GROWTH AND YIELD PARAMETERS OF OKRO AND MAIZE PLANTED ON CRUDE OIL REMEDIATED SOIL FOR SUSTAINABLE CROP PRODUCTION IN NIGER DELTA, NIGERIA

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Abstract

The study was carried out to assess the growth and yield parameters of okro and maize planted on crude oil remediated soil for sustainable crop production in Niger Delta, Nigeria. The study adopted experimental research design using Completely Randomized Block Design (CRBD) and was carried out in Ogulagha Grammar School, Demonstration Farm in Delta State, Nigeria. Four research questions guided the study. The sample for the study was 120 sack bags which represented 6 treatment groups replicated 5 times. A structured observation template was developed using information from the literature reviewed. The research instrument was subjected to face validation by three experts. Data were collected by the researcher with the help of one research assistant. The data collected were analyzed using mean to answer the research questions. The study found out that Adropogon gayanus and Sida-acuta as remedy to crude oil polluted soil can influence the growth and yield parameters of okra and maize in accordance with the volume of crude oil in the soil. It was recommended that Niger Delta Development Commission (NDDC) should encourage eco-friendly research and findings in their attempt to ameliorate the effects of crude oil spillage in Niger Delta, farmers should also adopt the cultivation of Andropogon-gayanus and Sida-acuta on crude oil polluted soil as a potential phytoremediation practice for sustainable agricultural production in Niger Delta, Nigeria.

Keywords: Remediation, Okra, Maize, Andropogon-gayanus and Sida-acuta

Introduction

Sustainable crop production mainly depends on the soil accommodating the crop. Khomiakov (2020) defined soil as a crucial component of the biosphere and global food system. Soil is important for food and feed production (Whendee et al, 2021); it provides food and nutritional security for human and animals (Fabio et al, 2020). The importance of soil lies in its ability to support plant growth (Durău, 2022) like okro and maize.

Okro and maize are two common crops in Niger Delta. Okra is a vegetable originated from Africa, cultivated in a wide variety of soils, and is one of the most important vegetables in the world, (Marin et al., 2017). Okro plays an important role in human diet due to the supply of carbohydrates, proteins, fats, minerals and vitamins (Abd El-Kader et al., 2010). It has vitamins A and C, being a source of calcium, iron, niacin, in addition to having medicinal qualities (Oliveira et al., 2014), and it has also attracted recent interest as a source of fibre.

Additionally, its seeds provide high-quality oil and the mucilage from its fruit can be used as a thickener in food industry (Alegbejo et al., 2008). Okra is a major food ingredient in the Niger Delta region; it is common to see it planted in gardens and small plots of land along side with maize.

Maize (*Zea mays* L., also commonly known as corn**)** is among the most important cereal crops across the world (George et al., 2023). The role of maize as a staple crop in Africa is comparable with wheat and rice in Asia (Nuss & Tanumihardjo, 2011). It is important for its carbohydrate, proteins, iron, vitamin B, and minerals (Victor and Sifan, 2015). According to Moses and Abiola (2012) the produce is consumed as maize meal, porridge, pastes and can be boiled or roasted as fresh as it comes from the farm. Maize is processed to produce oil for cooking (Umeh, 2024). It is also an important crop for animal feed. In Niger Delta, maize is produced through subsistence farming as part of mixed agricultural systems which lack inputs such as fertiliser, irrigation, improved seeds and efficient labor (Okonokhu et al., 2010). Smallholder farmers are the largest producers of maize in the Niger Delta region of Nigeria.

The Niger Delta region is estimated to cover about 70,000 square kilometers covering more than 40 ethnic groups (Ordinioha and Brisibe, 2013). The major agricultural produces in the region are cassava, cocoa, maize, okra, palm oil and yam, in addition to domestication of animals (Ikehi, et al 2014). The region is rich in crude oil which is currently explored in commercial levels. The crude oil obtained from this region accounts for about 90% of the country's economic growth (Ikhumetse, et al, 2022). The riches which this region supplies the country has however not translated to an improvement in the living standard of people in this region as the people continue to live in penury and always experience air, water and soil pollutions from oil spillage.

