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Contamination from Petroleum Products: Impact on Soil Seed Banks around an Oil Storage Facility in Ibadan, South-West Nigeria

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ABSTRACT: The plants, grown in the soils around a Fuel Holding Depot of the Nigerian National Petroleum Corporation, Ibadan, Oyo state, Nigeria have been investigated in this research in terms of their density and species composition so that the impact of contamination by petroleum products on soil seed banks could be determined. The study has used designated plots (25m by 25m) in a site, contaminated by petroleum products, as well as a non-contaminated site. In each plot, replicate soil samples have been collected randomly at 0-5 cm, 5-10 cm, and 10-15 cm, with the soil samples being subjected to emergence of seedling test for three months in order to determine the species composition, species density, and seed viability at different soil depths. Results show that 17 species from 14 families with a total seedling density of 975 seedlings (19,073 seeds/m^2) have been encountered in the seed bank of the non-contaminated soil, whereas just one species with 339 seedlings (6,632 seeds/m^2) has been recorded in the contaminated soil. Herbaceous species notably, *Spermacoce ocymoides*, *Spermacoce verticillata*, and *Peperomia pellucida* dominate the seed bank of the non-contaminated soil, whereas *Eleusine indica* is the sole species, encountered in the seed bank of the contaminated soil. There is a general reduction in seed viability as the soil depth is increased. In conclusion, contamination by petroleum products narrow the species composition and density of soil seed bank, though has no effect on seed viability, irrespective of soil depth. *Eleusine indica*, being the only species encountered in the contaminated soil, may be tolerant to petroleum hydrocarbon, thus portending useful potentials for phytoremediation.

Keywords: Seed bank, Species composition, Seed viability, Soil depths, *Eleusine indica*.

INTRODUCTION

Soil seed bank refers to viable seed repository in the soil (Abdella *et al.*, 2007), which corresponds to the seeds, not yet germinated but with the capacity to replace annual or perennial plants that disappear due to natural death, diseases and insect infestation, and disturbance by man and animals (Cabin & Marshal, 2000). The soil

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seed bank is the source of life cycle for annual plants and basically the cause of its succession (Roovers *et al.*, 2006). To completely describe a plant community, the buried viable seeds must be included, for they are a semblance of the above ground species composition (Bernhardt & Ubel, 2000). The seed bank partly describes the history of the vegetation and is likely to contribute to its future. There is similarity in the species composition of the seed bank and the above ground vegetation of frequently-disturbed habitats, but the variance between them increases as the vegetation matures. Similar disparities have been observed in dry grasslands (Welstein *et al*., 2007).

The existence of a pool of long-lived seeds for individual species typifies a stock of evolutionary memory, laid down by many generations of plants, perhaps over many decades (Bossuyt *et al.*, 2001). Knowledge of the buried viable seed population dynamics is practically significant in agriculture, forestry, and conservation. In forestry, seed banks play a major part in regeneration of trees after felling, where planting is often forgotten or omitted. Seed bank can also contribute to rehabilitation of degraded land (Valbuena *et al.*, 2001). Their presence in the soil of wet tropics undoubtedly helps preventing erosion by enabling a protective covering of vegetation to form quickly. It also helps understanding the relation among seed bank composition, seed depth, and seed dormancy (Sandrine *et al*., 2006). They are of considerable research interest, thanks to their demographic and evolutionary consequences for plant species (Cabin and Marshal, 2000; Robert *et al*., 2000).

Crude or refined oil spillage is a frequent occurrence in oil and gas processing operations, which is detrimental to the environment in several ways. Oil film floats in water which could prevent aeration, consequently killing fresh water or marine life. Oil spillage on land may delay vegetation growth and result in soil infertility for a long period of time, until natural processes reestablish stability. Several spillages of crude or refined oil products, caused by vandal activities, lack of maintenance of oil pipelines, or accidental spills reduce biodiversity, retard vegetation growth, and cause substantial disequilibria to the ecosystems of the host environment. Oil contamination of soil generally causes delayed seed emergence, which is due to poor aeration of soil and loss of seed viability. Reports by Abi & Nwosu (2009) also stated that oil spillage could inhibit germination of seeds and regeneration, causing cellular and stomata dysfunctionalities. Oil pollution may alter soil properties, lower porosity, and restrict penetration (Andrade *et al*. 2004).

