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Method Article

Accelerating phytoextraction of petroleum hydrocarbon with organic stimulant



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A B S T R A C T

Phytoremediation has widely been recognised as an eco-system friendly and effective technique for soil remediation. However, this method is generally slow, and most plants used for phytoextraction are incapable of thriving in crude oil polluted soils with high concentrations of petroleum hydrocarbon. Hence, organic stimulants were developed for accelerating the phytoremediation of crude oil polluted soils by enhancing the growth of cowpea through nutrient supplementation, and increasing the bioavailability of petroleum hydrocarbon by saponification. Moringa and pawpaw seeds are high in plant available nutrients and contain saponin, a phytochemical that increases the bioavailability of contaminants. Although both seeds and moringa seed powder have been used for water purification, they have not been explored in soil remediation studies. For these reasons, pawpaw seeds were processed into powdery form to increase their surface area as organic stimulants for enhancing phytoremediation of crude oil polluted soil. This study investigates the performance of pawpaw seed powder, relative to moringa seed powder, in increasing the removal rate of petroleum hydrocarbon by cowpea under crude oil polluted soil conditions. The key functions of the newly developed organic stimulant include:

- Increased bioavailability of petroleum hydrocarbon for phytoextraction.
- Enhanced shoot production in cowpea.
- Increased capacity of cowpea to remove petroleum hydrocarbons from soils.

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A R T I C L E I N F O

Method name: Pawpaw seed powder-An organic stimulant for improved phytoextraction of petroleum hydrocarbon

Keywords: Soil pollution, Petroleum hydrocarbon contamination, Phytoremediation, Pawpaw seed powder, Moringa seed powder

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Specifications table

Subject Area:	Environmental Science
More specific subject area:	Soil remediation
Method name:	Pawpaw seed powder-An organic stimulant for improved phytoextraction of petroleum hydrocarbon
Name and reference of original method:	Not applicable
Resource availability:	Not applicable

Background

The quest for increase in food production requires good quality soils, which are an important part of the ecosystem [1]. However, soil pollution resulting from crude oil spillages is one of the major environmental problems affecting ecosystem services and food production in most developing countries in the world, including Nigeria [2,3]. This is due to its adverse effects on soil properties and crop growth. Although soils serve as a sink for adsorption and absorption of ions [2], the deposition of petroleum hydrocarbon, especially at concentrations higher than the buffer capacity of soils could also result in groundwater contamination and health hazards [3]. These therefore underscore the need for soil remediation. Consequently, several physical [4], chemical [5,6] and biological [7,8] techniques have been deployed in remediating crude oil polluted soils, with phytoremediation being the most effective among the lot. Interestingly, plants vary in their potentials for phytoremediation, and with the exception of cowpea, which is high in metal tolerance; they could be restricted in growth and yield by petroleum hydrocarbon contamination, thereby slowing down the remediation process [9]. Several soil stimulants have been used to enhance the performance in phytoremediation. Inorganic stimulants such as nitrates and phosphates are costly and could be toxic [5], while organic stimulants such as biochar, manure and compost could be expensive to produce or bulky, though environmentally friendly.

Pawpaw seeds and moringa seeds contain saponin, which has been shown to increase the bioavailability of contaminants for phytoextraction [10]. Although several studies have focused on the use of both seeds for adsorption of dyes and heavy metals in contaminated waters [11,12], there are no reports on their potentials, especially as organic stimulants, for enhancing the remediation of crude oil polluted soils. In this paper, a Bonny light crude oil polluted alfisol was subjected to phytoremediation using cowpea, and pawpaw seed powder and moringa seed powder were used as stimulants to study their effects on the removal rate of petroleum hydrocarbon and yield performance of cowpea.

Procedures

The following steps were taken to produce the organic stimulants used for accelerating the phytoremediation of a crude oil polluted soil.

- (1) Fresh pawpaw seeds and moringa seeds were carefully extracted from ripe pawpaw fruits and mature moringa pods using sharp penknife, respectively.
- (2) The gelatinous pouch surrounding the pawpaw seeds was rinsed off in tap water and the water was allowed to drain off through a sieve. Thereafter, the seeds were sundried for three days to get rid of the surrounding moisture.
- (3) Both pawpaw seeds and moringa seeds were then oven-dried at 65°C to constant weight. Samples of pawpaw seeds and moringa seeds are shown in Fig. 1.
- (4) After oven-drying to constant weight, the seeds were allowed to cool before grinding to fine powder at room temperature. The resulting pawpaw seed powder (PSP) and moringa seed powder (MSP) are shown in Fig. 2.

