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Effect of Composting Mangrove Forest Litters on Remediation of crude-oil contaminated soil and Epigeal Emergence of Threatened Forest Tree Species

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***Abstract* -** The study evaluated the potency of three mangrove forest litter recombinant treatments and composting ages on the degradation of petroleum hydrocarbon. Contaminated soil samples from Shell Petroleum Development Company/Chevron Nigeria Limited Uto-Orogun right of way were infused with formulated composting mangrove forest litters balls at 5, 10 and 15-N (number) balls respectively in 10 replicates per treatments in a-4×3×10 completely randomized experimental design. These were allowed to degrade the crude oil molecules for a total period of 8 months and soil samples were analyzed for TPH, pH, and bulk density. Data were then subjected to analysis of variance (ANOVA) and significant means separated by the Duncan Multiple range test at 5%. The most decontaminated soil treatment was then used in the emergence trials of 400 seeds of IUCN-threatened *Dacryodes edulis*, *Irvingia gabonensis*, *Garcinia kola* and *Gambeya albidum* forest tree species at 100 seeds and 5 replicates per tree species under screen house conditions for 30days. Results showed TPH reduction that corresponded with increase in composting ages and number of decontamination balls with highest TPH reduction of 33% ($1.33\pm0.15 g/dm^3$) recorded at 6 months by the 15-N decontamination balls with significant increases in pH (7.4) and decline in soil bulk density ($1.50 g/cm^3$). Percentage epigeal emergence was *Dacryodes edulis* (43%) > *Garcinia kola* > *Gambeya albidum* > *Irvingia gabonenisis* (17%) at 4 weeks after planting. The study revealed composting mangrove forest litters as potential products for the remediation of crude oil-contaminated soil under sustained composting spectrum and in regeneration of the IUCN-threatened forest tree species in Delta State of Nigeria.

Key Words: Compost age, total petroleum hydrocarbon (TPH), shelf life, decontamination balls, emergence percentage.

I. INTRODUCTION

Biological approach to combating current world challenges with a view to mitigating carbon has significantly widened opportunities with compost products in agriculture, edaphic and atmospheric environments as a result of the varying degrees of potencies in generating veritable microbial communities to achieving set tasks [1,2]. This is because composts as naturally mediated products reserve capacities to provide specific activity that create internally apparent and aggressive community of microbes to manage key problems in biological environments. Composts are therefore specific spectrum shelf life products that act within a premise beyond which it efficiencies become undermined. The generation of compost product for utilization in different cornubations has been quite impactful in soil and plant related disease management [3,4].

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However, the sustainability of compost product have equally been shown to diminish with age especially after production, attaining highest efficacy after which its potential become ineffective in combating the challenge under field application. [5] showed decline in culturable microbial efficicacy after 3weeks due to decline in population and therefore emphasized the need for continued multiplication of microbial activities to form colony communities at different stages of composting which has often been truncated in processed compost products on the shelf. Faster and better growth response of *Terminalia spp* seedlings with compost in station pits than shelfed composts after 2months during the dry season in Asaba Urban forestry beautification project [6]. The report showed that the stems of station-pitted compost recorded higher quantity of buds with the roots having more root-hairs and higher moisture content than the seedlings with shelf compost.

The performance of microbes in compost products has also been related to nutrient resource availability for sustained microbial activity and multiplication has received significant emphasis as a readily reliable source for compost efficacy. [7] showed that higher bacteria community structures and higher degradation rates in the form of CO_2 was achieved with sustainably slow release nutrient source than liquid nutrient sources as teas. This constitute serious bane to shelf life of compost products, with every likelihood of rendering the attained science of such product uneconomically sound to attract further development. Therefore possibility of engaging and sustaining composting by direct utilization of compost feedstocks in service and not from the shelf represents better superior pathway to fortify spectra activities of compost mediated microbes. This is with a view to soliciting for sustainable growth, development and backup of compost microbial communities in service during composting to get more out of compost feedstocks [8].

However, [9] observed that spills from crude oil exploration and production activities affect the physical, biological and aesthetic value of the environment and the economic life as well as health of the local people and even distant environment [10]. Therefore, remediation methods to restore the perceived lost edaphic and economic activities due to crude oil contamination remains as critical capability proof to allow for potential adoption. Significantly higher total petroleum hydrocarbon removal rate was observed in unfinished compost amended experiments compared to finished compost due to its higher microbial activity released from different nutrient and organic carbon sources [11].

