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Effect of Crude Oil on the Emergence and Growth of Cowpea in Two Contrasting Soil Types from Abeokuta, Southwestern Nigeria

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ABSTRACT

This study assessed the effect of crude oil on the emergence and growth of cowpea in two different soil types (wetland/Fadama and upland soils) treated with 0 mL (control), 25, 50 and 75 mL unweathered crude oil per 2 kg soil. The results revealed that emergence day varied between 4-5 days with the exception of the 75 mL treatments which germinated between 6-8 days after planting. Emergence in both soils decreased by 31.25, 37.50 and 87.50% relative to the control for the 25, 50 and 75 mL treatments, respectively. The results obtained on the growth rate of the cowpea also showed a decrease in stem height, leaf number and percentage protein content with increasing crude oil contamination. However, stem height, leaf number and percentage protein content were higher in Fadama soils compared with upland soil while no particular pattern was observed for chlorophyll content in cowpea leaves.

Key words: Cowpea, crude oil, emergence, growth, soils

INTRODUCTION

The oil in the Niger Delta is highly variable in both physical and chemical properties. They are either greenish-brown coloured (Whiteman, 1982), paraffinic and waxy (Doust and Omatsola, 1990) with API gravity of between 30 and 40° (Thomas, 1995) or naphthenic and non-waxy oil (Kulke, 1995). They have low concentration of sulphur and other metals such as nickel and vanadium (Nwachukwu *et al.*, 1995). The Bonny light crude oil used in this green house study is classified as a class A crude oil type. It is light, volatile, highly fluid and often clear. It has capacity to spread rapidly on solid or water surfaces and has ability to penetrate porous surfaces such as dirt and sand and may be persistent in such matrix. This type of oil is highly toxic to humans, fish and other biota. Generally, the entrance of crude oil into the environment through either the natural seepage or spillages has caused a lot of wreckage to the agrarian communities of the Niger Delta. Also, the outbreak of fire incidences resulting from the oil spillages through oil pipe vandalization both in Niger Delta area and the intervals have resulted in the lost of hundred thousands hectares of farm lands, soil infertility and low crop yield. In crude oil contaminated soil, oil displaces air and water from the pore spaces leading to anaerobic conditions (Atlas, 1977). Soils treated with crude petroleum caused increase in anaerobic organisms by one-half to three fold (Baldwin, 1922). It also reduces the bulk of the soil density (Adams and Ellis, 1960). Presence of crude oil in soil is devastating to plant communities (Hutchinson and Freedman, 1978). Since, it is toxic to plants, establishing of vegetation may be difficult (Baker, 1970; Udo and Fayemi, 1975). According to Ekundayo *et al.* (2001), germination of seeds planted in crude oil polluted soil area may be delayed while percentage germination may also be significantly affected. Also, effects of crude oil on plants according to Sharma *et al.* (1980) have been found to include morphological aberration and reduction in biomass to stomata abnormalities while yellowing and dropping of leaves to complete shedding of leaves in areas of heavy pollution have been reported by Opeolu (2000). Crude oil spilled in soils have also been found to inhibit plant growth (De Jong, 1980) due to insufficient aeration of the soil resulting from the air displacement from the soil pore spaces by the crude oil (Rowell, 1977).

Cowpea (*Vigna unguiculata*) (Duke, 1981) used in this study to assess the effects of crude oil on seed germination and plant growth has been described by Akinyosoye (1976) as an annual crop of major source of protein in the West African diet. In the tropics and subtropics, cowpea provides food for millions of people and feed for a large number of livestock. It is cultivated extensively in West Africa and is the principal source of dietary protein in Nigeria (Brantley, 1992) from the swampy rain forest Niger Delta to the sparse savannah grassland of northern Nigeria. Cowpea is a crop that is tolerant to wide range of edaphic, climatic and physico-chemical conditions (Duke, 1981; McLeod, 1982; Agbenin *et al.*, 1990). Its tolerance of environmental stress resulting from perennial oil spillage in the country is discussed in this study.