The paucity of information on the significance of soil seed bank in the regeneration of native flora has been attributed to spatial heterogeneity and temporal variation of seed bank among others. There is, therefore, the need to understand how oil contamination impact on natural regeneration of soil seed bank. This study is therefore designed to determine the effect of oil contamination on species composition and the density of soil seed bank as well as seed viability, as affected by oil contamination at different depths of a soil core.

MATERIALS AND METHODS

A petroleum product storage facility in Nigerian National Petroleum Corporation, Omi-Apata, Ibadan, Nigeria, ($7^0$22″N of latitude and $3^0$55″E of longitude), in which frequent accidental spillage had occurred, resulting in contamination of the surrounding soil, was chosen for this study. Soil samples were collected in both the contaminated and non-contaminated sites, the latter being contiguous with the spillage site in August. The soil of the study plots was a derivative of old basement complex rock of Southwestern

Nigeria (Hall & Okali, 1979). Five major soil types were recognized in the area, viz., inselberg soil, hill creep soil, sedimentary non-skeletal soil, drift soils, and alluvial deposits (Hall & Okali, 1979). Two seasons were prominent in the study area: the raining and dry seasons. The raining season runs from March to October while the remaining months form the city's dry season. The study area had an annual rainfall of 1,121 mm. Annual temperature ranged between 23 and 32^{o}C with the highest range, recorded in the dry season.

Two plots, each 25 m by 25 m, were used for the study, one uncontaminated and the other contaminated by petroleum products. In both plots, soil samples were collected randomly at the depths of 0-5 cm, 5-10 cm, and 10-15 cm, respectively (with three replicates per depth), using a soil auger, 8.5 cm in diameter. The samples were kept in polythene bags and tagged appropriately, before getting transported to the laboratory, in which they were air-dried on benches for seven days. Soil samples were later subjected to seedling emergence test in order to determine seed viability, density, and species composition at different soil depths of the seed banks.

Soil samples, collected from both contaminated and non-contaminated sites, were spread in porous bowls in the screen house, watered daily, and monitored for emergence of seedlings. As seedlings were emerging from the soil samples in the plates, they were identified, enumerated, and removed. All the species were counted and identified to species level for each soil depth at IFE Herbarium, located within the Department of Botany, Obafemi Awolowo University, Ile-Ife, using morphological characteristics. Seedlings that emerged were identified either as herbs, shrubs, sedges, or grasses. The identification was done based on the Flora of West Tropical Africa (Hutchinson & Dalziel, 1972). Once a species got identified, it was removed to avoid double identification and seedlings that could not be identified or whose identity was in doubt were uprooted and taken to the IFE Herbarium for proper identification. The seedling emergence tests were carried out every three weeks for three months.

Data for seedling emergence were subjected to a one-way Analysis of Variance at $P<0.05$ to compare seedling emergence from the seed banks of the contaminated and non-contaminated soils along with the number of seedlings, emerging from different soil depths. Ecological models (Equations 1 and 2) were also employed to assess the extent of species' similarity and diversity.

- Sorenson (1948) similarity index was used to compare species composition of standing vegetation and soil seed banks.

$$Similarity\ \ index = \frac{2J}{A+B} \quad (1)$$

where, J stands for the species occurring in both contaminated and non-contaminated soil sample, A represents the number of species, emerging from non-contaminated soil samples at different depths, and B is the number of species, emerging from contaminated soil samples at different depths.

- Shannon Wiener index of diversity (H) was used to compare the similarity in species' composition and diversity between seed banks of contaminated and non-contaminated soils. Seeds/cm^2 was converted to seeds/m^2, as illustrated by Major and Pyott (2006).

$$H = -\Sigma\left[(pi) \times ln\ (pi)\right] \quad (2)$$

where, pi is the fraction of the number of seedlings, counted for each species, to total number of the seedlings.