Forest tree species of the tropical forest that are endemic to the southern Nigeria with a good proportion forming the Niger Delta belt, constitute veritable sources of soil conservation, livelihood support in providing food as well as fodder for economic activities. *Dacryodes edulis* (Local pear), *Irvingia gabonensis* (Ogbono), *Garcinia kola* (Bitter kola) and *Gambeya albidum* (Africa star apple) are evergreen multipurpose tree species indigenous to Africa with ecological services of carbon sequestration, windbreak, protection against soil percolation and amelioration of micro-climatic conditions. Dacryodes is an edible fruit rich in lipids and protein while Gambeya as a fruit pulp constitutes source of protein, oil, vitamin C and minerals. Irvingia is a sweet edible fibrous pulp fruit which is rich in vitamin C and medicinal oil that has seed often used as soup thickener and Garcina edible fruit with medicinal value [12,13].

Unfortunately, these services have been greatly affected due to crude oil contamination of available land resource to further hype the threat by deforestation and land hunger for agriculture in the region. The objective of study was therefore to source for alternative, indigenous and sustainable method that is readily available for use by the locals to degrade crude oil molecules in contaminated soil for the germination and growth of *Dacryodes edulis, Irvingia gabonensis, Garcinia kola* and *Gambeya albidum* as possible solution

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for reclamation crude oil-contaminated soils in Delta State for suitable agricultural purposes. Hence the use of mangrove forest litters at different composting peak periods to produce microbes for the degradation of crude oil molecules in

Description of study area

The study was conducted in Ughelli, Ughelli North Local Government Area of Delta State, on lat. 5^{o} 30" N and long. 5^{o} 59 E. The town is loacated in the upper coastal swamp forest ecological zone of Delta State. The soil type is sandy loose to loosely packed porous, brightly whilte in colour and platy in shape. The forest is swampy with ocassional artificial lakes created by sand dreggers and ponds for agriculture that further increased the coarse graining of the ecosytem.

The temperature is tropical but characteristic of the Niger-Delta and range between 27-33.4°C with approximately290-450mm and 53-70mm of rainfall in the wet and dry seasons respectively [14]. There are high crude oil prospecting and exploration activities along the forest belts that provide edaphic support against coastal erosion.

II. METHODOLOGY

Soil Contamination Procedure

Top soil (0-30cm Depth) sample was obtained with soil augar from free area adjoining the SPDC/CNL Uto-Orogun right of way (ROW) in Ughelli North LGA of Delta State. These were then contaminated with Bonny light crude oil obtained from NNPC Warri office at the rate of 20ml per 100g (2.00g/dm^3) in poly pots and allowed under screen house conditions for 7 days.

Compost Preparation and Infusion

Freshly collected mangrove forest soil and matter that comprised of leaves, twigs and roots were air dried under a screen house temperature of 28-30^{O}C for 78 hours. The vegetative matters were crushed manually and mixed with the mangrove soil in ratio 2:1 (W/W) to constitute litters which were loaded at the rate of 18g per 0.20mm mesh size sewn circular bag to form decontamination balls. Emanating decontamination balls were then infused at different depths in the crude oil contaminated soil at the rate of 5, 10 and 15-N balls per poly pot at 10 replicates per treatment type in a 4 x 3 x10 complete randomized experimental design. These were left under screen house condition and temperature to degrade the crude oil molecules by composting. The total petroleum hydrocarbon (TPH), pH and bulk density of soil were monitored at 2, 4, 6 and 8 months after infusion (MAI).

Determination of TPH

The TPH were determined using the ultra-violet (UV) visible spectrophotometer to determine the extent of decontamination after treatment with the balls. The pH of the balls was determined using the digital pH meter at 1:1 soil-water suspension [15]. The bulk density was determined by core method [16].

Epigeal trials

The most degraded crude oil contaminated soil by the composting formulation was subjected to epigeal emergence trials with 400 seeds of *Dacryodes edulis* (Local pear), *Irvingia gabonensis* (Ogbono), *Garcinia kola* (Bitter kola) and *Gambeya albidum* (Africa star apple) that passed viability tests by the flotation

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method. These were sown in twenty (20) different black polyethene fabricated germination troughs measuring 100cm x 100cm x 50cm at 100 seeds and 5 troughs per tree species under screen house conditions. Emergence was sampled on weekly intervals for 4 weeks and then percentage emergence calculated as ratio of the number of emerged seed to the total number of seeds sown, multiplied by 100.