MATERIALS AND METHODS

The experiment which was conducted in a green house consisted of 4-row seed flats with each row having 4 experimental pots. It involved two different soil types taken from Fadama and Crop Production and Protection (CPP) farms of the University of Agriculture, Abeokuta up to a depth of 20 cm with no known history of crude oil contamination. While the fadama is a wetland area, the CPP farm is located on an upland area, the brown coloured cowpea and experimental pots (16) were obtained from local market and bonny light crude oil was obtained from Warri Refinery Petroleum Corporation (WRPC). Two grams of each soil type were weighed separately into the experimental pots and treated with 0, 25, 50 and 75 mL of unweathered Bonny light crude oil by mixing. The soils without crude oil (i.e., 0 mL) served as controls. Four seeds were planted to approximately 2 cm deep in each experimental pot and treatments were conducted in duplicate. The experiment which started in January 2004, being the planting period of cowpea in the tropical rainforest (Akinyosoye, 1976), lasted for eight weeks. Determination of soil particle size was carried out using the hydrometer method (Gee and Bauder, 1986). pH of the soil solution was (soil: water ratio of 1:10) measured using pH meter. The growth parameters measured include weekly leaf height, bi-weekly recording of number of leaves, leaf area, leaf area ratio and relative growth rate. Similarly, chemical analysis performed include extraction and estimation of both chlorophyll and protein level. Every measurement was carried out in triplicate in order to ensure accuracy.

RESULTS

From the analysis of physical properties of the two soil types used in this experimental study, the Fadama (wetland) soil has been classified as loamy sand (i.e., 80% sand, 12% silt and 8% clay) with average pH of 6.55 and a bulk density of 1.63 g cm^{-3}. The second soil type from Crop Production and Protection (CPP) farm representing upland soil was also classified as sandy soil (i.e., 89% sand, 6% silt, 5% clay) with a mean pH value of 6.75, mean temperature of 27.40°C and a bulk density of 1.71 g cm^{-3} (Table 1). The two soil types were found to be suitable for the cultivation of the cowpea. Duke (1981) observed that cowpea is tolerant to a wide range of soil textures, pH range of between 4.3 and 7.9 but thrive in a low fertility soil with a pH of between 5.5

and 6.5 (McLeod, 1982). The result also showed that increase in soil concentration of crude oil from 0 to 75ml significantly decreased seedling emergence in the cowpea. For cowpea planted in loamy sand soils of Fadama farm, emergence reduced by 62.5, 75.0 and 87.5% in soils with 25, 50 and 75 mL of crude oil, respectively relative to the 0 mL (i.e., control).

Similarly, in the upland soils of CPP farm, emergence was 100% in the soils treated with 25 and 50 mL crude oil but there was 87.5% reduction in the soil treated with 75 mL of crude oil (Table 2). Emergence was observed to be higher in the sandy soils of CPP farm with a bulk density of 1.63 g cm^{-3} compared with a loamy sand of wetland soil which has a bulk density of 1.71 g cm^{-3}. The reason being that the CPP soil has larger pore spaces, enhanced better water infiltration and reduced tendency for the crude oil to clog the available soil air spaces. Since the loamy sand soil of Fadama was less porous to the crude oil, some of the cowpea seeds planted in the oil treated soil rotted eight days after planting, due to poor drainage condition. However, the mean emergence days in loamy sand soil of Fadama was observed to be 5.00±0.71 while that of the soil of CPP farm was 5.63±1.39. The faster rate of seed emergence in the loamy sand soil may have been attributed to its higher water retention capacity and higher organic matter content compared to the sand soil of CPP farm. Besides, a progressive increase in the stem height of the cowpea in the control (i.e., 0 mL) soil types was recorded (Table 3). For the loamy sand soils of the Fadama farm the peak height was 61.00 cm while a peak height of 24.69 cm was recorded for the sandy soils.