RESULTS AND DISCUSSION

Tables 1, 2, and 3 present the species' composition, total seedling densities, and percentage contribution of each species to the seed banks of the contaminated and non-contaminated soils at the depth of 0-5 cm, 5-10 cm, and 10-15 cm. A total of 975

seedlings or 19,073 seeds/m^2 emerged during the entire period of the germination study from non-contaminated soil samples. Seventeen species, belonging to 14 families, which comprised of 13 herbaceous species, 2 shrub species, 1 sedge species, and 1 grass species emerged. The emerging herbaceous species included *Ageratum conyzoides, Asystasia gangetica, Bryophyllum pinnatum, Chromolaena odorata, Cyathula spp., Cynedrella nodiflora, Laportea aestuans, Peperomia pellucida, Physalis angulata, Spermacoce ocymoides, Spermacoce verticillata, Solenostemon monostachyus, Talinum triangulare. Cyperus dilatatus* and *Claudium mariscus* were the only two sedge species to emerge, while the only emerging shrub species was *Desmodium canescence.* Similarly, the only grass species that emerged was *Panicum baumanni*. *Spermacoce ocymoides*, an herbaceous species, had the highest contribution to the seed banks with a sum of 320 seedlings (6,259 seeds/m^2) or 32.8% of the total density of the seed banks. *Spermacoce verticillata* and *Peperomia pellucida*, both herbaceous species, were ranked second and third with seedling density of 107 seedlings (3,325 seeds/m^2) or 17.4% and 134 seedlings (2,621 seeds/m^2) or 13.7% of the total seed density of the seed banks, respectively. They followed by *Laportea aestuans*, in the fourth place, with seedling density of 116 seedlings (2,269 seeds/m^2) or 11.9% of the total seedling of the seed bank, while *Cyathula* species had just one seedling (20 seeds/m^2) in the seed bank, equal to 0.1% of the total seed density of the seed banks. Other species had intermediate values.

The seed density, obtained for non-contaminated soil samples may be attributed to the predominance of herbaceous species in the seed banks, variation in species composition, and period of time for seedling emergence (3 months), allowing more species to form or come out of dormancy. The high seed density, obtained for the seed banks of the non-contaminated soil samples, is in agreement with the findings of Cao *et al.* (1997) who recorded densities of 29,945 and 24,740 seeds/m^2 for two secondary forests that were dominated by *Macaranga denticulate* and *Trema orientalis*, respectively, as well as the findings of Oke *et al.* (2006) who reported a density of 6,724-21,872 seeds/m^2. Herbaceous species were dominant in the seed banks of the non-contaminated soil which could be attributed to the openness of the study plot, enhancing the dispersal of this herbaceous species to the study plot. According to Isichei *et al.* (1986), opening of forest canopy allows the germination of herbaceous species. Another reason for preponderance of herbaceous species could be that seeds of woody or tree species are larger than those of herbaceous species or the fact that most woody species lack specific dormancy mechanism (Hall and Swaine, 1980). The emergence of herbaceous species like *Chromolaena odorata, Laportea aestuans, Spermacoce ocymoides, Spermacoce verticillata,* and *Talinium triangulare* in the first few weeks from the seed banks of the non-contaminated soil sample indicates that their seeds were the first set of seeds to have suitable condition for germination and also the short dormancy period of herbaceous species. This is similar to the study of Oke (2006) that showed *Chromolaena odorata* and *Euphorbia heterophylla* were the first set of seedlings to emerge in the first few weeks from soil samples, taken under a tropical rain forest in Nigeria. Epp (1987) stated that the emergence of seedling from the seed banks of forest soils depended on the dormancy, enforced on them by burial.

A total of 339 seedlings (6,632 seeds/m^2) emerged from the seed banks of the contaminated soil samples at depths of 0-5 cm, 5-10 cm, and 10-15 cm, respectively. *Eleusine indica*, a grass species belonging to the family Poaceae, dominated the soil seed banks with seedling density of 339 or 100%

of total seed density. The presence of few individual species in the seed banks of the contaminated soil samples, compared with the non-contaminated ones, is an indication of the level of degradation occurring as a result of oil contamination which suppressed seed germination and emergence. A comparison between the total number of seedlings that emerged from the seed bank of the contaminated and non-contaminated soil showed significant difference ($p<0.05$).