Oil spillage is the release of crude oil into the environment such as soil and ocean because of human activities (Briggs and Briggs, 2018; Ndimele, et al, 2018). The Niger Delta region has unfortunately experienced numerous oil spill incidents over the years, leading to significant environmental damage and social disruption. The pollution of soil by crude oil and its derivatives lead to reduction of soil pH, poor soil aeration and presence of heavy metals (Jolaoso, et al, 2019; Ebiye, Oku and Alexander, 2021). These challenges make such soils unable to sustain plant growth. Currently, there are over 20 communities affected by crude oil spillage in Niger Delta, these communities include: Ogoniland, Ogulagha, Bony Island, Okrika, Ikarama, Nembe among others. To sustain agricultural production in Niger Delta Nigeria especially in these oil polluted areas, it is necessary to remediate contaminated soil.

Soil remediation is the method adopted to amend polluted soil. Cooper (2013) defined soil remediation as the process of purifying and revitalizing a contaminated soil. According to Muralikrishna and Manickam (2017), soil remediation refers to the process of restoring or improving the quality of contaminated soil to a level that is safe for human health, ecosystems, and intended land use. Remediation of contaminated soil can be carried out using different methods such as chemical remediation (Essien, and John, 2010), soil washing, thermal desorption and bioremediation (Cooper, 2013). Chemical remediation involves the addition of reagents or chemicals to the soil to facilitate the breakdown, transformation, or immobilization of contaminants (Essien, and John, 2010). Soil washing is a physical remediation technique used to remove contaminants from soil by washing the soil with water or aqueous solutions containing surfactants, chelating agents, or other chemicals (Muze, et al, 2020). Thermal desorption is a remediation technique that uses heat to volatilize and remove contaminants from soil, sediments, or sludges (Azubuike, Chikere, andOkpokwasili, 2016). Bioremediation is the use of biological means to remove or reduce contaminants from a given sample of soil. According to Azubuike, Chikere and Okpokwasili (2016), some of the techniques used in soil bioremediation are bioventing, biosparging and phytoremediation.

Bioventing is a remediation technique used to treat contaminated soil and groundwater by enhancing the aerobic biodegradation of organic contaminants (Muze et al, 2020). The author further posited that biosparging is a remediation technique similar to bioventing, but specifically targeting contaminated groundwater. Phytoremediation simply means the use of plants to purify soil (Beans, 2017). Keeran, et al (2019) stated that phytoremediation is the use of plants to remove or render pollutants harmless in an environment. Several plant species have been utilized for phytoremediation efforts in Nigeria and globally. These plants possess various characteristics that make them effective at removing, degrading, or immobilizing contaminants from soil, water, or air (Poznyak, Oria and Poznyak, 2019). Examples of plant species used globally include willow trees, poplar trees, Indian Mustard¸ Sunflowers and Water Hyacinth amongst others (Adesina et al, 2020; Akpoveta, 2016; Ali et al, 2021; Azubuike, Chikere and Okpokwasili, 2016). Two promising plants for this purpose especially because of their extensive root system, adaptability to diverse environment and are mostly found growing in crude oil polluted sites in the Niger-Delta region of Nigeria even when other plants struggle to survive are *Andropogon gayanus* and *Sida acuta.*

Andropogon gayanus is a grass weed commonly known as Gamba grass and belongs to the Poaceae family. *Andropogon gayanus* is native to the tropical and sub-tropical regions of Africa (Heuzé, et al 2021). The grass weed thrives in sandy soils, withstands long periods of drought and tolerates aluminium toxicity (Flores,et al, 2014; Lima,et al, 2020). *Andropogon gayanus* serves as a forage crop which provides high nutritious value to livestock especially when harvested at a tender age. According to Heuzé, et al, (2021), the plant is also used in thatching and making of mat. *Andropogon gayanus* has shown promise for phytoextraction and rhizofiltration of contaminants (Heuzé et al, 2021) even though it has not been tried on the Niger Delta soil. Its extensive root system allows it to uptake and accumulates pollutants and nutrients contributing to soil remediation efforts (Ebiye, Oku and Alexander, 2021). By utilizing *Andropogon gayanus* for phytoremediation, contaminated sites in the Niger Delta might be rehabilitated without the need for invasive soil excavation or chemical treatments. Additionally, the grass's ability to prevent soil erosion could help contain pollutants and protect nearby water bodies from further contamination (ElyandSmets, 2017). *Andropogon gayanus* is well distributed in many parts of Niger Delta alongside other common weeds such as *Sida acuta.*