There appears to be little variation in the stem heights between treatments and control in the sandy soils from upland as in the loamy sand soils of wetland. However, no stem height was recorded for the cowpea seeded in loamy sand soil treated with 75 mL of crude oil since all the seedlings died. Also, the stem height growth for the cowpea seeded in the sandy soils of upland farm for the 75 mL crude oil treatment was slowest with an increase of 3.85 cm from week 1 to week 6. This may be due to increased phytotoxicity of the crude oil to the plants. Leaf number per plant in control treatment of cowpea in both soils increased progressively from week 1 to 6 (Table 3). Peak

Table 1: Properties of soils from the study area

			Particle distribution				
Locations	Textural class	Bulk density (g cm^{-3})	% Sand	% Silt	% Clay	pH	Organic matter content (%)
Wetland soil (Fadama)	Loamy sand	1.7	80.0	12.3	7.6	6.6	4.2
Upland soil (CPP)	Sand	1.6	88.9	6.3	4.8	6.8	2.6

Table 2: Effects of crude oil on the emergence of cowpea seedlings (8 days) after planting

		Emergence			
Soil location/type	Treatment	Days of emergence			% Emergence
Fadama soil (Loamy sand soil)	0	4			100.0
	25	5			37.5
	50	5			25.0
	75	6			12.5
CPP soil (Sandy soil)	0	5			100.0
	25	5			100.0
	50	5			100.0
	75	8			12.5
		0 mL	25 mL	50 mL	75 mL
Average% emergence of planted cowpea seeds in both soils		100.0	68.8	62.5	12.5
Average decrease in% emergence in both soils relative to control		-	31.2	37.5	87.5

leaf number was 16.00 and 11.63 at week 6 for loamy sand and sandy soils, respectively. Besides, in the loamy sand soils, the leaf number was highest and equal in the 25 and 50 mL treatments in weeks 2 and 3. Also in the sandy soils, the leaf numbers were equal at 25 and 50 mL treatment and also equal for weeks 3, 4, 5 and 6 at 75 mL treatments. It was evident that crude oil had effect on the leaf number of the cowpea plants. The cowpea planted in the loamy sand soils were observed to have more leaves than those planted in the sandy soils. This agreed with Akinyosoye (1976) who claimed that cowpea planted in the rainforest soils tend to produce too many leaves and a reduced number of seeds. At harvest, protein and chlorophyll contents of the cowpea were found to decrease relative to crude oil concentration in both type of soils. However, the loamy sand soils were observed to have higher percentage protein and chlorophyll contents when compared with the sandy soils with slight modification in the control treatment for protein analysis while no specific pattern was observed in chlorophyll content (Table 3). The observed higher protein content in the loamy sand soils might have been due to increased organic matter compared with the sandy soils. Since, the seedlings died before harvest, no results were obtained for the 75 mL treatment.

Statistical analysis of data using analysis of variance (Table 4) indicates that there is significant difference between number of cowpea leaf, wetland loamy soil and upland sandy soils at p<0.004

Table 3: Effects of soil crude oil contamination on the growth parameters, protein and chlorophyll contents of cowpea seedlings

Soil location/ type	Treatment (mL)	Leaf No. W1	W2	W3	W4	W5	W6	Stem height (m) W1	W2	W3	W4	W5	% Protein	Chlorophyll content (mg L^{-1})
Fadama soil	0	Nil	2.8	5.8	8.5	10.4	16.0	20.9	27.30	42.3	59.6	61.0	10.1	2.2
(Loamy sand)	25	Nil	3.0	6.0	8.3	9.3	12.8	6.7	9.23	11.6	12.4	13.4	8.6	9.2
	50	Nil	3.0	6.0	6.0	4.5	4.5	9.3	10.00	10.1	4.5	4.6	8.3	1.6
	75	Nil	1.0	1.5	0.0	0.0	0.0	1.0	1.30	0.0	0.0	0.0	Nil	Nil
CPP soil	0	Nil	3.0	6.0	7.0	9.5	11.6	13.0	21.50	23.3	24.2	24.7	10.2	7.6
(Sand)	25	Nil	1.5	2.8	4.6	7.1	8.9	7.1	9.40	11.8	12.4	12.6	6.3	2.4
	50	Nil	1.5	2.8	4.0	6.2	6.4	5.2	8.70	9.9	10.2	11.4	5.3	2.8
	75	Nil	0	1.5	1.5	6.4	2.5	0.5	2.80	3.8	3.9	4.0	Nil	Nil

