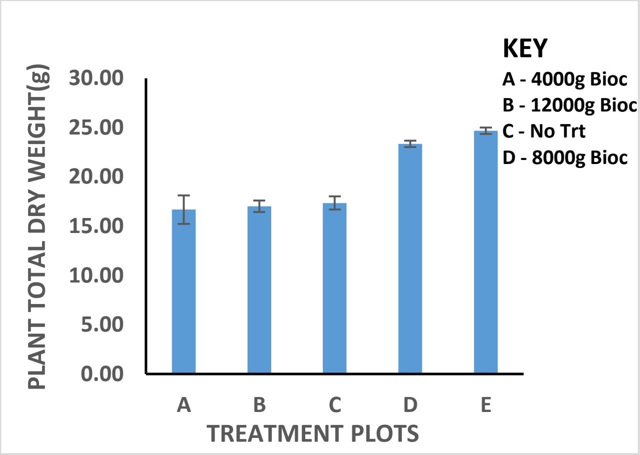

Fig. 11: Plant total dry weight in the various treatment plots

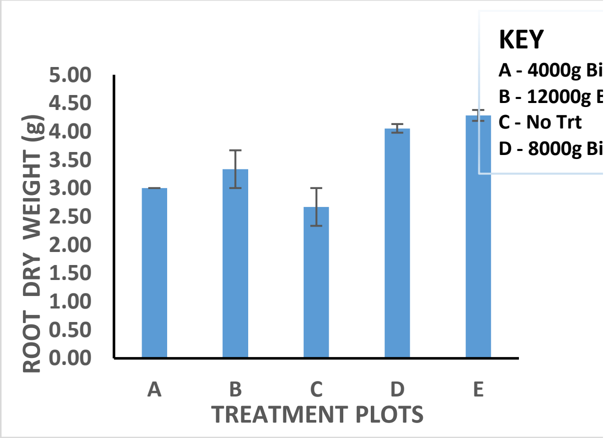

Fig. 12: Root dry weight in the various treatment plots

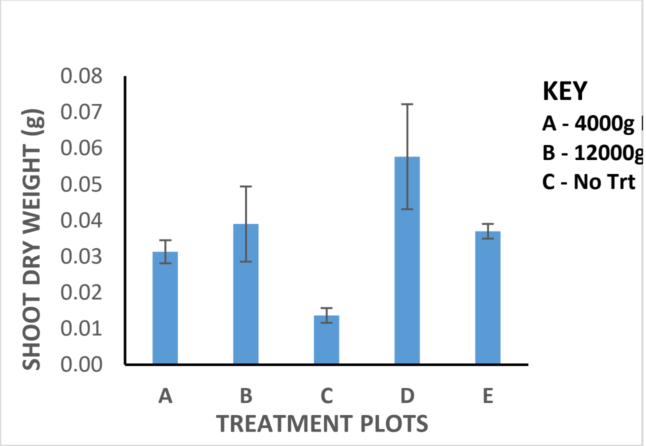

Fig. 13: Shoot dry weight in the various treatment plots

DISCUSSION

Healthy plant development in terms of growth (plant height, plant girth, biomass, etc) and leaf characteristics (leaf length, leaf width, leaf area ratio, leaf length/width ratio, etc), are aided and sustained by nutrient availability in the soil, favourable environmental and climatic conditions (Chindah *et al*., 2007). While loss of leaves (wilting/senenscence), stunted growth in leaf length, leaf width, plant height, plant girth, etc, is an indication of the absence of nutrients, presence of harmful pollutants, unfavourable atmospheric and environmental condition or a combination of all or some of the above factors in the plant immediate environment (Mensah *et al*., 2013).

