Evaluation of *Tectona grandis* (Linn.) and *Gmelina arborea* (Roxb.) for Phyto-remediation in Crude Oil Contaminated Soils

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Summary

A study on the effectiveness of *Tectona grandis* and *Gmelina arborea* as forest species for the phyto- remediation of crude oil contaminated soils showed that both plants responded differently to the crude oil effects. Although the plant height, number of leaves, leaf area, plant girth and the dry biomass of the test plants were significantly P≥0.05 affected at higher levels of oil treatments 10% and 15%, the 1% and 5% levels of contamination did not significantly P≤0.05 differ from the seedlings planted in the uncontaminated soils. *T. grandis* and *G. arborea* as shown in this study could be good species for phyto- remediation of crude oil contaminated habitats due to oil exploration and exploitation especially at low concentrations.

Key words

Tectona grandis, Gmelina arborea, seedlings, phyto-remediation, crude oil contaminated soils

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Introduction

Environmental pollution from oil is one of the consequences of oil exploitation and exploitation in Nigeria particularly, and in the Niger Delta area (Agbogidi *et al.*, 2005a; Agbogidi and Ofuoku, 2005). The Niger Delta region commonly referred to as the hub of oil industrial activities, forms a natural habitat to forests and their vast diversities (Ogbe, 2005). Oil pollution effects have been shown to have devastating effects on agricultural lands and tree species (Agbogidi *et al.,* 2005a; Agbogidi and Ejemete, 2005; Agbogidi and Eshegbeyi, 2006). Although a lot of measures including chemical control are available for reclamation of oil impacted sites, the use of indigenous tree species to remediate oil polluted soils is not only economical, but also, environmentally friendly. This is because the plants may bio-concentrate or bio-accumulate some toxic components in the crude oil including heavy metals and other hydrocarbon contaminants in their structures and systems. Soils renovated by the plants are stripped of their pollutants. The benefits of phyto remediation include simple technology, its versatility and little or no energy cost.

There is however, paucity of information on the restoration of oil-impacted soils using forest tree species. *Tectona grandis* (Teak) and *Gmelina arborea* (Gmelina) belong to the family Verbenaceae (Keay, 1989). Both are exotic species to Nigeria but have been widely cultivated in the rainforest zone of many countries including Nigeria (Keay, 1989). This study was designed to evaluate the effectiveness of *Tectona grandis* and *Gmelina arborea* seedlings for phyto-remediation in crude oil contaminated soils.

Materials and methods

The study was conducted in Delta State University (DELSU), Asaba Campus, Nigeria. Asaba is located at latitude 6º 14'N and longitude 6º 49'E of the Equator. Asaba lies in the tropical rainforest zone and it is characterised by rainfall ranging from 1500 mm to 1849.3 mm. The mean temperature is 28 ± 6ºC, relative humidity is between 69 and 80% and monthly sunshine of 4.8 hours (Asaba Meteorological Station, 2003).

Teak is highly valued among the hardwoods because of its durability hence Bhat and Hwan (2004) and Nakata and Isoda (2005) stated that among timbers, teak is of high value in wood industry. Gmelina is valued for its fast growth. Twenty (20) weeks old seedlings of *T. grandis* were sourced from the Forestry Research Institute of Nigeria (FRIN) lbadan, Oyo State. The seedlings (14 weeks of age) of G. *arborea* were obtained from the Departmental nursery of Forestry and Wildlife, Delta State University, Asaba Campus.

The crude oil (with specific gravity of 0.8788 gcm^{-3}) was sourced from the Nigerian National Petroleum Corporation (NNPC), Warri, Delta State while the soil mixture used (2:1 ratio of topsoil to rotten manure) was collected from the Gmelina plantation behind the Department of Forestry and Wildlife, DELSU, Asaba Campus. The crude oil concentrations used were 0, 1, 5, 10 and 15% w/w of soil. The experiment was laid out in a randomized complete block design (RCBD) with four replicates.