Table 1. Species composition of plants from the soil seed banks

S/N	Species	Family	Non-contaminated soil	Contaminated soil
1	*Ageratum conyzoides*	Asteraceae	+	-
2	*Asystasia gangetica*	Acanthaceae	+	-
3	*Bryophyllum pinnatum*	Crassulaceae	+	-
4	*Chromolaena odorata*	Asteraceae	+	-
5	*Cladium mariscus*	Cyperaceae	+	-
6	*Cyathula spp*	Amaranthaceae	+	-
7	*Cyperus dilatatus*	Cyperaceae	+	-
8	*Desmodium canescens*	Papilonaceae	+	-
9	*Eleusine indica*	Poaceae	-	+
10	*Laportea aestuans*	Urticaceae	+	-
11	*Panicum baumanni*	Poaceae	+	-
12	*Peperomia pellucida*	Piperaceae	+	-
13	*Physalis angulata*	Solanaceae	+	-
14	*Spermacoce ocymoides*	Rubiaceae	+	-
15	*Spermacoce verticillata*	Rubiaceae	+	-
16	*Solenostemon monostachyus*	Labitae	+	-
17	*Synedrella nodiflora*	Asteraceae	+	-
18	*Talinum triangulare*	Portulacaceae	+	-

'+' = available '-' = not available

Table 2. Species density and percentage contribution of species to the seed bank of non-contaminated soil

S/N	Species	Number of seedling	Seeds/m^2	%SB
1	*Ageratum conyzoides*	5	99	0.51
2	*Asystasia gangetica*	16	313	1.64
3	*Bryophyllum pinnatum*	4	78	0.41
4	*Chromolaena odorata*	30	587	3.08
5	*Cladium mariscus*	2	39	0.21
6	*Cyathula spp*	1	20	0.10
7	*Cyperus dilatatus*	2	39	0.21
8	*Desmodium canescens*	76	1487	7.80
9	*Eleusine indica*	-	-	-
10	*Laportea aestuans*	116	2269	11.9
11	*Panicum baumanni*	3	59	0.31
12	*Peperomia pellucida*	134	2621	13.7
13	*Physalis angulata*	35	685	3.59
14	*Spermacoce ocymoides*	320	6259	32.8
15	*Spermacoce verticillata*	170	3325	17.4
16	*Solenostemon monostachyus*	3	59	0.31
17	*Synedrella nodiflora*	17	333	1.74
18	*Talinum triangulare*	41	802	4.21
	Total	975	19,073	

Note- %SB= percentage contribution to the seedbank

Table 3. Species density and percentage contribution of species to the seed bank of contaminated soil

S/N	Species	Number of seedling	Seeds/m^2	%SB
1	*Ageratum conyzoides*	-	-	-
2	*Asystasia gangetica*	-	-	-
3	*Bryophyllum pinnatum*	-	-	-
4	*Chromolaena odorata*	-	-	-
5	*Cladium mariscus*	-	-	-
6	*Cyathula spp*	-	-	-
7	*Cyperus dilatatus*	-	-	-
8	*Desmodium canescens*	-	-	-
9	*Eleusine indica*	339	6632	100
10	*Laportea aestuans*	-	-	-
11	*Panicum baumanni*	-	-	-
12	*Peperomia pellucida*	-	-	-
13	*Physalis angulata*	-	-	-
14	*Spermacoce ocymoides*	-	-	-
15	*Spermacoce verticillata*	-	-	-
16	*Solenostemon monostachyus*	-	-	-
17	*Synedrella nodiflora*	-	-	-
18	*Talinum triangulare*	-	-	-
	Total	339	6,632	

Note- %SB= percentage contribution to the seedbank

Table 4 gives the species composition of standing vegetation in both contaminated and non-contaminated sites. Nineteen plant species, belonging to 14 families, were found in the standing vegetation of the non-contaminated site. The predominant species were herbs and few tree species. The list shows that 17 herbaceous species (89.5%) and two tree species (10.5%) were present, with the predominant plant species in the standing vegetation of the non-contaminated site being *Ageratum conyzoides, Aspilia heliantus, Boerhavia coccinea, Chromolaen aodorata, Cleome ciliata, Commelinia species, Elaeis guineensis, Euphorbia hirta, Euphorbia heterophylla, Ipoemea involucrata, Laportea aestuans, Mangifera indica, Mimosa pudica, Peperomia pellucida, Portulaca oleraceae, Spermacoce ocymoides, spermacoce verticillata, Tridax procumbens,* and *Talinum triangulare.* The species composition of the standing vegetation of the contaminated site was predominantly *Eleusine indica* belonging to the family Poaceae, and common in the standing vegetation and seed bank of the contaminated site.

Comparing the species composition of seed banks and the standing vegetation of the non-contaminated site revealed that out of the 19 species in the seed bank of the contaminated soil samples, 7 species (36.8%) were present in the standing vegetation, while 12 species (63.2%) were not. Common species to the seed bank and standing vegetation were *Ageratum conyzoides, Chromolaena odorata, Laportea aestuans, Peperomia pellucida, Spermacoce ocymoides, Spermacoce verticillata,* and *Talinum triangulare.* In the contaminated soil samples, only one species emerged from the seed bank, being also the only species, represented in the standing vegetation.