Results showed that, there was steady growth and improvement in leaf production and development of other plant parameters in the double control Plot-E (non polluted site) with time, as the plants in this plot recorded the best plant growth development among all the treatment options, which is so because of the absence of pollutants inhibiting plant growth (Chindah *et al*., 2007, Koul and Taak, 2018); while leaf production and general plant growth was slow with time on the remediated plots because of the presence of crude oil pollutants inhibiting plant growth (Chindah *et al*., 2007, Balogun *et al*., 2015). The gradual increase in growth of plant parameters on the remediated plots, is an indication that, remediation had an impact on the polluted soil, which in turn gradually enhanced plant development (Li *et al*., 1990; Koul and Taak., 2018). The variation in the growth and leaf characteristics in the remediated plots showed that nature and quantity of pollutants, quality and quantity of remediation materials, type of remediation materials, etc, have effects on plant growth parameters (Ngwu and Edeh, 2018). It has been reported by Beesley *et al*. (2011), Yuan and Xu (2011), Chen *et al*. (2012) and Mohan *et al*. (2012) that the remediation materials (biochar), helps in plant growth and development by adsorbing inorganic contaminant from soil, facilitate nutrient availability, enhances microbial activities in soil, boost soil organic matter availability, water retention capacity and crop production in soils. This justifies the improved performance of the test plant in the remediated site as compared to the control (non-remediated plot). The plot treated with 8000g of biochar (Plot-D), recorded the highest amount of leaf production and overall plant growth performance, among the remediated plots, which was closely followed by the plot treated with 12000g of biochar (Plot-B), while the other remediated Plot–A, maintained relatively static leaf development and moderate growth in other plant parameters with time, after initial leaf production on the 25 day of planting. This shows that the quantity of remediation material used in a remediation process has an important role to play on the effectiveness/success of the remediation process; indicating that lower quantity of biochar may be ineffective while higher quantity such as 12000 g may be toxic. Moderate quantity of biochar may produce a good result in term of remediation process. The quantity of Biochar (8000g) was moderate enough to have sustained the growth of vegetative parameters, without being toxic to crude oil degraders and the plants. In other words, the remediation materials (biochar) were able to supply the necessary nutrients required by microorganisms for biodegradation, optimum nutrient level and other materials required for sustainable plant growth (Li *et al*., 1990, Zhang *et al.,* 2013)

The non-remediated Plot-C, recorded the least amount of leaf production and very slow overall plant development with time. Leaf production and general plant development on this plot was high at the initial stage (25-50 days after planting), but experienced a decrease after 75 days of planting. The abysmal performance of the plant at the non-remediated plot-C compared to the remediated plots could be attributed to the toxicity of the pollutant and inadequate nutrient supply to aid further microbial degradation of the pollutants and support plant growth hence the plants could no longer survive the harsh conditions (Pezeshski *et al*., 2000).

CONCLUSION

From the results of this research, biochar obtained from *Rhizophora racemosa* plants applied on artisanal refining impacted-mangrove vegetation, increased soil nutrients and facilitated bioremediation processes for the growth of *Rhizophora racemosa* seedlings. It was also observed the success of the remediation and subsequent growth of the test plant depend on the quantity of biochar applied in which 8000 g biochar proved to be the best among the different treatment used. Hence, biochar obtained from *Rhizophora racemosa* plants should be employed as remediation materials in the vast artisanal refining impacted-mangrove vegetation across the Niger Delta, as it is cost effective, eco-friendly and readily available material in the immediate environment, thereby providing indigenous solution to a locally generated problem.

REFRENCES

Balogun, O.B. (2015). A study of the tectonic processes in the Niger Delta and adjacent regions as derived from mantle density and isorate analysis. *Ife Journal of Science*. 18(4): 931-947.

Beesley, L., Moreno-Jiménez, E., Gomez-Eyles, J. L., Harris, E., Robinson, B., and Sizmur, T. (2011). A review of biochars' potential role in the remediation, revegetation and restoration of contaminated soils. *Environmental Pollution*, *159*(12), 3269-3282.

Bian, R., Joseph, S., Cui L., Pan G., Li, L., Liu, X., Zhang, A., Rudlidge, H., Wong, S., Chia, C., Marjo, C., Gong, B., Munroe, P. and Donne, S. (2014). A three-year experiment confirms continuous immobilization of cadmium and lead in contaminated paddy field with biochar amendment. *Journal of Hazardous Materials,* 272:121–128.

Chindah, A.C., Braide, S.A., Amakiri, J. and Onohurhefe J. (2007). Effect of Crude oil on the Development of Mangrove (*Rhizophora mangle* L.) Seedling from the Niger Delta, Nigeria. *Revista UDO Agricula* 7(1): 181-194.

Duke, N.C., Pinzon Z.S., and Prada M.C. (1997). Large-Scale damage to mangrove forests following two large oil spills in Panama. *Biotropica* 29 (1): 2-14.

Guo, J., Li, J., Chen, H., Bond, P. L., and Yuan, Z. (2017). Metagenomic analysis reveals wastewater treatment plants as hotspots of antibiotic resistance genes and mobile genetic elements. *Water Research*, 123: 468-478.