III. RESULTS

Effect of composting ages on crude oil degradation

Table 1 shows the effect of composting mangrove soil litters on the degradation of crude oil molecules. The TPH concentration varied significantly ($p > 0.05$) for the four different composting ages and three different quantities of decontaminated balls. At two months compositing period, the TPH concentration was highest (1.90 ± 0.48g/dm^3) and then least at 6 months (1.33 ± 0.15g/dm^3). There were significant differences among the four composting ages although there was no significant difference in the composting ages of 6 and 8 months with the 5-N decontamination balls.

The 10-N decontamination balls recorded the least degradation with the highest TPH concentration (1.87± 0.37g/dm^3) at two months composting while the highest effect of degradation of crude oil molecule was recorded at six months composting period with a TPH concentration of 1.41± 0.17g/dm^3. There was however significant difference among the other composting ages.

TPH concentration was significantly different for the four composting ages with respect to the 15-N decontamination balls. However, the least (1.33 ± 0.15g/dm^3) and highest (1.90 ± 0.48g/dm^3) TPH concentrations were recorded by at six and two months composting ages respectively.

Table 1: Effect of Composting Mangrove litters on Total Petroleum Hydrocarbon

	TPH(g/dm^3)		
Ages of Balls (Months)	**5**	**10**	**15**
	(Numbers of Balls per Pot)		
2.00	1.90 ± 4.84x10^{-1a}	1.87 ± 3.73x10^{-1a}	1.83 ± 3.23x10^{-1a}
4.00	1.80 ± 3.02x10^{-1b}	1.60 ± 2.34x10^{-1bc}	1.50 ±2.11x10^{-1b}
6.00	1.71 ± 2.83x10^{-1c}	1.41 ± 1.71x10^{-1d}	1.33 ± 1.53x10^{-1c}
8.00	1.70 ± 2.65x10^{-1c}	1.61 ± 2.44x10^{-1b}	1.50 ± 2.32x10^{-1b}

Means+ standard error in the same column with same superscript are not significantly different (p > 0.05)

Effect of composting age on pH

The pH varied significantly ($p > 0.05$) for the four different composting age and three different quantities of decontaminants balls (Table 2). At six months compositing period, the pH was highest (7.40) and then least at four months (5.20). There were significant differences among the four (4) composting ages although no significant difference in the composting ages of six and eight months with 5-N decontamination balls.

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The 10-N decontamination ball recorded the highest pH (7.01) at six months compositing period while the least pH (5.20) was recorded at two (2) and four (4) months composting periods. There was no however significant difference with pH at six months composting period.

Table 2: Effect of composting mangrove litters on the pH of contaminated soil

Ages of Balls (Months)	pH (H_2O) 5	10 (Number of Balls/ Pot)	15
2.00	5.80^{c}	5.20^{a}	5.80^{cd}
4.00	5.30^{d}	5.20^{c}	6.20^{c}
6.00	6.60^{a}	7.01^{a}	7.40^{a}
8.00	6.40^{b}	6.80^{b}	6.60^{ab}

Means in the same column with same superscript are not significantly different ($p > 0.05$)

Effect of composting litter on soil physical properties

The bulk density varied significantly ($p > 0.05$) for the four different composting age and three different quantities of decontamination balls (Table 3). At two months composting period the bulk density was highest ($1.89 g/cm^3$) and then least at eight months ($1.58 g/cm^3$). There were significant differences among the four composting ages as well between the composting ages of six and eight months with 5-N decontamination balls with the bulk densities of $1.6 g/m^3$ and $1.58 g/ m^3$ respectively.

The 10-N decomposition ball recorded the highest bulk density ($1.88 g/cm^3$) at two months composting while the least $1.53 g/cm^3$ was recorded at six months composting period. However, there was significant different difference four and six months with bulk densities of $1.78 g/cm^3$ and $1.57 g/cm^3$ respectively.

The bulk density of the four composting ages with respect to the 15-N decontamination balls. However, the least bulk density ($1.50 g/cm^3$) and highest ($1.84 g/cm^3$) were recorded at two and six months composting ages respectively.