The seedlings of both *T. grandis* and *G. arborea* were transplanted to the crude oil treated soils including the uncontaminated (control) soils at 20 weeks and 14 weeks of age respectively. The seedlings were watered to field capacity immediately and after wards, every other day until the end of sampling period. One seedling was transplanted into each poly pot (30/20 cm). There were five treatments and each consisted of 8 poly pots. The experiments were replicated four times. A total of 200 seedlings were transplanted per plant species. The set up was monitored for 3 months after transplanting and parameters were measured every month starting from the first month after transplanting (MAT). Parameters measured were plant height, number of leaves, leaf area, collar girth and dry biomass. Plant height was measured with a measuring tape at a distance from soil level to terminal bud. Number of leaves was determined by visual counting of the number of leaves per seedling per treatment. Leaf area determination was by tracing the leaves on a graph paper and the total leaf area per plant was obtained by counting the number of 1cm squares. Collar girth of stem at 3 cm from soil level was measured using veneer calipers. At the end of the trial (3 MAT), the plants were harvested and sorted into roots, stems and leaves per treatment. The various parts were oven dried at 75º C for 18 hours following the procedure of ISTA (1966).

Data collected were subjected to analysis of variance and significant means were separated with the Duncan's multiple range test (DMRT) using SAS (1996).

Results and discussion

The results showed that both plants responded differently to crude oil treatment. The growth of *G. arborea* in the presence of the oil contaminant was significantly ($P \leq 0.05$) higher when compared with that of *T. grandis* throughout the experimental period (Tables 1, 2, 3, 4 and 5). The observed significant differences in the growth characters of *G. arborea* and *T.grandis* indicated that plants respond differently to crude oil treatments. This observation corroborates to the reports of Agbogidi and Ofuoku (2005) who stated that plants response to environmental stress depends on an innate genetic response of the plant

Table 1. Plant height (cm) of *Tectona grandis* and *Gmelina arborea* affected by crude oil (% w/w) in soil

Plant species	Plant height/oil level				
	0	1	5	10	15
1MAT					
T. grandis	29.1a	29.0a	28.4a	20.8b	18.6c
G. arborea	0.6a	40.4a	39.5a	32.3b	28.4c
2MAT					
T. grandis	32.0a	31.6a	31.2a	22.4b	20.0c
G. arborea	42.3a	42.1a	41.8a	36.4b	30.2c
3MAT					
T. grandis	34.4a	33.6a	33.2a	22.5b	20.0c
G. arborea	46.2a	45.3a	45.0a	36.6b	30.2c

Means in the same column with different superscripts and within the same MAT are significantly different at P≤0.05 using Duncan's multiple range test. MAT= month after transplanting.

Table 2. Number of leaves/plant of *T. grandis* and *G. arborea* affected by crude oil (% w/w) in soil

Plant species	Number of leaves/oil level				
	0	1	5	10	15
1MAT					
T. grandis	6.0a	5.8a	5.4a	3.6b	3.2c
G. arborea	7.2a	7.0a	6.2a	4.0b	3.7c
2MAT					
T. grandis	7.8a	6.0a	5.6a	3.7b	3.0c
G. arborea	8.4a	8.0a	7.7a	4.1b	3.3c
3MAT					
T. grandis	8.3a	7.0ab	5.7ab	3.2b	2.4c
G. arborea	8.9a	8.7a	7.8b	4.0b	3.0c

Means in the same column with different superscripts and within the same MAT are significantly different at P≤0.05 using Duncan's multiple range test. MAT= month after transplanting.

Table 3. Leaf area (cm^2)/seedling of *T. grandis and G. arborea* influenced by crude oil (% w/w) in soil

Plant species	Leaf area/oil level				
	0	1	5	10	15
1MAT					
T. grandis	56.4a	56.1a	54.0a	30.6b	26.4c
G. arborea	70.6a	68.2a	68.2a	46.7b	32.5c
2MAT					
T. grandis	60.7a	59.3a	58.0a	32.1b	27.4c
G. arborea	82.4a	82.2a	80.6a	46.9b	32.2c
3MAT					
T. grandis	64.3a	63.4a	59.6a	31.3b	25.0c
G. arborea	88.9a	88.2a	87.7a	42.6b	30.1c