Indices of similarity and diversity were estimated to ascertain the extent of similarity and diversity between the two study sites (Tables 5 and 6). The similarity of species composition for the standing vegetation in the contaminated site, on one hand, and the seed banks, on the hand, was assessed, using Sorenson index to show a similarity of 100% between them, while the Sorenson index of similarity between the standing vegetation and seed bank of non-contaminated site was low, giving a value of 38.88%, which showed that most of the species, emerging

from the seed bank, had no representation in the standing vegetation. Comparing the seed banks of contaminated and non-contaminated soil samples revealed that there was no similarity. Shannon Wiener species diversity index showed that the non-contaminated soil samples had a higher species diversity (H = 2.06) than the contaminated one, having a lower index (H=0.00). The difference in similarity index, observed between the seed banks of both contaminated and non-contaminated soil samples, indicated the disparity in species composition of their seed banks, which can be attributed almost exclusively to the presence of petroleum products in contaminated soil samples, given that the sites were adjoining and contiguous. The high index of species diversity of non-contaminated soil seed bank (H= 2.06) reflected the great number and even distribution of species in the seed bank, thanks to its protection from oil contamination, while the low index of species diversity recorded for the seed bank of the contaminated soil samples (H = 0.00) was as a result of petroleum product contamination, likely to inhibit other species' survival. The significant difference in the total seed bank density of contaminated and non-contaminated soil samples was a reflection of the difference in their seedling densities and species composition. A low index of similarity (38.88%), recorded for the seed bank and standing vegetation of the non-contaminated soil samples, indicates a low similarity level in species composition of the seed bank and standing vegetation. A small number of the total species, emerging as seedlings in the seed bank, had representation in the standing vegetation that might be due to different patterns of dormancy and germination requirement (Williams, 1983). This trend has been observed and reported in most soil seed bank studies (Thompson & Grime, 1979; Staaf & Martins, 1987). William (1993) observed low similarity between the tree species composition of the buried seeds and the vegetation, used in the study of soil seed bank in Lower Montane forest of Mexico. Olmsted & Curtis (1947) reported that fifteen species in the seed bank of deciduous and coniferous stands in Maine, Japan, lacked reproductive adults in the standing vegetation. Similarly, Oke *et al*. (2006) found considerable disparity between the standing vegetation and soil seed bank.

The 100% index of similarity, reported in this study from the comparison between the seed bank and the standing vegetation of the contaminated site, indicated a high level of correspondence. Rysdgreen & Hestmark (1997) observed a moderate resemblance between soil propagule bank and above ground vegetation in the boreal forest, while Dessaint *et al*. (1991) observed high correlation (88.9%) between the species composition of the seed bank and that of the standing vegetation. Wilson *et al*. (1985) reported that it was only in a repeatedly disturbed arable field that correlation between standing vegetation and the seed bank species could be found. Miller (1999) obtained a figure between 5 and 43%. Relative to this, the figure obtained for the contaminated soil was higher, indicating that the seed bank of the contaminated site for the present study was subject to recent anthropogenic disturbances due to petroleum product contamination.

Figure 1(a-d) demonstrates viability results of the seeds at the depths of 0-5 cm, 5-10 cm, and 10-15 cm, throughout the study. Results showed that there was a general reduction in viability of seeds with soil depth in the seed bank of the non-contaminated soil. A total seedling density of 476 (9311 seeds/m^2) at the depth of 0-5 cm, 450 (8802 seeds/m^2) at 5-10 cm, and 49 (958 seeds/m^2) at 10-15 cm were observed. In addition, seed bank of the contaminated soils had a total seedling density of 162 (3169 seeds/m^2) at 0-5 cm, 108 (2112 seeds/m^2) at 5-10 cm, and 59 (1154 seeds/m^2) at 10-15 cm. Comparing the number of seedlings,

emerging at the depths of 0-5 cm, 5-10 cm, and 10-15 cm showed a significant decrease ($p< 0.05$) in seed viability with soil depth in both contaminated and non-contaminated soils. Several studies have shown a link between soil depth and seed bank density, e.g. Rydgreen & Hestmark (1997) in their study of soil propagule bank in a boreal old growth spruce forest in Michigan reported that 80.5% of the total seeds were found in the top 2 cm depth of the soil. The concentration of seeds within the surface profile (0-5 cm) of the top soil was also similar with the results, obtained from Eucalyptus forest (Tacey & Glossop, 1980; Howard & Hartemink, 2000).