Sida acuta is a weed commonly known as wire weed. It is a perennial plant belonging to the family of Malvaceae. *Sida acuta* is native to the tropics and subtropics and it is widely distributed in the Niger Delta (Benjumea, et al, 2016; Kew Science, 2021). It grows in a wide range of soil types and can survive different conditions including drought except for flooded clay soil (Cabi, 2022). *Sida acuta* serves as food for livestock. It is also used for medicinal purposes (Idrees,et al, 2018; Adesina, et al, 2020). *Sida acuta* has demonstrated promise in removing heavy metals, organic pollutants, and nutrients from contaminated soil and water (Benjamin et al, 2016; Cabi, 2022). Its ability to absorb and accumulate contaminants, coupled with its adaptability to diverse environmental conditions, makes it an asset for soil remediation efforts (Ebiye, Oku and Alexander, 2021). *Sida acuta* offer several environmental advantages, including erosion control, restoration of degraded ecosystems, and suppression of weed infestations (Azubuike et al, 2016; Beans, 2017). The plant's resilience to local environmental stress enhances its suitability for phytoremediation practices and it can be found growing as weeds in the midst of Okra and maize farm. This study therefore explores natural means to remedy crude oil polluted soil which have been rendered unproductive to plant growth with locally available plants such as *Andropogon gayanus* and *Sida acuta*.

Methodology

The study adopted experimental research design based on Completely Randomized Block Design (CRBD). The study was carried out in Ogulagha Grammar School, Demonstration Farm. Ogulagha is an oil producing community in Burutu Local Government Area of Delta State. The people of Ogulagha community are farmers, they engage in fish farming and planting of crops in the little available portion of land. There is a deserted plot of land in the community for over a year due to crude oil spillage. Attempt to cultivate crops on the polluted land have not been successful. However, there are traces of *Andropogon gayanus and Sida acuta* around the polluted land. The study area was selected with respect to the foregoing, easy access to crude oil, climatic consideration, and the relationship between the study area in terms of agricultural activities with other neighbouring communities in the Niger-Delta region.

The population of this study was 150 sack bags filled with 20kg soil samples, 10 litres of crude oil, 10kg seeds each for *Andropogon gayanus, Sida acuta,* Okro and Maize. The sample for the study was 120 sack bags filled with 20kg soil samples, 6 litres of crude oil, 120 *Andropogon gayanus* seeds, 120 *Sida acuta* seeds, 240 Okro and Maize seeds respectively. The 120 sack bags filled with 20kg soil samples represented 6 treatment groups replicated 5 times making 30 sets. 4 sack bags from the 30 sets were randomly selected from each treatment group for the study. The materials for data collection were A*ndropogon gayanus, Sida acuta,* Okra, Maize, soil, crude oil, measurement tape, liquid measuring cup, measuring scale, sack bag and spade. The research instrument was subjected to face validation by three experts.

The study lasted for 4 months and 3 weeks (141 days). It started 6th October, 2024 to 24th February, 2025. 3000kg of loamy soil were gathered within the premises of the Ogulagha Grammar School, Demonstration farm. 20kg from the 3000kg of loamy soil were measured into 150 sack bags. The 150 sack bags filled with 20kg soil samples represented 6 treatment groups; each group had 25 sack bags. The treatments were T1= 20 kg soil + 0 ml crude oil, T2= 20 kg soil + 0 ml crude oil, T3= 20 kg soil + 50 ml crude oil, T4= 20 kg soil + 50 ml crude oil, T5= 20 kg soil + 100 ml crude oil, T6= 20 kg soil + 100 ml crude oil. 2 litres of crude oil was used as pollutant for T3 and T4 treatment group. 4 litres of crude oil was used as pollutant for T5 and T6 treatment group respectively. Consequently, 48 hours after the various treatment groups were polluted, 2 seeds of *Andropogon gayanus* each were planted in T1, T3 and T5 also 2 seeds of *Sida acuta* each were planted in T2, T4 and T6 respectively. However, after two months when *Andropogon gayanus* and *Sida acuta* were harvested, 2 seeds of Okro each were planted in the bags where *Angropogon gayanus* was harvested and 2 seeds of Maize each were planted in the bags where *Sida acuta* was harvested. 4 sack bags were randomly selected from each treatment group for the study. Records of growth and yield parameters for Okro and Maize were collected on a weekly basis for 10weeks.