Means in the same column with different superscripts and within the same MAT are significantly different at P≤0.05 using Duncan's multiple range test. MAT= month after transplanting.

system as influenced by other environmental factors. The result also showed that crude oil has variable effects on the test plants with different levels of oil contamination. This finding gives support to earlier work of Agbogidi and Nweke (2005) and Agbogidi *et al.* (2005b) who reported

Table 4. Collar girth (cm)/seedling of *T. grandis* and *G. arborea* influenced by crude oil (% w/w) in soil

Plant species	Collar girth/oil level				
	0	1	5	10	15
1MAT					
T. grandis	3.1a	3.0a	2.9a	2.5b	2.4b
G. arborea	3.5a	3.4a	3.2a	3.1b	3.0c
2MAT					
T. grandis	3.4a	3.2a	3.1a	2.6b	2.5c
G. arborea	3.7a	3.5a	3.4a	3.0b	2.6c
3MAT					
T. grandis	3.6a	3.5a	3.3a	2.4b	2.2c
G. arborea	3.9a	3.8a	3.6a	2.8b	2.4c

Means in the same column with different superscripts and within the same MAT are significantly different at P≤0.05 using Duncan's multiple range test. MAT= month after transplanting.

Table 5. Dry biomass (g) of *T. grandis* and *G. arborea* affected by crude oil (% w/w) in soil

Oil in soil (%w/w)	Plant parts		
	Leaves	Stems	Roots
T. grandis			
0	4.4a	6.4a	3.6a
1	4.2a	6.1a	3.4a
5	4.1a	5.9a	3.1a
10	3.0b	4.3b	2.4b
15	2.2c	3.2c	2.0c
G. arborea			
0	6.6a	8.6a	4.7a
1	6.3a	8.4a	4.5a
5	6.1a	8.2a	4.4a
10	4.0b	5.0b	3.3b
15	3.2c	3.6c	2.7c

Means in the same column with different superscripts and within the same plant species are significantly different at P≤0.05 using Duncan's multiple range test.

that crude oil application to soil has varying effects on plant growth.

Although plant height, number of leaves, leaf area, collar girth and the dry biomass of the test plants were significantly (P≥0.05) affected at higher levels of oil treatment (10 and 15%), the seedlings subjected to 1 and 5% levels of contamination did not differ significantly (P≤0.05) from seedlings that were planted in the uncontaminated soils throughout the sampling period (Tables 1,2,3,4 and 5). These results are consistent with those of Agbogidi and Ejemete (2005), Agbogidi and Eshegbeyi (2006), and Agbogidi and Nweke (2005) who noted that growth characters of plants including plant height and collar growth were not significantly affected by crude oil treatment at lesser concentrations of crude oil contamination. The observed reduction in the performances of the test plants at higher oil levels (10% and 15%) in this study could be attributed to the altered structure of the soil following crude oil application to soil. Reduction in the number of leaves and leaf area may be due to leaf fall. Defoliation of leaves consequent upon soil treatment with crude oil has been reported by Agbogidi *et al*. (2005b). It could be due to inadequate leaf turgidity stemming from the altered nature of the soil as a result of crude oil treatment. The observed negative interaction between the dry matter accumulation of the seedlings and the crude oil contamination level could be interpreted as a derangement of the soil-water relation of the plants consequent upon the presence of the oil thereby inhibiting translocation of both photosynthates and water throughout the plant body. This finding is in agreement with the reports of Bamidele and Agbogidi (2006).

T. grandis and *G. arborea* as shown in this study did not suffer tremendous reductions in growth up to 10% oil treatment hence they could be good species for phyto-remediation of crude oil contaminated habitat. A good phyto-remediation species is one that thrives well in a contaminated habitat (Bamidele and Agbogidi, 2006) and the evidence presented in this study does support the use of *T. grandis* and *G. arborea* in phyto-remediation of soils contaminated by oil due to crude oil exploration and exploitation. The present study is very relevant in the present quest for environmentally friendly processes for remediation of oil-polluted areas.

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