



RESEARCH PAPER

Physiological effects of crude oil on plants

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Abstract

This study evaluated the effect of petroleum crude oil contaminated soil on the mineral nutrient elements. The word petroleum means “rocky oil” or “oil from the earth”. Although exactly how crude oil originated is not established, it is generally agreed that crude oil is derived from the remains of animals and plants that lived in marine water millions of years ago. As more layers deposited on top of one another of these remains, pressure and heat acting on them chemically converted the organic material into what is called crude oil. Physiological effects of crude oil on plants including the seed germination, seedling and plant growth. Generally, crude oil contamination causes reduction of plant growth as it interferes with the uptake of nutrients by plants. It also causes competition for the little nutrient available in the polluted soils between plants and soil microbes and ultimately suppresses the growth of plants in such soil.

KEYWORDS:

Contamination, petroleum, crude oil, seed germination, plant growth.

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Introduction

Petroleum oil spillage on soil generally retards plant growth and soil productivity (Ekpo and Nwaankpa 2005, Ladousse and Tramier 1991, Okpokwasili and Odokuna 1990), reduces aeration by blocking air spaces between soil particles, hence creates a condition of an aerobiosis

(Rowell 1977) and causes root stress in plants, which also reduces leaf growth (Smith *et al.* 1989). Pollution of agricultural soil by crude oil has in turn significantly affected the growth performance of plants. Agbogidi (2011) reported that contamination of soil with crude oil



significantly reduced biomass accumulation in some plants Agbogidi (2010).

In maize, Okonokhua *et al.* (2007) observed that plant height, root number, root length and grain yield were adversely affected by soil crude oil contamination. Kekere *et al.* (2011) reported that crude oil pollution negatively affected leaf number, total leaf area, plant height, stem girth, total biomass as well as crop yield in *Vigna unguiculata*. They further reported a reduced leaf chlorophyll content, nutritional composition and elevated level of heavy metal uptake in the fruits. Ojimba and Iyagba (2012) observed that the outputs of horticultural crops were significantly reduced in crude oil-polluted farms than in non-polluted farms. They concluded that crude oil pollution had detrimental and negative effect on horticultural crops output, farm income and area of farmland cropped. It has been reported that crude oil in soil makes it unsatisfactory for plant growth (Baek *et al.* 2005). This is due to insufficient aeration of the soil because of displacement of air from spaces between the soil particles by crude oil. Udo and Fayemi (1975) discovered that plants growing in an oil-polluted environment are generally retarded with chlorosis of leaves, coupled with dehydration of the plant. Generally, crude oil contamination causes reduction of plant growth as it interferes in the uptake of nutrients by plants. It also causes competition for the little nutrient available in the polluted soils between plants and soil microbes and ultimately suppresses the growth of plants in such soil.

1.1. Effects on seeds germination:

Germination of seeds in soil polluted with crude oil may significantly reduce the seed germination (Ekundayo *et al.*, 2001; Achuba & Peretimo, 2007; Alzway *et al.*, 2025). Apparently, the hydrocarbon film created on the seed surface prevents the imbibitions of water and oxygen to the developing embryo. The inhibition of seed germination in oil contaminated soil also can be directly or indirectly related to the presence of oil in germination media, furthermore Anolifeo *et al.*, (2010) and Edema (2012) poor germination of seed is attributed to the penetrating power of the volatile fractions of oil. In

contact with a seed, oil would enter the seed coat and readily kill the embryo (Bhat *et al.*, 2008 & Njoku *et al.*, 2009). The seed germination also can be indirectly prevented by unfavorable soil conditions such as surface crusts and drought conditions related to soil being contaminated with crude oil residues (Adam & Duncan, 2002; Achuba, 2006). Sharifi *et al.* (2007) have reported that the crude oil soaked cotyledons or embryo lead to poor germination of seeds. Many studies of the effects of crude oil in maize (corn) have examined the effects of crude on physiological parameters such as percentages of seed germination (Ekundayo *et al.*, 2001; Mansour, and Alzway, 2021). Seed germination of okra (Adenipekun *et al.*, 2009), soybeans (Agbogidi *et al.*, 2006) and *Amaranthus hybridus* under the effect of oil (Odjegba & Sadiq, 2002; Agbogidi & Edema, 2011; Alzway and Mansour, 2024) plant species were delayed in due to the soil polluted with crude oil. Generally, petroleum hydrocarbon contamination causes retardation of seed germination (Pezeshki *et al.*, 2000; Omosun *et al.*, 2008) and resulted in adverse biological effects (Edema, 2012). Some researchers consider naphthalene as a more important source of crude oil toxicity than low molecular weight aromatics. It is believed that the low boiling point unsaturated hydrocarbons such as benzene, toluene, xylene and naphthalene, can reduce the level of nutrient availability plant nutrient in contaminated soils (Sverdrup *et al.*, 2003) and can also increase the levels of other elements such as iron and zinc (Kekere *et al.*, 2011) are the most toxic components in crude oil (Eriyamremu *et al.*, 2007). Generally, the entrance of crude oil into the environment through either the natural seepage or spillages has caused a lot of problems to the polluted sites. Gasoline on the other hand is a complex mixture of organic compounds and it also has been shown to be toxic to plants and delayed the seed germination (Trapp *et al.*, 2001; Anon, 2003). Germination and root elongation are two critical stages in plant development that are sensitive to environmental contaminants. Plants that are able to germinate successfully and tolerate the contaminant are considered tolerant plants (Ogbo, 2009., Mansour., *et al.*., 2021).