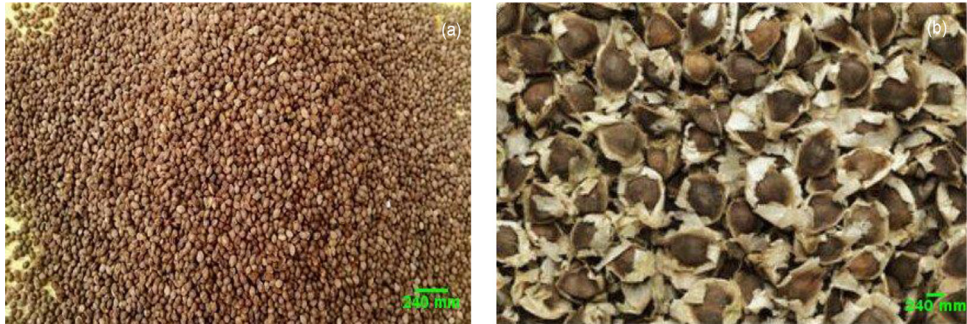


Fig. 1. Samples of (a) pawpaw seeds and (b) moringa seeds used for the study.

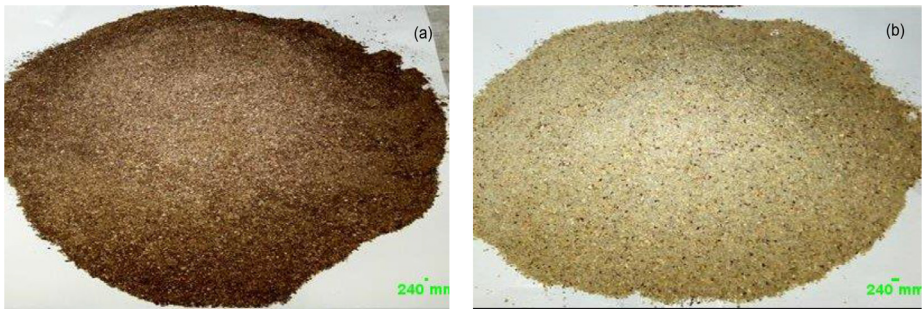


Fig. 2. Samples of (a) pawpaw seed powder and (b) moringa seed powder used as stimulants.

Table 1

Chemical constituents of organic stimulants.

Parameter	Moringa seed powder	Pawpaw seed powder
pH	7.5	7.8
Total organic carbon (%)	40.0	38.4
Total nitrogen (%)	2.1	1.8
Total phosphorus (%)	0.2	0.2
Ca (%)	2.2	1.4
Mg (%)	0.7	0.9
Na (%)	0.9	0.7
K (%)	2.2	3.1
Mn (mg kg ⁻¹)	120.0	163.0
Fe (mg kg ⁻¹)	1780.0	944.0
Cu (mg kg ⁻¹)	8.4	6.4
Zn (mg kg ⁻¹)	22.1	17.8
Saponin (g 100g ⁻¹)	1.1	1.3

- (5) Four rates (100, 150, 200, and 250 g m⁻²) of PSP and MSP were applied as stimulants to 12,400 mg kg⁻¹ petroleum hydrocarbon contaminated soil subjected to phytoremediation by cowpea. [Table 1](#) presents the chemical constituents of the stimulants, while the treatment codes and interpretations are presented in [Table 2](#).
- (6) Keep the soil moisture content at 60% field capacity.

Table 2
Treatment codes and their descriptions.

Treatment code	Description
Control	No stimulant application
MSP100	Moringa seed powder applied at 100 g m ⁻²
MSP150	Moringa seed powder applied at 150 g m ⁻²
MSP200	Moringa seed powder applied at 200 g m ⁻²
MSP250	Moringa seed powder applied at 250 g m ⁻²
PSP100	Pawpaw seed powder applied at 100 g m ⁻²
PSP150	Pawpaw seed powder applied at 150 g m ⁻²
PSP200	Pawpaw seed powder applied at 200 g m ⁻²
PSP250	Pawpaw seed powder applied at 250 g m ⁻²