The instrument for data collection was a structured observation template. The structured items of the instrument were developed by the researcher using the related literature reviewed. Data were collected by the researcher and one research assistant. Data collected were analyzed using mean to answer the research questions.

The following research questions guided the study

1. What are the effects of crude oil remediated soil on the growth parameters of okra?
2. What are the effects of crude oil remediated soil on the growth parameters of maize?
3. What are the effects of crude oil remediated soil on the yield parameters of okra?
4. What are the effects of crude oil remediated soil on the yield parameters of maize?

Presentation and Discussion of Results

Research Question 1: What are the effects of crude oil remediated soil on the growth parameters of okra?

Table 1: Mean Analysis of the Growth Parameters of Okra Planted in Crude Oil Remediated Soil

Parameters	**T1**	**T2**	**T3**
Plant Height (cm)	21.76	19.20	16.64
Leaf Area(cm)	7.06	7.33	6.28
Number of Leaves	2.37	2.40	2.29
Number of Nodes	1.34	1.45	1.35
Number of Branches	2.22	2.33	1.82

T1= 20 kg soil + 0 ml crude oil planted okra,T2= 20 kg soil + 50 ml crude oil planted okra,T3= 20 kg soil + 100 ml crude oil planted okra

Results presented in Table 1 showed that okra plant height (21.76) was highest in unpolluted soil (T1).Leaf area (7.33 cm), number of leaves (2.40), number of nodes (1.45) and number of branches (2.33) were highest in 50 ml crude oil remediated soil. Furthermore, okra plant height (16.64 cm), leaf area (6.28 cm), number of leaves (2.29) and number of branches (1.82) were least in 100 ml crude oil remediated soil. This shows the ability of okra to grow in crude oil remediated soil (with *Adropogon gayanus*). The findings of this study were in line with the findings of Umeh et.al (2024) in a study on effects of organic soil amendment on the growth and yield of okra in South-eastern Nigeria; where it was found out that poultry manure + rice husk + compost + cow dung performed significantly well in plant height and number of leaves. The findings of the study were further in conformity with the findings of Victor and Sifan (2015) who carried out a study on the growth and yield of okra as influenced by compost application under different light interactions; where it was found out that compost generally increased growth rate and leaf area.

Research Question 2: What are the effects of crude oil remediated soil on the growth parameters of maize?

Table 2: Mean Analysis of the Growth Parameters of Maize Planted in Crude Oil Remediated Soil

Parameters	T1	T2	T3
Plant Height (cm)	106.5	82.59	59.87
Number of leaves/plant	6.25	3.79	3.69
Leaf Length (cm)	46.88	38.50	39.83
Leaf Area (cm^2)	4.40	4.51	4.29
Stem Diameter (cm)	2.88	3.15	3.09

T1= 20 kg soil + 0 ml crude oil planted maize,T2= 20 kg soil + 50 ml crude oil planted maize,T3= 20 kg soil + 100 ml crude oil planted maize

Table 2 showed that unpolluted soil (T1) produced maize with the highest plant height (1.06.5 cm), number of leaves/plant (6.25) and leaf length (46.88 cm) while the 50 ml crude oil remediated soil (T2) produced maize with the highest leaf area (4.51 cm^2) and stem diameter (3.15 cm). Table 7 further showed that least plant height (59.87 cm), number of leaves/plant (3.60) and leaf area (4.29 cm^2) were produced in 100ml crude oil remediated soil while the least stem diameter (2.88 cm) was produced in unpolluted soil (T1). This is a testament of the effect of *Sida-acuta*, as a remedy to crude oil polluted soil, as some growth parameters of maize planted in the remediated soil were better than those planted in unpolluted soil. The findings of the study were in line with the findings of Ali, et al (2021) who carried out a study on biochar and Bacillus sp. MN54 assisted phytoremediation of diesel and plant growth promotion of maize in hydrocarbons contaminated soil in Pakistan; where it was found out that *Bacillus sp.*MN54 and biochar additive phytoremediated petroleum hydrocarbons contaminated soil with notable output in maize plant cultivated. The findings of the study were further in consonance with the findings of Fatima, et al. (2018) who carried out a study on the successful phytoremediation of crude-oil contaminated soil at an oil exploration and production company by plants-bacterial synergism in Pakistan; the study revealed that *Leptochloafusca* and *Brachiariamutica* possess phytoremediation abilities.