2.1. Effects on Seedling:

Petroleum hydrocarbon contamination may affect plants by retarding seedling growth and development (Pezeshki *et al.*, 2000). The percentages of seedling emergence of the maize under the effect of water soluble fraction of crude oil were decreased as the level of contamination increased. Seedling growing on contaminated soil with water soluble fractions exhibited the lowest rate of seedling emergence (Njoku *et al.*, 2012; Alzway *et al.*, 2025). Bioassays such as measurements of early seedling growth have been used to monitor the bio effects of oil contaminated sites (Dorn & Salanitro, 2000; Agbogidi, 2011, Alzway *et al.*, 2025). The effects of crude oil contaminated soil at several sublethal biochemical processes such as chlorophyll contents in the leaves of cowpea were decreased under oil contaminated sites (Anon, 2003). With respect to grass species, the work by Merkl *et al.*, (2004) and Alzway & Mansour., 2024 suggests that grasses such as rye grass and *Amaranthus hybridus* are fairly tolerant (Jyoti & Chaudhry, 2012).

3.1. Plant growth:

Oils vary in their toxicity according to the content of unsaturated compounds, aromatics, and acids. The higher the concentration of these constituents, the more toxic the oil (Kekere *et al.*, 2011). The effects of oil pollution vary according to the type, time and age of the plant species (Edema, 2012). Oil polluted soils are not well ventilated which in turn decrease plant growth and development (Victor & Sadiq, 2002). Oil pollutions reduce some plant growth parameters such as plant height, leaf number, leaf surface, plant fresh and dry weight and biomass (Omosun *et al.*, 2008), photosynthetic pigments and also nutrient absorption (Rosso *et al.*, 2005). Plant responses to oil pollution are different and depend on plant species, type of oil, amount and concentration, exposure times and environmental conditions (Pezeshki *et al.*, 2000; Spiars *et al.*, 2001; Zangh *et al.*, 2007; Besalatpoor *et al.*, 2008). Although the effects of the individual petroleum products on plants have been evaluated by many reports (Victor & Sadiq, 2002; Omosun *et al.*, 2008), limited information's are available on the combined effects of different petroleum products

on plant species. There is the need to study the combined effects of petroleum products on plants because most of them are present in an environment at the same time (Pezeshki *et al.*, 2000; Akaninwor *et al.*, 2007). Crude oil is phytotoxic because it creates unsatisfactory conditions for plant growth ranging from heavy metal toxicity to inhibited aeration of the soil. In general petroleum derivatives such as diesel fuels, are phytotoxic to plants at relatively low concentrations. At levels below this phytotoxic level, the development of plants grown in diesel fuel contaminated soil differs greatly from plants grown in normal soil conditions (Njoku *et al.*, 2009; Mut *et al.*, 2010). On the other hand, *salicornia* and black nightshade plants can be relatively resistant to oil pollution (Meudes *et al.*, 2005, Hamaden, 2021). Environmental pollution of crude oil has been shown to have adverse effects on plant growth (Opeolu, 2000). Toxicity symptoms observed in plants exposed to oil pollution include chlorosis, necrosis, stunted growth, suppression of leaves, and reduction in biomass, and large stomatal abnormalities. When oil coats plant leaves, it can block stomata and reducing the photosynthesis of plants (Adenipekun *et al.*, 2008). The presence of petroleum hydrocarbons in soils has a negative impact on plant growth and development (Das & Mukherjee, 2007). Their harmful effects include inhibition of plant growth, reduction of photosynthetic pigments; slowdown of nutrient assimilation and reduction in the growth of roots and aerial organs. It is also postulated that some fractions of petroleum can dissolve biological membranes and as a consequence, disrupt the plant root structure (Peng *et al.*, 2009). It is known that roots under stress reduce leaf growth via stomatal conductance (Ekundayo *et al.*, 2001). The anatomy of plants have been used to monitor the environmental pollution for example Victor & Sadiq (2002) have reported morphological and stomatal abnormalities as an effect of environmental pollution on plants. Also (Zhang *et al.*, 2007) reported that stomata in *Chromolaena odorata* were greatly affected by crude oil which showed a reduced number of stomata per unit area of the leaf (Anoliefo *et al.*, 2003). Oils reduce transpiration rate,