Table 3: Effect of composting mangrove litters on bulk density of contaminated soil

Ages of Balls (Months)	Bulk Density(g/cm^3) 5	10 (No of Balls/ Pot)	15
2.00	1.89^{a}	1.88^{a}	1.84^{a}
4.00	1.80^{b}	1.78^{bc}	1.74^{b}
6.00	1.68^{c}	1.53^{d}	1.50^{bc}
8.00	1.58^{d}	1.57^{b}	1.55^{b}

Means in the same column with same superscript are not significantly different ($p > 0.05$)

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Epigeal trial

The emergence percentage of the four threatened indigenous forest tree species are shown in Figure 1. The *Dacryodes edulis* recorded the highest (43%) and least (17%) emergence at 4 weeks after planting. At the first sampling interval, there was no emergence of *Gambeya albidum* and *Irvingia gabonenesis* while *Dacryodes edulis* and *Garcinia kola* recorded 10% and 4% emergence respectively.

During the second sampling interval, Irvingia did not record any emergence as only the Dacryodes, Garcina and Gambeya showed 25%. 10% and 10% emergence respectively. Then at the third interval, it was Dacryodes (38%), Garcina (22%), Gambeya (17%) and Irvingia (15%).

The emergence at last sampling interval of four weeks was Dacryodes (43%) > Garcina (28%) > Gambeya (20%) > Irvingia (17%).

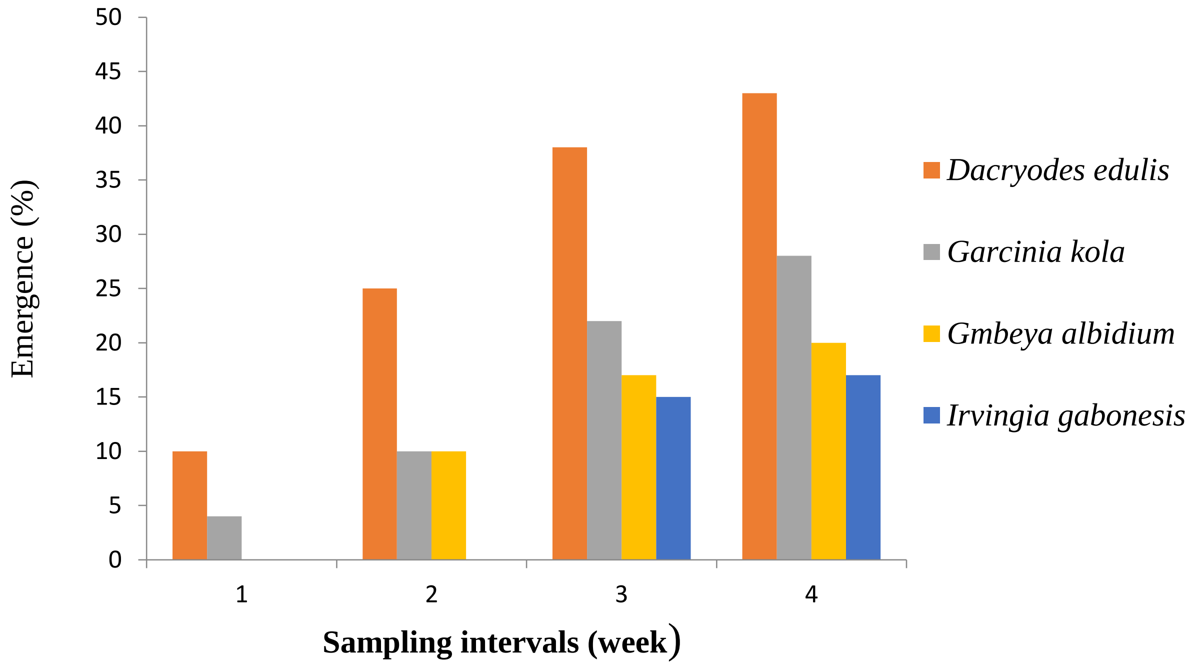

Figure 1: Effect of composting mangrove forest litters-remediated crude oil contaminated soils on emergence of forest trees species

IV. DISCUSSIONS

The study showed that a crude oil-contaminated soil with a concentration of 2.00g/dm^3 TPH achieved at least a-5% reduction in TPH when infused with mangrove forest compost for a period of 2 months. The recombinant mangrove forest compost achieved the highest reduction of petroleum hydrocarbon with 15-N composting balls at six months period with no further reduction at eight months. It therefore, implied that six months aging period is adequate for the recombinant mangrove compost to sustain microbial activities essential for crude oil molecule degradation. This finding agreed with [17] that natural microbial community of compost soil degraded crude oil molecules with increasing nutrient content under favourable environmental conditions