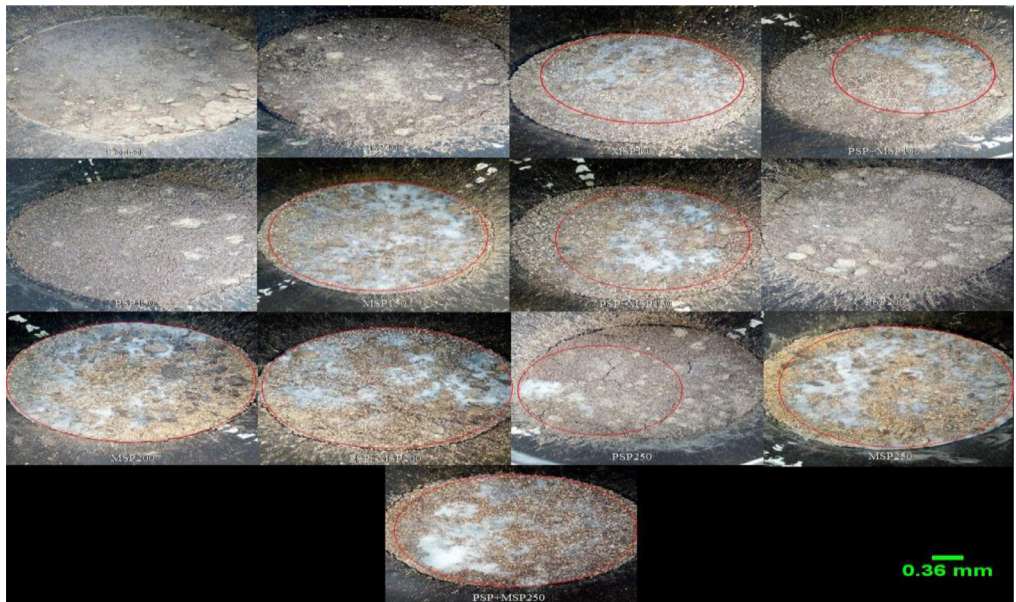


Fig. 3. Evidence of microbial growth (in red circles) in crude oil polluted soil treated with pawpaw seed powder and moringa seed powder stimulants.

Method validation

As shown in Fig. 3, there were indications of microbial growth evidenced by the presence of moulds in soils treated with stimulants. This is proof of enhanced degradation of petroleum hydrocarbon by microbes in treated soils when compared with the control. After two years of cropping, the removal rate of petroleum hydrocarbon was significantly influenced to varying degrees by the treatments (Fig. 4). The removal rate of petroleum hydrocarbon by cowpea was increased by the stimulants relative to the control, and PSP, especially at 150 g m⁻², gave the highest removal rate (78.2%). For MSP, the maximum removal rate (66.1%) was obtained at 250 g m⁻² MSP.

In terms of the agronomic performance of cowpea on a crude oil polluted soil, PSP was superior to MSP by increasing cowpea shoot by 80.2% relative to MSP's 17.0% increase (Fig. 5a). Remarkably, both stimulants had their peak performance on cowpea shoot when applied at 100 g m⁻² (Fig. 5b). Similarly, the superior effect of PSP on cowpea shoot led to a marked increase of 239.3% in cowpea yield, while MSP was able to increase cowpea yield by 72.7% (Fig. 6a). Within the treatments, the yield of cowpea was best when PSP was applied at 250 g m⁻², and this was comparable to 150 g m⁻² PSP

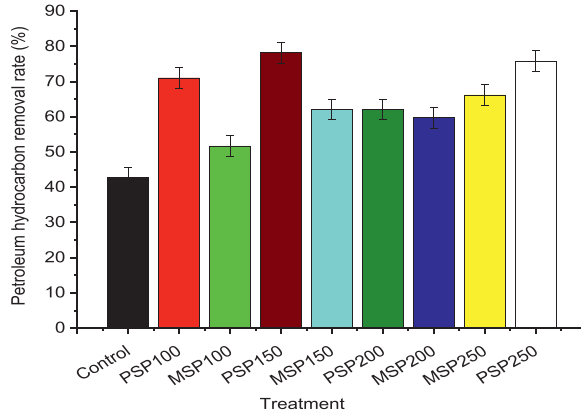


Fig. 4. Removal rate of petroleum hydrocarbon as influenced by organic stimulants.

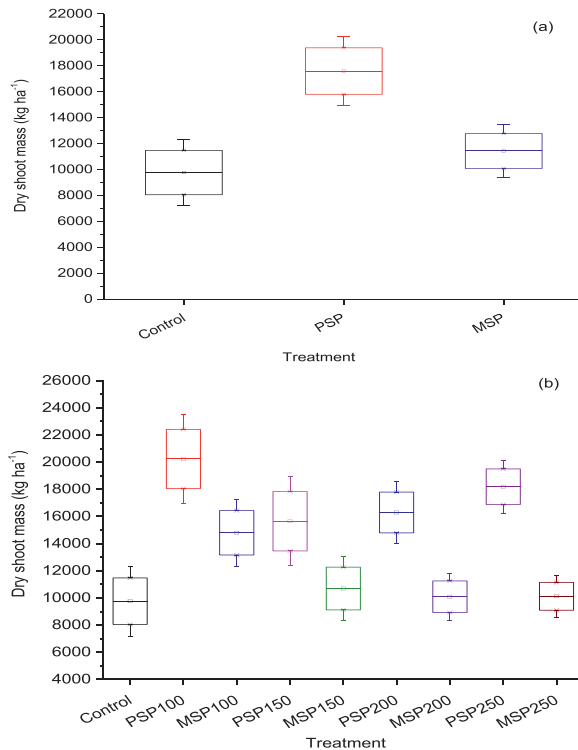


Fig. 5. Cowpea dry shoot mass as influenced by organic stimulants.