Research Question 3: What are the effects of crude oil remediated soil on the yield parameters of okra?

Table 3: Mean Analysis of the Yield Parameters of Okra Planted in Crude Oil Remediated Soil

Parameters	T1	T2	T3
Number of fruits/stand	8.4	2.4	1.4
Fruit Length (cm)	7.6	4.6	3.5
Fruit Weight (g)	100	50	43
Number of ridges/fruit	7.2	6	4.6

T1= 20 kg soil + 0 ml crude oil planted okra,T2= 20 kg soil + 50 ml crude oil planted okra,T3= 20 kg soil + 100 ml crude oil planted okra

Table 3 showed that okra planted in unpolluted soil (T1) had the highest number of fruits/stand (8.4), fruit length (7.6 cm), fruit weight (100 g) and number of ridges/fruit (7.2) while the okra planted in 100 ml crude oil remediated soil (T3) had the least number of fruits/stand (1.4), fruit length (3.5 g), fruit weight (43 g) and number of ridges/fruit. This is an indication that the outcome of yield parameters of okra planted in crude oil remediated soil (with *Andropogon gayanus*) varies depending on the range of soil contamination. The findings of the study were in agreement with the findings of Mal, et al (2013)in a study on the growth and yield parameters of Okra influenced by *Diazotrophs* and chemical fertilisers; where it was found out that the maximum growth parameters, highest yield and yield attributing characters of Okra were a product of the volume of *Diazotrophs* and chemical fertilisers applied to the soil. The findings of the study were further in consonance with the findings of Otuaro, et al (2024) in a study on the effect of different mulching materials on growth parameters and yield of Okra production in Nigeria; where it was found out that among the biodegradable and non-biodegradable mulches used in the study white polythene mulch was most effective with notable impact on the overall crop yield.

Research Question 4: What are the effects of crude oil remediated soil on the yield parameters of maize?

Table 4: Mean Analysis of the Yield Parameters of Maize Planted in Crude Oil Remediated Soil

Parameters	T1	T2	T3
Cob length (cm)	19.4	19.2	18.4
Cob weight (g)	258.4	262.2	224.8
Number of seeds per cob	127.4	128.8	125
Weight of 1000 seeds (g)	312.8	302.4	252.8

T1= 20 kg soil + 0 ml crude oil planted maize,T2= 20 kg soil + 50 ml crude oil planted maize,T3= 20 kg soil + 100 ml crude oil planted maize

Results in Table 4 showed that unpolluted soil (T1) had the highest cob length (19.4 cm) and weight of 1000 seeds (312.8 g) while the 50 ml crude oil remediated soil (T2) had the highest cob weight (262.2 g) and number of seeds per cob (128.8). Meanwhile, 100 ml crude oil remediated soil (T3) had the least cob length (18.4 cm), cob weight (224.8 g), number of seeds per cob (125) and weight of 1000 seeds (252.8 g). Consequently, *Sida-acuta* as a remediator to crude oil polluted soil was most effective in 50 ml crude oil polluted soil compared to 100ml crude oil polluted soil.The findings of the study in this direction were in consonance with the findings of Amoke and Amadi (2023) in a study on the potentials of bioremediation of palm oil mill effluent: Effects on growth and yield parameters of maize plant; the study showed a favourable effect on the growth parameters measured, with visible inhibitory effects on the yield parameters. The findings of the study on effects of crude oil remediated soil on the yield parameters of maize were also in line with the findings of George et al (2023) in a study on soil quality alteration and maize yield after organic amendment in China; where it was found out that biochar-straw based soil management approach and poultry manure can improve soil quality and grain yields. Furthermore, the findings of the study on effects of crude oil remediated soil on the yield parameters of maize contradicts the findings of Okonokhu, et al (2010) in a study on the effects of spent engine oil on soil properties, growth and yield of maize; where it was found out that growth parameters were stunted with significant low yield. Therefore, it is expected that crude oil polluted soil must be remediated for sustainable agricultural production.