probably by blocking stomata and intercellular spaces. This may also be the reason for the reduction of photosynthesis through the disruption of chloroplast membranes (Joner *et al.*, 2004). Oils may inhibit translocation probably by physical interference with mineral up take. The severity of the above effects depends on the composition and amount of oil, environmental conditions and plant species. According to Ekundayo *et al.* (2001) and Njoku *et al.* (2008a) growth of plants growing in oil polluted soil was seriously retarded and chlorosis of leaves coupled with dehydration of the plants indicating water shortage. High amounts of heavy metals in spent crude oil may be one cause of the retarded growth and chlorosis of leaves of plants growing in oil polluted sites (Kekere *et al.*, 2011). Leaf chlorophyll contents and growth of okra were adversely and severely affected by oil concentration above 2 % (Eriyamremu *et al.*, 2007). Crude oil spills into the soil affects have reduced the germination, plant physiology and ultimately the growth and anatomical development of plants, and also nutrient uptake as well as water availability to plants (Agbogidi & Nweke, 2005). Generally, crude oil contamination causes reduction of plant growth as it interferes with the uptake of nutrients by plants. It also causes competition for the little nutrient available in the polluted soils between plants and soil microbes and ultimately suppresses the growth of plants in such soil (Johnson *et al.*, 2005). Cell membranes are damaged by penetration of hydrocarbon molecules, leading to leakage of cell contents (Agbogidi & Eshegbeyi, 2006). At the cellular level, plants exposed to diesel oil show signs of oxidative stress, as well as degradation of chlorophyll. Moreover, an increase in the production of stress-related phytohormones, accumulation of toxic substances in plant tissues and, in consequence, a decrease in their total size and biomass production are also observed (Njoku *et al.*, 2008 a; (Njoku *et al.*, 2008b). Grasses are sometimes used to remediate chemically contaminated soils, because their root systems are extensive and fibrous (Ogbo, 2009, Hamaden, 2021). The fibrous root system forms a continuous, dense rhizosphere, which provides ideal conditions for phytoremediation (Adam & Duncan,

2002). Found that rhizomatous plants had a high ability to recover after oil spills. Other workers also have found rhizomatous plants to have an advantage over non rhizomatous species in ability to recover following an oil spill (Teng *et al.*, 2010). The literature also suggests that perennial plants generally are fairly resistant than annuals, also found the effect of crude oil to be more severe on herbaceous species and attributed this to their high degree of succulence coupled with their non-rhizomatous habit (Parrish *et al.*, 2005; Kathi & Khan, 2011). Additionally, Parrish *et al.* (2005) have postulated that halophytes are able to absorb significant amounts of aromatic hydrocarbons (Pezeshki *et al.*, 2000; Spiare *et al.*, 2001; Shanid 2007; Besalatpoor *et al.*, 2008 and revealed higher levels of total soluble sugars, proteins and free amino acids when grown in hydrocarbon polluted soil, than those grown in control soil. However, the chlorophyll contents were significantly lower in plants grown in petroleum contaminated soil compared to control plants (Peretiemo & Achuba, 2007). It has been also reported that crude oil pollution negatively affected leaf number, total leaf area, plant height, stem girth as well as total biomass yield in cowpea (Ojimba & Iyagba, 2012). The decrease in the growth rate of cowpea also showed in stem height, leaf number and percentages protein of contents with increasing crude oil applications (Kaure *et al.*, 2012). They concluded that crude oil pollution had detrimental and negative effects on plant species production (Njoku *et al.*, 2009) reported that addition of natural fertilizer generally improved plant growth, leaf area, dry weight, chlorophyll contents, and pod production in *Glycine max* grown in soil contaminated with various concentrations of crude oil. Crude oil pollution had a significant profound effects on the growth of soybeans plant at various treatments of (Mubeen *et al.*, 2012). Researchers recorded a reduction in growth rate and leaf chlorophyll contents of beans and wheat by as much as of 80 % caused by the effect of petroleum hydrocarbons (Sodaeizadeh & Hosseini, 2012). It is believed that *Allophylus edulis* is a tolerant species and therefore important for restoring the vegetation of areas contaminated by petroleum hydrocarbons. Has good

natural regeneration ability and fast regrowth, with longer root length than in non-contaminated soil (Adenipekun *et al.*, 2008). Tolerant plant species are more likely to survive, which can change the makeup of a plant community. For example, observation of various species *Spartina* (cordgrass) in a brackish marsh after a crude oil spill in South Louisiana showed that some species recovered from exposure to oil more readily than others. *Spartina alterniflora* displayed the best regrowth and also the greatest increase in growth after the spill, suggesting that this species was more tolerant to oil than other cord grass species in the same area (Merkl *et al.*, 2004). Also fruit plants such as strawberry also have a high ability to recover following an oil spill. Vegetable plants such as tomatoes and lettuce are considered to be fairly sensitive (Ojimba & Iyagba, 2012) but parsnip was fairly tolerant to light oil sprays. Grasses found to be fairly tolerant (Victor & sadiq, 2002, Alzway & Mansour.,2024). With respect to cultivated plant species such as barley , oats and wheat, the work by Grażyna *et al.* (2005, Mansour. *etal* .,2021) indicated that oats and wheat are fairly tolerant and barley, was the most sensitive (Dorn & Salanitro, 2000; Eze *et al.*, 2012). Based on the literature, the tolerance of plant species such as corn is not well known.