(Fig. 6b). On the other hand, the maximum yield obtained in MSP was at 150 g m⁻², and this resulted in a substantial increase of 153.9% in cowpea yield compared with the control. At the end of two years of study, phytoextraction of petroleum hydrocarbon was substantially enhanced by PSP, with the least petroleum hydrocarbon concentration (2700 mg kg⁻¹) in crude oil polluted soil recorded at PSP150 (Fig. 7), while the lowest application rate of PSP (100 g m⁻²) resulted in the absorption of the highest concentration of petroleum hydrocarbon (2650 mg kg⁻¹) in cowpea shoot (Fig. 8).

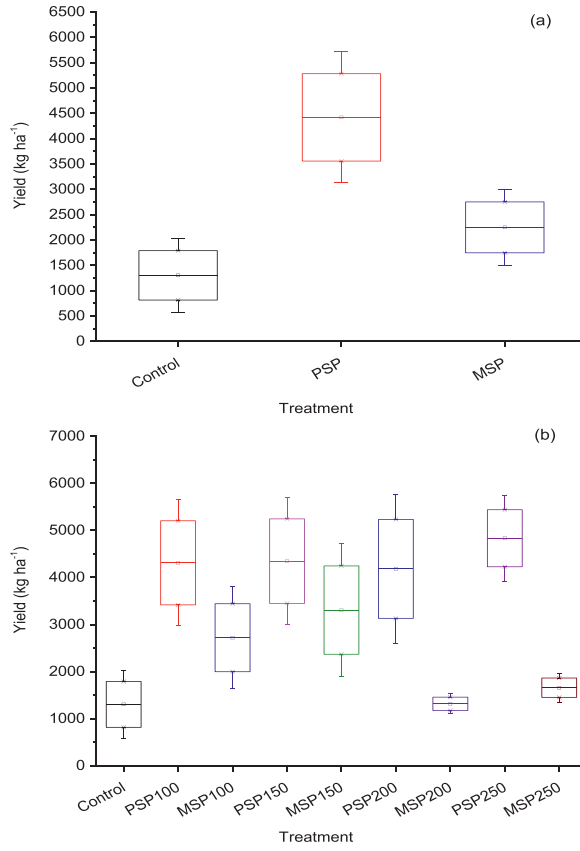


Fig. 6. Cowpea yield response to organic stimulants.

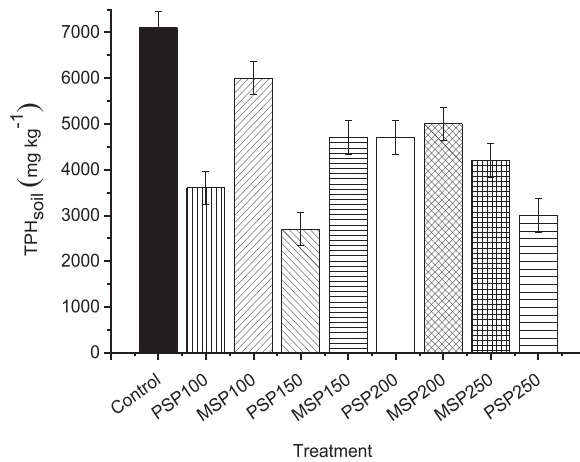


Fig. 7. Effects of organic stimulants on petroleum hydrocarbon degradation in soil.

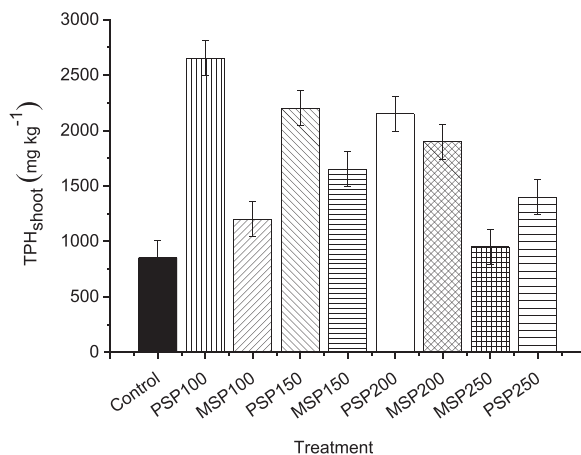


Fig. 8. Petroleum hydrocarbon absorption in cowpea shoot as influenced by organic stimulants.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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