Hammond, J., Shackley, S. M., Miller, P., Cook, J., Buckingham, S. and Pappa, V.A. (2013). Biochar field testing in the UK: Outcomes and implications for use. *Carbon Management*. 4:159–170.

Li, Y., Morris, J.T. and Yoch, D.C. (1990). Chronic low hydrocarbon amendments stimulate plant growth and microbial activity in salt-marsh microcosms. *Journal of applied Ecology*. 27: 159-171.

Liu, J., Wang, R., Huang, B., Lin, C., Wang, Y., and Pan, X. (2011). Distribution and bioaccumulation of steroidal and phenolic endocrine disrupting chemicals in wild fish species from Dianchi Lake, China. *Environmental Pollution*, *159*(10), 2815-2822.

Kookana, R. S., Sarmah, A. K., Van Zwieten, L., Krull, E., and Singh, B. (2011). Biochar application to soil: agronomic and environmental benefits and unintended consequences. *Advances in agronomy*, *112*, 103-143.

Koul, B. and Taak, P. (2018). Biotechnology Strategies for Effective Remediation of Polluted Sites. Springer Nature Singapore Plc. Ltd. Pp 77-115.

Mensah, S.I., Okonwu, K. and Yabrade, M. (2013). Effects of crude oil application on the growth of mangrove seedlings of *Rhizophora racemosa* G. Meyer. *Asian Journal of Biological Sciences.* 10(3):9-23.

Mohan, P. K., Sreelakshmi, G., Muraleedharan, C. V., and Joseph, R. (2012). Water soluble complexes of curcumin with cyclodextrins: Characterization by FT-Raman spectroscopy. *Vibrational Spectroscopy*, *62*, 77-84.

Ngwu, O. E., and Edeh, V. N. (2018). Effect of varying rates of NPK 15: 15: 15 fertiliser on the physicochemical properties of the soil, growth and yield of cucumber,(*Cucumis sativus* L.). *International Journal of Plant and Soil Science*. 28(4), 1-7.

Oh S.Y, Son J.G., Lim, O.T. and Chiu, P.C. (2012). The role of black carbon as a catalyst for environmental redox transformation. *Environmental Geochemistry and Health.* 34(1):105–113.

Okoro, C. C. (2009). Biosurfactant-enhanced remediation of hydrocarbon contaminated mangrove swamp. *International Journal of Biological and Chemical Sciences.* 3(1): 63-74.

Pezeshki, S. R., Hester, M. W., Lin, Q., and Nyman, J. A. (2000). The effects of oil spill and clean-up on dominant US Gulf coast marsh macrophytes: a review. *Environmental Pollution*, *108*(2), 129-139.

SDN., (2012). *Communities not Criminals:Illegal oil refining in the Niger Delta: trying to understand an informal Economic*. Stakeholders Democratic Network Publications, 22 Okoriji, D/line, Portharcourt, 2012. Pp 5-42.

Social Action, (2017). Social Development Integrated Centre: *Proceedings from the National Conference on Oil theft and illegal refineries: Addressing ecological disaster, liveliholds, revenues losses and insecurity*. March, 2017. Pp 3-4.

Tanee, F. B. G., and Kinako, P. D. S. (2008). Comparative studies of biostimulation and phytoremediation in the mitigation of crude oil toxicity in tropical soil. *Journal of Applied Sciences and Environmental Management*, *12*(2): 88-104.

Xu X., Cao, X., Zhao, L., Wang, H., Yu, H. and Gao, B. (2013). Removal of Cu, Zn, and Cd from aqueous solutions by the dairy manure-derived biochar. *Environmental*

Science Pollution Research 20(1):358–368.

Yabrade, M., and Tanee, F. B. G. (2016). Assessing the Impact of Artisanal Petroleum Refining on Vegetation and Soil Quality: A Case Study of Warri South West Salt Wetland of Delta State, Nigeria.

Zabbey, N. and Tanee, F.B.G. (2016). Assessment of asymmetric mangrove restoration trials in Ogoniland, Niger Delta, Nigeria: lessons for the future. *Ecological Restoration*. 34(3), 245-257.

Zhang, X., Wang, H., He, L., Lu, K., Sarmah, A., Li, J. and Huang, H. (2013). Using biochar for remediation of soils contaminated with heavy metals and organic pollutants. *Environmental Science and Pollution Research*, *20*(12), 8472-8483.