Table 4. Plant species composition of the standing vegetation of the contaminated and non-contaminated sites

S/N	Species	Family	Non-Contaminated Soil	Contaminated Soil
1	*Ageratum conyzoides*	Asteraceae	+	-
2	*Aspilia helianthus*	Asteraceae	+	-
3	*Boerhavia coccinea*	Nycetaginaceae	+	-
4	*Chromolaen aodorata*	Asteraceae	+	-
5	*Cleome ciliate*	Capparidaceae	+	-
6	*Commelinia spp*	Commelinaceae	+	-
7	*Eleusine indica*	Poaceae	-	+
8	*Elaeis guineensis*	Arecaceae	+	-
9	*Euphorbia hirta*	Euphorbiaceae	+	-
10	*Euphorbia heterophylla*	Euphorbiaceae	+	-
11	*Ipomoea involucrate*	Convolvulaceae	+	-
12	*Laportea aestuans*	Urticaceae	+	-
13	*Mangifera indica*	Anacardiaceae	+	-
14	*Mimosa pudica*	Fabaceae	+	-
15	*Peperomia pellucida*	Piperaceae	+	-
16	*Portulaca oleraceae*	Portulacaceae	+	-
17	*Spermacoce ocymoides*	Rubiaceae	+	-
18	*Spermacoce verticillata*	Rubiaceae	+	-
19	*Tridaxprocumbens*	Asteraceae	+	-
20	*Talinumtriangulare*	Portulacaceae	+	-

'+' = available '-'= not available

Table 5. Shannon Wiener index of species diversity (H) of studied seed banks

S/N	Plant species	Non-contaminated soil (no of seedling)	Contaminated soil (no of seedling)	Pi	Pi ln Pi
1	*Ageratum conyzoides*	5	-	0.005	-0.026
2	*Asystasiagangetica*	16	-	0.016	-0.066
3	*Bryophyllumspp*	4	-	0.004	-0.022
4	*Chromolaenaodorata*	30	-	0.031	-0.108
5	*Cladiummariscus*	1	-	0.001	-0.007
6	*Cyathulaspp*	17	-	0.017	-0.069
7	*Cyperusspp*	2	-	0.002	-0.012
8	*Desmodiumcanescens*	76	-	0.078	-0.199
9	*Eleusineindica*	-	339	1.000	-
10	*Laporteaaestuans*	116	-	0.119	-0.253
11	*Panicumbaumanni*	3	-	0.003	-0.017
12	*Pepperomia pellucida*	134	-	0.137	-0.272
13	*Physalisangulata*	35	-	0.036	-0.120
14	*Spermacoceocymoides*	320	-	0.328	-0.366
15	*Spermacoceverticcillata*	170	-	0.174	-0.304
16	*Solenostemonmonostachyus*	3	-	0.003	-0.017
17	*Synedrellanodiflora*	17	-	0.017	-0.069
18	*Talinumtriangulare*	41	-	0.042	-0.133
	Total	975	339		*H= 2.06

Pi = number of seedlings, counted for each species/total number of seedling, H= Shannon Wiener index of diversity

Note: H for contaminated site = 0.00 since only one species existed. *Shannon Weiner index for non-contaminated site

Table 6. Comparison of species composition and similarity indices (based on Sorenson index) between the seed bank and standing vegetation of the two study sites

	Non-contaminated soil	Contaminated soil
- Number of species in the standing vegetation	19	1
- Number of species in the seed bank	17	1
- Species, common to standing vegetation and seed bank	7	1
- Sorenson index of similarity between standing vegetation and seed bank (%)	38.88	100
- Sorenson index of similarity between seed bank of contaminated and non-contaminated soils	0	0