Conclusion

From the findings of the study, it was concluded that *Andropogon-gayanus* and *Sida-acuta* are both capable of managing crude oil polluted soil according to the volume of the pollutant on the soil. To confirm their phytoremediation potential on contaminated soil, Okra and Maize were planted on remediated soil and the growth and yield parameters of okro and maize planted on crude oil remediated soil were found sustainable for crop production in Niger Delta, Nigeria.

References

Abd El-Kader, A. A.; Saaban, S. M.; Abd El-Fattah, M. S. (2010) Effect of irrigation levels and organic compost on okra plants (*Abelmoschus esculentus* L.) grown in sandy calcareous soil. *Agriculture and Biology Journal of North America,* 1, 225-231. https://doi.org/10.5251/abjna.2010.1.3.225.231

Adesina, D. A., Adefolalu, S. F., Jigam, A. A. and Lawal, B. (2020). Antiplasmodial effect and sub-acute toxicity of alkaloid, flavonoid and phenolic extracts of Sida acuta leaf on Plasmodium berghei-infected animals. *Journal of Taibah University for Science* 14(1), 943-953

Akpoveta, O. V. (2016). Fenton oxidative mechanism and its kinetics on the remediation of soil contaminated with unrefined petroleum oil. *Journal of Chemical Society of Nigeria*, 41(2), 54 – 61.

Alegbejo, M.; Ogunlana, M.; Banwo, O. (2008) Survey for incidence of okra mosaic virus in northern Nigeria and evidence for its transmission by beetles. *Spanish Journal of Agricultural Research*, 6, 408-411. https://doi.org/10.5424/sjar/2008063-342

Ali, M. H., Khan, M. I., Bashir, S., Azam, M., Naveed, M., Qadri, R., Bashir, S., Mehmood, F., Shoukat, M. A., Li, Y., Alkahtani, J., Elshikh, M. S. andDwiningsih, Y. (2021). Biochar and Bacillus sp. MN54 assisted phytoremediation of diesel and plant growth promotion of maize in hydrocarbons contaminated soil. *Agronomy* 11(1795). https://doi.org/10.3390/agronomy11091795

Azubuike, C. C., Chikere, C. B., andOkpokwasili, G. C. (2016). Bioremediation techniques-classification based on site of application: principles, advantages, limitations and prospects. *World Journal of Microbiology and Biotechnology*, *32*(11), 180. https://doi.org/10.1007/s11274-016-2137-x

Beans, C. (2017). Phytoremediation advances in lab, lags in field. *Proceedings of the National Academy of Sciences* 114 (29) 7475-7477; DOI: 10.1073/pnas.1707883114

Benjumea, D. M., Gómez-Betancur, I. C., Vásquez, J., Alzate, F., García-Silva, A. andFontenla, J. A. (2016). Neuropharmacological effects of the ethanolic extract of Sida acuta. *RevistaBrasileira de Farmacognosia* 26(2), 209-215. https://doi.org/10.1016/j.bjp.2015.09.011

Benjumea, D. M., Gómez-Betancur, I. C., Vásquez, J., Alzate, F., García-Silva, A. andFontenla, J. A. (2016). Neuropharmacological effects of the ethanolic extract of Sida acuta. *RevistaBrasileira de Farmacognosia* 26(2), 209-215. https://doi.org/10.1016/j.bjp.2015.09.011

Briggs, I. L. and Briggs, B. C. (2018). Petroleum industry activities and human health. In P. E. Ndimele (Ed.), *The political ecology of oil and gas activities in the Nigerian aquatic ecosystem*, 143 – 147. Doi: 10.1016/b978-0-12-809399-3.00010-0

Cabi (2022). Invasive Species Compendium. Wallingford, UK: CAB International. Retrieved March 15, 2022 from www.cabi.org/isc.