2. Mechanism of action of crude oil:

Plant responses to oil pollution are different and depend on plant species, oil kind, amount and concentration, exposure times and environmental condition (Pezeshki *et al.*, 2000; Spiare *et al.*, 2001; Zangh *et al.*, 2007; Besalatpour *et al.*, 2008). Soil polluted by crude oil have been found to inhibit plant growth (Agbogidi, 2011) resulting in hypoxic state of the soil the displacement of air from the soil pore spaces by the crude oil. Soil polluted with petroleum (Adedokun & Ataga, 2007; Besaltpour *et al.*, 2008). Changes in soil properties due to contamination with petroleum derived substances can lead to water and oxygen deficits as well as to shortage of available forms of nitrogen and phosphorus (Njoku, 2008). The seed germination also can be indirectly inhibited by unfavorable soil conditions such as surface crusts and droughty soil

conditions related to soil being contaminated with oil (Adam & Duncan, 2002). After penetrating into a plant, the oil may travel in the intercellular spaces and possibly also in the vascular system. Cell membranes are damaged by penetration of hydrocarbon molecules, leading to leakage of cell contents. Oils reduce transpiration rate, probably by blocking stomata and intercellular spaces. This may also be the reason for the reduction of photosynthesis. The effects of oils on respiration rates are variable, but an increase of respiration rate often occurs. Oils inhibit translocation probably by physical interference with ion up take. The severity of the above effects depends on the constituents and amount of the oil, on the environmental conditions, and on the species of plant involved (Spiare *et al.*, 2001). Whether or not a plant survives upon exposure to oil depends on what parts of it are damaged. It is also expected that some fractions of petroleum can dissolve biological membranes (Peng *et al.*, 2009). At the cellular level, plants exposed to diesel oil show signs of oxidative stress, as well as degradation of chlorophyll. Moreover, there is an increase in the production of stress-related phytohormones, accumulation of toxic substances in plant tissues and a decrease in their total size and biomass production (Lin & Mendelsshohn, 2009). The oil with low viscosity will distribute in the soil and penetrate the roots more than the high viscous oil (Treutter, 2006). Many researches showed that the presence of the oil resides in the soil has negative effects on the plant metabolism and protein synthesis (Richard *et al.*, 2007; Teng *et al.*, 2010). Oil pollution has damaging effect on the entire ecosystem and makes the soil condition unfavorable for plant growth due to reduction in the level of plant nutrient availability or rise in the toxic levels of certain elements (Ekpo & Nwaankpa, 2005; Okpokwasili & Odokuma, 2007; Besaltpour *et al.*, 2008; Bamidele & Igiri, 2011). Oil polluted soils are not well ventilated and lead to a decrease in plant growth and development (Victor & Sadiq, 2002). Oil pollutions reduce some plant growth parameters such as: plant height, leaf number, leaf surface, plant fresh and dry weight, biomass (Omosun *et al.*, 2008), photosynthetic pigments and also nutrient absorption (Rosso *et al.*, 2005).

Plants are highly susceptible to oil exposure and this may kill them within a few weeks to several months. There are several plant species that are capable of growing in soils polluted with hydrocarbons and they participate in their degradation through the rhizosphere, part of the root, which favours the growth of several microorganisms and increases biomass and microbial activity, accelerating degradation processes of crude oil (Quinones-Aquilar *et al.*, 2003; Baek *et al.*, 2005. Mansour *etal*,2021. Alzway. & Mansour .,2024). Presence of crude oil in soil as a factor of stress has negative effects on catalase, invertase and amylase activities in plant seedlings. Addition of 10 % crude oil may inhibit invertase and amylase activities (Inoni *et al.*, 2006). Crude oil induced environmental stress up on the plant seedlings. This is indicated by the increase in free sugar, total protein and amino acids and a decrease in chlorophyll contents of the leaves seedlings. The activities of total amylase and starch phosphorylase from the cotyledon and mitotic activity of the meristems of the root seedling were inhibited by the various concentrations of crude oil (Bamidele & Agbogidi, 2000). Increased level of catalase activity is an indication of increased production of free radicals by exposing plants

to crude oil. While decrease in activities of detoxification mechanisms of hydrogen peroxide can generate severe cell damage due to increase production of toxic oxygen radicals (Edema, 2010). Pollution caused by petroleum is one of the most serious problems worldwide. Urease, protease, invertase, lipase and dehydrogenase activities were significantly reduced in plants exposed to oil contaminated soils (Palese *et al.*, 2003). Information concerning enzymes activity studies in oil contaminated soils are still not engh to this direction.

4. Conclusion:

In this study, the effect of petroleum crude oil contaminated soil on the growth and The changes in soil properties and the rhizosphere bacterial biomass .Oil pollution in whatever form is toxic to some plant species and their environment has been observed by many researcher workers that crude oil affects soil properties and this in turn affects the physiological, anatomical and development of plants grown on such soils. The germination process is a very extremely sensitive phase in plant growth and development, being indicative to any type of environmental contaminants.