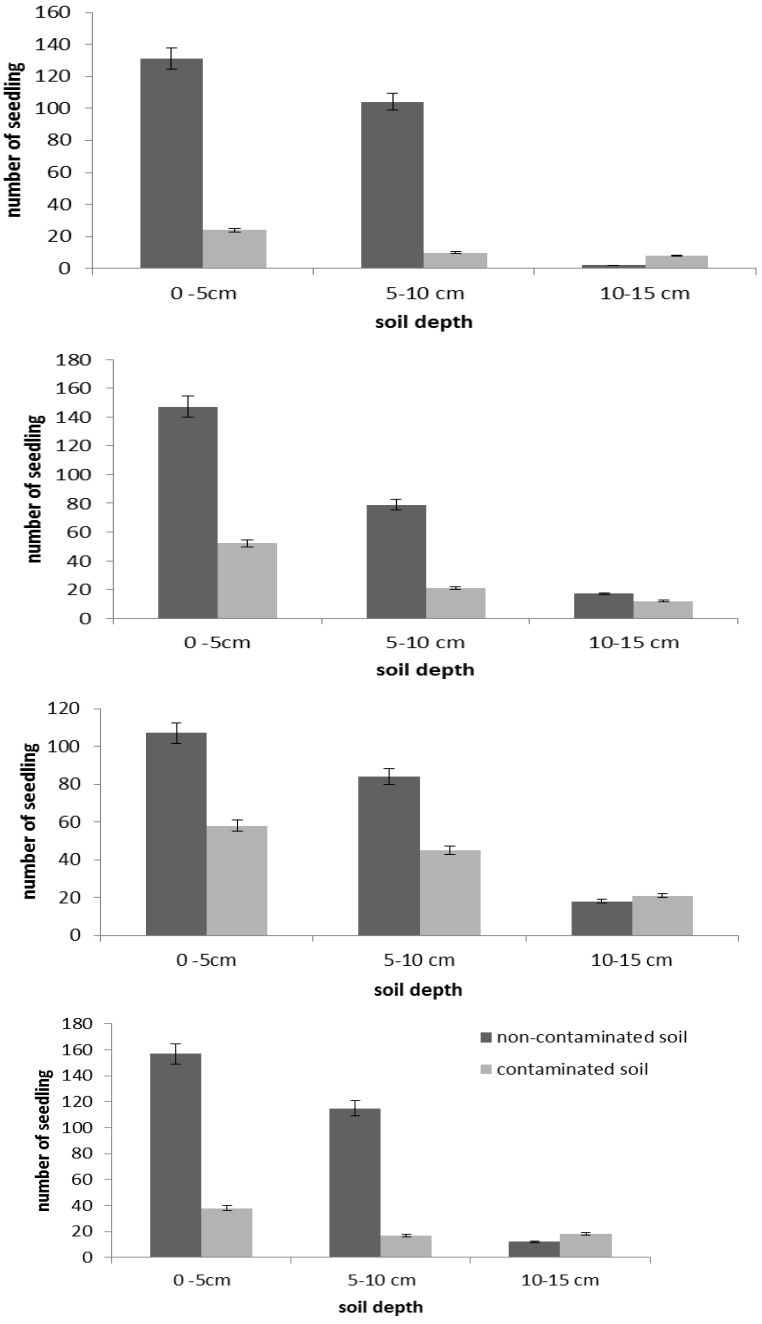

Fig 1. Seedling emergence at different soil depths after (a) 3, (b) 6, (c) 9, and (d) 12 weeks of observation

CONCLUSION

This study revealed the dominance of herbaceous species in the seed bank of non-contaminated soil samples, while just one species was encountered in the seed bank of the contaminated soil samples. Seventeen species, belonging to 14 families, were found in the seed bank of the non-contaminated soils with a total seedling density of 975 (19,073 seeds/m^2). Seed bank of the contaminated soils had a total seedling density of 339 (6,632 seeds/m^2) with only *Eleusine indica* in its seed bank. A low level of similarity (38.88%) existed between the seed bank and standing vegetation of the non-contaminated site. A high level of correlation (100%) existed between the seed bank and standing vegetation of the contaminated site, without any similarity existing between the seed banks of the contaminated and non-contaminated soils. High species diversity index (H=2.06) was estimated for the seed bank of the non-contaminated soils, while no diversity index (0.00) was recorded for the seed bank of the contaminated soils. A general reduction trend in seed viability with increasing soil depth was also observed. These results indicate that areas, affected by petroleum product contamination, cannot revegetate by native ability, thus the need for deliberate attempt to regenerate such areas by reintroduction of native species. *Eleusine indica* is potentially capable of phytoremediation, suggesting that it has petroleum hydrocarbon tolerability.

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