Cooper, S. (2013). *Soil remediation and the environment*. Retrieved December 24, 2021 from https://eponline.com/Articles/2013/09/19/Soil-Remediation-and-the-Environment.aspx?Page=1

Daran, A., Croitoru, M. and George, C. (2022) Achievements and perspective of growing fruits on sandy soils.*Fruit Growing Rescue* 28 (1)

Ebiye, A., Oku, H. O. and Alexander, C. B. (2021). Crude oil polluted Niger Delta environment: conservation techniques for survival. *Scholars Bulletin* 7(9), 252-263. DOI: 10.36348/sb.2021.v07i09.004

Ely, C. S. and Smets, B. F. (2017). Bacteria from wheat and cucurbit plant roots metabolize PAHs and aromatic root exudates: implications for rhizodegradation. *International Journal of Phytoremediation* 19(10), 877 – 883. https://doi.org/10.1080/15226514.2017.1303805

Essien, O. E., John, I. A (2010). Impact of crude-oil spillage pollution and chemical remediation on agricultural soil properties and crop growth. *Journal of Applied Science and Environmental Management* 14 (4) 147 – 154

Fabio, T., Brigitha, B., Francesco, G. C. and Garcia, M. C. (2020) Soil fertility management in organic greenhouse: *An analysis of the european contest*. DIO: 10.17660//ActaHortic.2020.1164.15

Flores, R. A., Collier, L. S., Santos, C. L. R., Borges, B. M. M. N., Moda, L. R. and Silva, A. R. (2014). *Andropogon* grass consortium with stylo in two times: the forage response and sources of phosphorus rates. *Bioscience Journal* 30(5), 824-832

George, O. O., Zhihua, L., Kolapo, O. O., Kehinde, O. E. and Yaku, S. (2023) Soil quality alteration and maize yield after organic amendment application to a PellicVertirol in China.*International Journal of Waste Resources* 5(112) http://dx.doi.org/31.2172/18252-5211.1430195

Heuzé, V., Tran, G., Assouma, H., Bazan, S. and Lebas, F. (2021). Gamba grass (*Andropogon gayanus*). Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/510 Last updated on September 23, 2021, 17:31

Idrees, M., Batool, S., Kalsoom, T., Raina, S., Sharif, H. M. A., and Yasmeen, S. (2018). Biosynthesis of silver nanoparticles using *Sida acuta* extract for antimicrobial actions and corrosion inhibition potential. *Environmental Technology*, 1–8. Doi:10.1080/09593330.2018.1435738

Ikehi, M., Onu, F, Ifeanyieze, F, Paradang, P., (2014) Faming families and climate change issues in Niger Delta Region of Nigeria. Extent of Impact and Adaptation Strategies, *Agricultural Science*, 5, 1140-1151

Ikhumetse, A. A., Abioye, O. P., Ijah, U. J. J. and Bankole, M. T. (2022). A critical review of oil spills in the Niger Delta aquatic environment: causes, impacts and bioremediation assessment. *Environmental Monitoring and Assessment 194*(816). https://doi.org/10.1007/s10661-022-10424-x

Jolaoso, A. O., Njoku, K. L., Adedokun, A. H. andAdesuyi, A. A (2019). Assessment of automobile mechanic workshop soils in Lagos and the genotoxic potential of the simulated leachate using *Allium cepa L*. *Environmental quality*, 34(2019), 48-62

Keeran, N. S., Balasundaram, U., Govindan, G. andParida, A. K. (2019). *Prosopis juliflora*: A potential plant for mining of genes for genetic engineering to enhance phytoremediation of metals. In M. N. V. Prasad (Ed.) *Transgenic Plant Technology for Remediation of Toxic Metals and Metalloids*, Academic Press, (pp. 381-393) https://doi.org/10.1016/B978-0-12-814389-6.00018-3.