5. References

1. Achuba F I. (2006). The effect of sublethal concentrations of crude oil on the growth and metabolism of Cowpea (*Vigna unguiculata*) seedlings. *Environmentalist*. **26**:17 - 20.
2. Achuba FI. and Peretiemo-Clarke BO. (2007). Effect of spent oil on soil catalase and dehydrogenase activities. *Int Agrophy*. **22**: 1 - 4.
3. Adam G. and Duncan H. (2002). Influence of diesel fuel on seed germination, *Environmental Pollution*. **120** (2): 363 - 370.
4. Adedokun OM. and Ataga AE. (2007). Effects of amendments and bioaugmentation of soil polluted with crude oil, automotive gasoline oil, and spent engine oil on the growth of cowpea (*Vigna unguiculata* L. Walp). *Sci. Res. Essay*. **2** (5): 147 - 149.
5. Adenipekun CO. and Oyetunji O J. and Kassim L Q. (2009). Screening of *Abelmoschus esculentus* L. Moench for tolerance to spent engine *Journal of Applied Biosci-ences*. **20**: 1131 - 1137.
6. Adenipekun C O., Oyetunji O J. and Kassim L S. (2008). Effect of spent engine oil on the growth parameters and chlorophyll content of Corchorus olitorius Linn. *Environmentalist*. **28**: 446 - 450.
7. Agbogidi, O. M. (2010). Screening six cultivars of cowpea (*Vigna unguiculata* (L) Walp) for adaptation to soil contaminated with spent engine oil. *Academic Arena*, 2(4), 33-40.
8. Agbogidi O M. (2011). Effects of crude oil contaminated soil on biomass accumulation in *Jatropha curcas* L. seedlings. *Journal of Ornamental and Horticultural Plants*. **1** (1): 43 - 49.
9. Agbogidi OM. and Nweke FU. (2005). Effect of crude oil polluted soil on the performance of okra (*Abelmoschus esculentus* L.) Moench in Delta state. *Afr. J. Nat. Sci*. **8**: 31 - 35.
10. Agbogidi OM., Nweke FU. and Okechukwu EM.

- (2006). Yield performance of five cultivars of soya beans (*Glycine max* (L.) Merr) as influenced by soil contaminated with crude oil. *Niger. J. Trop. Agric.* **8**: 303 - 308.
11. Agbogidi OM. and Edema NE. (2011). Loss of toxicity of oiled soils by two forest species: studies on *Dacryodes edulis* (Don G. Lam K. J.) and *Gambaya albida* (Linn). *Biol. Environ. Sci. J. for the Tropics.* **8**(4): 74 - 78.
 12. Agbogidi OM. and Eshegbeyi OF. (2006). Performance of *Dacryodes edulis* (Don. G. Lam H.J.) seeds and seedlings in a crude oil contaminated soil. *J. Sustainable For.* **22** (3/4): 1 - 14.
 13. Akaninwor JO., Ayeleso AO. and Monago CC. (2007). Effect of different concentrations of crude oil (Bonny light) on major food reserves in guinea corn during germination and growth. *Scientific Research and Essay.* **2**(4): 127 - 131.
 14. *Alzway A.A.A, Mansour G.A.H ,Ahire K.D, and Attitalla.I.H,(2025).Impact of light crude oil contamination on seed germination and seedling growth in *Zea mays* L. *Research in Ecology.* **7**(4):20-31.DOI:<https://doi.org/10.30564/re.v7i4.9506>.
 15. Alzway A.A.A, Mansour G.A.H.,(2024).Effect of different of heavy crude oil on the physiological responses of *Amaranthus hybridus* L.(Never-fading flower) species. [53\(1\):214-229.](https://Cuestionesdefisioterapia.com)
<https://Cuestionesdefisioterapia.com>.
 16. Anoliefo GO. Vwioko DE. and Mpamah P. (2003). Regeneration of *Chromolaena odorata* L. K. & R. in crude oil polluted soil: A possible phytoremediating agent. *Benin Science Digest.* **1**: 9 - 14.
 17. Anoliefo GO., Ikhajiagbe B., Berena AT. and Okoro RE. (2010). Bioremediation of crude oil-polluted soil by using *Vernonia amygdalina* and manure. *International Research Journal of Biotechnology.* **1**(4): 37 - 43.
 18. Anon A. (2003). Remediation of petroleum contaminated media. *J. Bioremed.* **5**: 445 - 560.
 19. Bamidele JF. Igiri A. (2011). Growth of seashore paspalum (*Paspalum vaginatum*) in soil contaminated with crude petroleum oil. *J. Appl. Sci. Environ. Manage.* **15** (2): 303 - 306.
 20. Baek KH., Kim H S., Oh H M., Yoon B D., Kim J. and Lee I S. (2005). Effect of crude oil, oil components and bioremediation on plant growth. *Journal of Environment.* **40**: 88 - 97.
 21. Bamidele J F. and Agbogidi O M. (2000). Toxicity of odidi petroleum oil and its water soluble fraction on three aquatic macrophytes, *Nigerian Journal of Science and Environment.* **2**: 113 – 121.
 22. Bhat MA., Ahmad S., Aslam J., Mujib A. and Mahmooduzzfar (2008). Salinity stress enhances production of solasodine in *Solanum nigrum* L.
 23. Besalatpour AA., Hajabbasi MA., Khoshgof-Tarmanesh AH. and Afyuin M. (2008). Remediation of petroleum contaminated soils around the tehran oil refinery using phytostimulation method, *J. Agric.Sci. Natur. Resour.* **44**: 13 - 23.
 24. Das K. and Mukherjee AK. (2007). Crude petroleum-oil biodegradation efficiency of *Bacillus subtilis* and *Pseudomonas aeruginosa* strains isolated from a petroleum-oil contaminated soil from North-East India. *Bioresource Technology.* **98**: 1339 - 1345.
 25. Dorn PB. and Salanitro JP. (2000). Temporal ecological assessment of oil contaminated soils before and after bioremediation, *Chemosphere.* **40** (4): 419 -426.
 26. Edema N E. (2010). Comparative assessment of produced water (PW) and water soluble fraction (WSF) of crude oil on the growth and catalase activity of *Allium cepa* L. *Journal of Applied Biosciences.* **30**: 1866 - 1872.
 27. Edema N. (2012). Effects of crude oil contaminated water on the environment. in: crude oil emulsions composition stability and characterization. [Manar El-Sayed Abdul-Raouf (Ed.)]. *InTech Open Access Company.* **9**: 170 - 180.
 28. Ekpo MA. and Nwaankpa IL. (2005). Effect of crude oil on microorganisms and growth of ginger (*Zingiber officinale*) in the tropics. *J. Sustainable Trop Agric Res.* **16**: 67 - 71.
 29. Ekundayo EO., Emede TO. and Osayande DI. (2001). Effects of crude oil spillage on growth and yield of maize (*Zea mays* L.) in soils of midwestern