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The result revealed that there are correlations between TPH and soil pH, bulk density and porosity. This may not be unrelated with the capacity of microbial compost build-up to degrade by utilizing the crude oil molecules in the soil that clog pore spaces to reduce soil aeration [18]. Thus, at highest concentration of TPH, resulted to recording the lowest pH value which is an indication of high carbon content. This also sufficiently accounted for a highest bulk density. Consequently, at lower concentration level of TPH which indicated a reduction in the level of the crude oil contaminant present in the soil, there was corresponding increase in the pH that tended towards alkalinity with a commensurate reduction in bulk density.

The pH increased with composting age and quantity of decontamination balls. At six months, the 5, 10 and 15-N significantly adjusted pH from neutral (6.6 – 7.3) to slightly alkaline (7.4 – 7.8) ranges. This inclination toward alkalinity was observed to increase with the number of balls. Hence, the influence of the number of decontamination balls on pH showed that microbial population could have implications in the remediation process. This finding agrees with [19] that population of microbes within a compost system could lead to faster degradation of crude oil molecules, particulary when composting is sustained.

However at 8months, the potencies dwindled and staggered irrespective of the number of decontamination balls with the 10 and 15-N balls within the neutral pH range. This decline may not be unconnected with the likelihood of exhaustion with regards to the back up microbes in the compost feedstock that may have supported the activity, even at low rate from 2months. This finding significantly attests to the postulation that shelf compost products have lower microbial efficacy compared to sustainable composting type with probable regenerating potential.

Further more, as the quantity of decontamination balls increased, there was reduction in the bulk density of contaminated soil. This feat achieved with quantity of balls compared favorably with the aging period of compost at six and eight months for the 10 and 5-N balls respectively, even attaining better bulk density with 15-N at six months. This implied that composting beyond six months may not be necessary under sufficient quantity of feedstock materials that can sustainably maintain the process. This could be as a result of increasing number of colony forming units to aid the degradation of crude oil molecules on account of higher number of balls, probably due to the accessibility of carbon materials by competition [20].

Gain in composting time is very significant in maximizing the component microbial activities before retarding factors begins to set in. This gain in time is critical to the pursuit of remediation and land restoration purposes for suitable uses, especially in land-hunger communities.

The soil physical properties were adjusted by the composting microbes during the decontamination as shown by the pH range and bulk density to suit emergence. Although given uniform silvicultural treatment, the result showed that Dacryodes had the highest emergence rate at the first, second, third and forth sampling intervals. Irvingia did not emerge until the second interval while by the third interval all the trial species recorded various emergence percentages. There was however, no emergence response in the control. These differential epigeal emergence may probably be due to the differences in the response of various coating mesocarps to the uniform compost growth media at the given resultant bulk density. This is because higher ratio of compost in nursery materials promote growth and survival percentages of seedlings [21] due to an increasing aeration and sustained microbial activity by the compost feedstock. Furthermore, the bathing of protoplasmic mass by available water regime from the composting process which varied with sizes of the seed materials may also have accounted for the delay in emergence of the Gambeya and Irvingia

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[22]. This may also have been responsible for the poor percentage increases in the emergence of Gambeya and Irvingia at the third and forth sampling intervals compared to Dacryodes and Garcinia.

The high bulk density of the control may have impacted on available water capacity, root growth, movement of air and water through soil [23] to prevent the essential lubrication of the seed coats and iniate epigyl germination. Hence, no emergence was observed in the unremediated crude oil-contaminated soil unlike the compost infused soils to reveal mangrove recombinant compost as viable cheaper options to chemical surfactants [24,25].

V. CONCLUSION

Composting mangrove litters at various ages demonstrated different potencies for the degradation of crude oil molecules in contaminated soil. The highest efficacy in reduction of total petroleum hydrocarbon and soil bulk density with the 15-N composting balls at six months peak period led to the highest epigeal emergence of evaluated IUCN-threatened forest tree species. Therefore, sustained composting activity is a novel approach for better and higher microbial community compared to existing shelf compost products especially for forest regeneration activities of endemic IUCN threatened and vulnerable forest tree species in Delta State.

VI. ACKNOWLEDGMENT

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