Kew Science (2021). *Sida acuta* Burm.f. plants of the world online. Royal Botanic Gardens, Kew, UK. Retrieved March 15, 2022 from https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:235518-2#sources

Khomiakov, C. (2020) Soil is an essential component of the biosphere and the global food system (Critical Assessment of the Situation). *Moscow University Soil Science Bulletin* 75, (4-5) 147-158

Lima, J. R. L, Rodrigues, R. C., Sousa, G. O. C., Costa, C. S., Parente, H. N. and Santos, F. N. S. (2020). Ecophysiology of *Andropogon* grass subjected to different cutting frequencies and intensities. *RevistaBrasileira de EngenhariaAgrícola e Ambiental* 249(9), 610-615. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v24n9p610-615

Marin, M. V.; Santos, L. S.; Gaion, L. A.; Rabelo, H. O.; Franco, C. A.; Diniz, G. M. M.; Silva, E. H. C.; Braz, L. T. (2017) Selection of resistant rootstocks to *Meloidogyne enterolobii* and *M. incognita* for okra (*Abelmoschus esculentus* L. Moench). *Chilean Journal of Agricultural Research*, 77, 58-67. https://doi.org/10.4067/S0718-58392017000100007

Moses, B. A., and Abiola U. (2012) Effects of different soil amendment on the growth and yield parameters of okra in a tropical rainforest of Southwestern, Nigeria. *Journal of Environmental studies and Conservation Practice*, *20*(8), 25-31.

Muralikrishna, I. V., and Manickam, V. (2017). Introduction. *Environmental Management*, 1–4. Doi:10.1016/b978-0-12-811989-1.00001-4

Muze, N. E., Opara, A. I, Ibe, F. C. and Njoku, O. C. (2020). Assessment of the geo-environmental effects of activities of auto-mechanic workships at Alaoji Aba and Elekahia Port Harcourt, Niger Delta, Nigeria. *Environmental Analysis Health and Toxicology* 35(2), https://doi.org/10.5620/eaht.e2020005

Ndimele, P. E., Saba, A. O., Ojo, D. O., Ndimele, C. C., Anetekhai, M. A. andErondu, E. S. (2018). Remediation of crude oil spillage. In P. E. Ndimele (Ed.), *The political ecology of oil and gas activities in the Nigerian aquatic ecosystem*, 369 – 384. Doi: 10.1016/b978-0-12-809399-3.00024-0

Nuss, E. T., &Tanumihardjo, S. A. (2011). Quality protein maize for Africa: Closing the protein inadequacy gap in vulnerable populations. *Advances in Nutrition*, 2, 217–224. Https://doi.org/10.3945/an.110.000182

Okonokhua, B. A., Ikhajagbe, B., Anoliefo, G. O. and Emade, T. O. (2010) The effects of spent engine oil on soil properties and growth of maize.Nigeria. *International Journal of Waste Resources* 5(112) http://dx.doi.org/11.4172/1252-5211.1330195

Oliveira, A. P. de; Silva, O. P. R. da; Silva, J. A.; Silva, D. F. da; Ferreira, D. T. A. de; Pinheiro, S. M. G. (2014) Produtividade do quiabeiroadubado com estercobovino e NPK. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 18, 989-993. https://doi.org/10.1590/1807-1929/agriambi.v18n10p989-993

Ordinioha, B. and Brisibe, S. (2013). The human health implications of crude oil spills in the Niger delta, Nigeria: an interpretation of published studies. *Nigerian Medical Journal: Journal of the Nigeria Medical Association*, *54*(1), 10 – 16. https://doi.org10.4103/0300-1652.108887

Poznyak, T. I., Oria, I. C. andPoznyak, A. S. (2019). Ozonation modeling in solid phase. In T. I. Poznyak, I. C. Oria and A. S. Poznyak (Eds.) *Ozonation and Biodegradation in Environmental Engineering* (pp. 277-323). Elsevier. https://doi.org/10.1016/B978-0-12-812847-3.00020-2.

Umeh, O. A., (2024) Effects of organic soil amendment on the growth and yield of okra in IfiteOgwari, Southeastern Nigeria.*African Journal of Agricultural Extension, 12*(17), 835-941.

Victor, A. D. and Sifan, A. A. (2015) Growth and yield of okra as influenced by compost application under different light interactions.*Journal of Clinical Practice, 22*(7), 127-131.

Whendee, L. S., Pete, S., Saskia, D. K. and Tapan, K. A. (2021) The role of soil in delivering nature's contribution to people. *Philosophical Transactions of the Royal Society*. https://DIO.org//10.1098/rstb.2020.0169