- Nigeria. *Plant Foods Hum. Nutr.* **56**: 313 - 324.
30. Eriyamremu GE., Asagba SO., Onyeneke EC. and Aguebor-Ogie B. (2007). Bonny light crude oil and its fractions alter radicle galactose dehydrogenase activity of beans (*Phaseolus vulgaris* L.) and maize (*Zea mays*). *Trends in Appl Sci Res.* **2**: 433 - 438.
 31. Eze C N., Maduka J N., Ogbonna JC. and Eze E A. (2012). Department of Microbiology, University of Nigeria, Nsukka. for carrots and parsnips. *Proc. Am. Soc. Hort. Sci.* **45**: 445 - 448.
 32. Hamaden. G A. (2021). Physiological responses of *Solanum nigrum* .L species to the heavy crude oil. International journal of medical and pharmaceutical research.2(2):22-32.
 33. Grażyna P., Grzegorz NJ., Krzysztof U. and Robin LB. (2005). The application of bioassays as indicators of petroleum-contaminated soil remediation, *Chemosphere.* **59** (2): 289 - 296.
 34. Inoni OE., Omotor DG. and Adun FN. (2006). The effect of oil spillage on crop yield and farm income in Delta State, Nigeria. *Journ. Central Eur. Agri.* **7** (1): 41 - 49.
 35. Johnson DL. Anderson DR. and McGrath SP. (2005). Soil microbial response during the phytoremediation of a PAH contaminated Soil. *Soil Biol Biochem.* **37**: 2334 - 2326.
 36. Joner EJ., Hirman D., Szolar OHJ., Todorovic D., Leyval C. and Loibner AP. (2004). Priming effects on PAH degradation and ecotoxicity during a phytoremediation experiment. *Environmental Pollution.* **128**: 429 - 435.
 37. Jyoti L. and Smita C. (2012). Effect of diesel fuel contamination on seed germination and growth of four agricultural crops. *Institute of environmental studies, kurukshetra university.* **4**: 311 - 317.
 38. Kathi S. and Khan AB. (2011). Phytoremediation approaches to PAH contaminated soil. *Indian Journal of Science and Technology.* **4** (1): 56 - 63.
 39. Kaure Sh., Singh H P., Batish D R. and Kohli R K. (2012). Role of Monoterpenes in *Eucalyptus* Communities. *Current Bioactive Compounds.* **8**: 101 - 107.
 40. Kekere O., Ikhajiagbe B. and Apela B R. (2011). Effects of crude petroleum oil on the germination, growth and yield of *Vigna Unguiculata* walp L. *Journal of Agriculture and Biological Sciences.* **2** (6): 158 - 165.
 41. Lin Q. and Mendelsshohn IA. (2009). Potential of restoration and phytoremediation with *Juncus roemerianus* for diesel-contaminated coastal wetlands. *Ecol. Eng.* **35**:85 - 91.
 42. Ladousse, A. and Tramier, B. (1991): Results of 12 years of research in spilled oil bioremediation. – Proceeds Inipol EAP22, Oil Spill Conference, American petroleum Institute, Washington, DC
 43. Mansour G.A.H , Alzway A.A.A, Hassan.M.Y and Attitalla. I. H., (2021). Physiological responses of some plant species to crude oil and its effects residues on seed germination. *Ann. Bio. Sci,* 9(9):38-46.
 44. Mansour. G A.H. and Alzway A.A.(2021). Effects of heavy crude oil on the physiological responses of *Zea mays* L. species. *Annals of biological sciences,* 9(6):13-21.Available online at <http://abiosci.com/archive.html>.
 45. Meudes A, dussauze J, deslandes E and poupart N(2005). Uptake of four pahs occurring into aerial plant tissue artificially exposed to heavy fuel oil in salicornia , *international oil spill conference.*
 46. Merkl N., Schultze-Kraft R. and Infante C. (2004). Phytoremediation in the tropics. The effect of crude oil on the growth of tropical plants. *Bioremediation J.* **8**: 177 - 184.
 47. Mubeen K., Nadeem M A., Tanveer A. and Zahir Z A. (2012). Allelopathic effects of sorghum and sunflower water extracts on germination and seedling growth of rice (*Oryza sativa*L.) and three weed species. *Journal of Animal and Plant Sciences.* **22** (3): 738 - 746.
 48. Mut H., Ayan I., Basaran U., Onal-Asci O. and Acar Z. (2010). The effects of sheep manure application time and rates on yield and botanical composition of secondary succession rangeland. *Afr. J. Biotech.* **9** (23): 3388 – 3395.
 49. Njoku KL. Akinola MO. and Busari TO. (2012). Effect of time of application of spent oil on the

- growth and performance of maize (*Zea mays*). *African J Environ Sci Technolol*. **6**: 67 - 71.
50. Njoku KL., Akinola MO. and Taiwo BG. (2009). Effect of gasoline diesel fuel mixture on the germination and the growth of *Vigna unguiculata* (Cowpea). *African Journal of Environmental Science and Technology*. **3** (12): 466 - 471.
 51. Njoku K L., Akinola M O. and Oboh B O. (2008a). Growth and performance of *Glycine max* L. (Merrill) in crude oil contaminated soil augmented with cow dung. *Nat. Sci.* **6** (1): 48 - 58.
 52. Njoku K L., Akinola M O. and Oboh B O. (2008b). Germination, survival and growth of accessions of *Glycine max* L. (Merrill) (Soybean) and *Lycopersicon esculentum* L. (Tomato) in crude oil polluted soil. *R. Journ. Environ. Toxicol.* **2** (2): 77 - 84.
 53. Njoku K L., Akinola M O. and Taiwo B G. (2009). Effect of gasoline diesel fuel mixture on the germination and the growth of *Vigna unguiculata* (Cowpea). *Afri. J. Environ. Sci. and Technol.* **3** (12): 466 - 471.
 54. Njoku KL. (2008). Evaluation of glycine max and lycopersicon esculentum in the remediation of crude oil polluted soil. *Ph.D Thesis, University of Lagos, Nigeria*.
 55. Odjegba VJ. and Sadiq AO. (2002). Effects of spent engine oil on the growth parameters, chlorophyll and protein levels of *Amaranthus hybridus* L. *Environmentalist*. **22**: 23 - 28.
 56. Ogbo E M. (2009). Effects of diesel fuel contamination on seed germination of four crop plants - *Arachis hypogaea*, *Vigna unguiculata*, *Sorghum bicolor* and *Zea mays*. *African J. Biotechn.* **8**: 250 - 253.
 57. Ojimba TP. and Iyagba AG. (2012). Effects of crude oil pollution on Horticultural crops in Rivers State, Nigeria. *Global Journal of Science Frontier Research Agriculture and Biology*. **12** (4): 37 - 43.
 58. Okpokwasili, G. C. and Odokuma, L. O. (1990): Effect of salinity on biodegradation of oil spills dispersants. – *Waste Manage.* **10**: 141–146
 59. Okpokwasili GC. and Odokuma LO. (2007). Effect of salinity on biodegradation of oil spills dispersants. *WasteManagement*. **10**: 141 - 146.
 60. Okonokhua, B. O., Ikhajiagbe, B., Anoliefo, G. O. & Emede, T. O. (2007). The Effects of Spent Engine Oil on Soil Properties and Growth of Maize (*Zea mays* L.). *Journal of Applied Science and Environmental Management*, **11** (3), 147 – 152.
 61. Omosun G., Markson A A. and Mbanasor O. (2008). Growth and anatomy of *Amaranthus Hybridus* as affected by diferrent crude oil concentrations *American-Eurasian Journal of Scientific Research*. **3** (1): 70 - 74.
 62. Opeolu BO. (2000). Effects of lead on the performance and nutrient quality of two cowpea varieties. M.Sc. Thesis, deperment of crop protection and environmental biology, University of Ibadan, Nigeria. Ottawa, Canada.1 - 74.
 63. Palese AM., Giovannini G., Luches S., Dumonte S. and Perucei P. (2003). Effect of fire on soil C, N and microbial biomass. *Agronomite*. **24**: 47 – 53.
 64. Parrish Z D., Banks MK. and Schwab AP. (2005). Effect of root death and decay on dissipation of polycyclic aromatic hydrocarbons in the rhizosphere of yellow sweet clover and Tall fescue. *Journal of Environmental Quality*. **34**: 207 - 216.
 65. Peng S., Zhou Q., Cai Z. and Zhang Z. (2009). Phytoremediation of petroleum contaminated soils by *Mirabilis Jalapa* L. in a greenhouse plot experiment. *Journal of Hazardous Materials*. **168**: 1490 - 1496.
 66. Peretiemo-Clarke BO and Achuba FI. (2007). Phytochemical effect of Petroleum on Peanut (*Arachis hypogea*) Seedlings .*Plant Path. J.* **6**: 179 - 182.
 67. Pezeshki SR., Hester MW., Lin Q. and Nyman JA. (2000). The effects of oil spill and clean-up on dominant US gulf coast marsh macroptes (Review), *Environmental Pollution*. **108**: 129 - 139.
 68. Quinones-Aquilar EE., Ferra-Cerrato R., Gavi FR. , Fernandez L., Rodriguez VR. and Alarcom A. (2003). Emergence and growth of maize in a crude oil polluted soil. *Agrociencia*. **37**: 585 - 594.

69. Richard BG., Glenn SF., Christopher MR. and Bertkn RO. (2007). Oil spill source Identification by comprehensive two-dimensional gas chromatography (GC*GC) IN: Oil spill environmental forensics: fingerprinting and source. Eds: Wang Z. and Stout S. Pp. 169 - 206.
70. Rosso PH., Pushnik JC., Lay ML. and Ustin S. (2005). Reflectance properties and physiological responses of *Salicornia virginica* to heavy metal and petroleum contamination, *Journal of Envir onmetal Pollution*. **137**: 241 - 252.
71. Rowell, M. J. (1977): Effects of crude oil spills on soils: a review of literature. – In: Toogood, J. A. (ed.): The reclamation of agricultural soils after oil spills. Part I. Edmonton, Canada, pp. 1–33
72. Shahid GH. (2007). Potential hazards of gasoline additives in altering soil environment in favour of harmful microorganisms. *Int. J. Environ. Res. Public Health*. **1** (1): 1 - 4.
73. Sharifi M., Sadeghi Y. and Akbarpour M. (2007). Germination and growth of six plant species on contaminated soil with spent oil. *Int. J. Environ. Sci. Tech*. **4**: 463 - 470.
74. Spiares JDE., Kenwrthy K. and Rhykerd R. (2001). Emegence and height of plants seeded in crude oil cont aminated Soil, *Texas Journal of Agriculture and Natural Re-sources*. **14**: 37 - 46.
75. Sodaiezadeh H. and Hosseini Z. (2012). Allelopathy an environmentally friendly method for weed control. *International Conference on Applied Life Sciences, Turkey*. 387 - 392.
76. Smith, B., Stachowisk, M. and Volkenburgh, E. (1989): Cellular processes limiting leaf growth in plants under hypoxic root stress. – *J. Exp. Bot.* **40**: 89–94.
77. Sverdrup LE., Krogh PH., Nielsen T., Kj C. and Stenersen J. (2003). Toxicity of eight polycyclic aromatic compounds to red clover (*Trifolium pretense*), ryegrass (*Lolium perenne*), and mustard (*Sinapsis alba*). *Chemosphere*. **53**: 993 – 1003.
78. Teng Y., Shen Y., Luo Y., Sun X., Sun M. and Christie P. (2010). Influence of rhizobium meliloti on phytoremediation of polycyclic aromatic hydrocarbons by alfalfa in an aged contaminated soil, *Journal of Hazardous Materials*. **10**: 1 - 29.
79. Trapp S., Kohler A., Larsen LC., Zambrano KC. and Karlson U. (2001). Phytotoxicity of fresh and weathered diesel and gasoline to willow and poplar trees. *J. Soils Sediment*. **1** (2): 71 - 76.
80. Treutter D. (2006). Significance of flavonoids in plant resistance. Springer-Verlag, *Environmental Chemistry Let-ters*. **4**: 147 - 157.
81. Udo, E. J. & Fayemi, A. A. A. (1975). The effect of oil pollution on germination, growth and nutrient uptake of corn. *Journal of Environmental Quality*, **4**, 537-540.
82. Victor JO. and Sadiq AO. (2002). Effects of spent engine oil on the growth parameters chlorophyll and protein levels of *Amaranthus hybridus* L., *Journal of The Environmentalist*. **22**: 23 - 28.
83. Zhang CG., Leung KK., Wong YS. and Tam NFY. (2007). Germination, growth and physiological responses of man-grove plant (*Bruguiera gymnorhiza*) to lubricating oil poll ution, *Journal of Environmental and Experimental Botany*. **60**: 127 - 136.