Table 4: Analysis of variance for emergence time, number of leaves, stem height of cowpea in two varieties of crude oil contaminated soils at 95%

Parameters			Sum of squares	Df	Mean square	F	Sig.
No. of leaves	Fadama	Treatment	205.427	3	68.476	6.779	0.004**
	Loamy	Error	161.613	16	10.101		
	Soil	Total	367.040	19			
	CPP	Treatment	86.621	3	28.874	4.512	0.018**
	Sandy	Error	102.391	16	6.399		
	Soil	Total	189.012	19			
Stem height	Fadama	Treatment	5127.341	3	1709.114	19.628	0.000**
	Loamy	Error	1393.214	16	87.076		
	Soil	Total	6520.555	19			
	CPP	Treatment	872.393	3	290.798	31.653	0.000**
	Sandy	Error	146.995	16	9.187		
	Soil	Total	1019.387	19			
Emergence time	Soil	Treatment	0.781	1	0.781	0.484	0.513 ns
	Type	Error	9.687	6	1.615		
		Total	10.469	7			

**: Highly significant; ns: Not significant and $p<0.018$, respectively. Similarly, the relationship between the cowpea stem heights and the two soil types are both significant at $p<0.000$ while there is no significant difference in the emergence time of the cowpea seedlings in the two soil types contaminated with varieties of crude oil.

DISCUSSION

The different treatment used in this study represents unpolluted (0 mL) and different levels of pollution (25-75 mL). In this study, germination result of the cowpea was in conformity with the 3-5 days reported by Pandey (1987) and 4-5 days by Akinyosoye (1976) regardless of levels of contamination. Exceptions were the 6 and 8 days for the 75 mL of crude oil in the loamy sand and sandy soils treatments, respectively. This result agrees with the study of Ekundayo *et al.* (2001) where delay in germination of maize in crude oil polluted soils was observed while Gill *et al.* (1992) also observed that concentration of 75.0 cm^{-3} of crude oil treatment proved most toxic to the plant. Emergence was also significantly affected by crude oil pollution as average percentage emergence of planted seeds decreased from 68.8, 62.5 and 12.5% for the 25, 50 and 75 mL treatments, respectively (Table 2). This also agrees with the observation of Ekundayo *et al.* (2001) that germination percentage was significantly affected by oil pollution. Campbell and Vavrek (1999) also showed that the number of seedlings germinating from seeds in oil contaminated wetland soil declined relative to uncontaminated soils. The result also indicated that emergence was not significantly affected by soil types, however reduced emergence was observed in the loamy sand soils relative to the sandy soils of CPP farm. Also, mean emergence in loamy sand soils was 43.75±38.86 and 78.13±43.75% was recorded for the sandy soils. This could have been due to impaired water drainage and oxygen diffusion in the loamy sand soils which had a lower bulk density of 1.63 compared to 1.71 g dm^{-3} in sandy soils as a result of the coagulatory effect of crude oil on the soil. Although, this result agrees with Gill *et al.* (1992) while Atuanya (1987) observed that seeds sown in such soils failed to germinate.

Severe yellowing of leaves was observed in the soil treated with 25, 50 and 75 mL of crude oil 2 weeks after planting. Also complete shedding of leaves was observed in the sandy soil treated with 75 mL of crude oil 3 weeks after planting followed by death of seedling. This observation agrees with Opeolu (2000) who reported that light oil pollution caused yellowing of leaves and dropping of leaves soon after planting while heavy oil contamination resulted in complete shedding of leaves. Leaf number per plant in control pots in both soils increased progressively from first week to the sixth week, after planting. However, there was a remarkable impact of soil type on leave number since cowpea sown in loamy soil was observed to have more leaves when compared with the one sown in sandy soil. This may be attributed to increased organic matter present in the loamy soil which might have induced increased production of leaves in the cowpea plants. Akinyosoye (1976) observed that cowpea seeded in rainforest tropical soils tend to produce too many leaves and a reduced number of seeds. It was also observed that plant growth was poor in polluted soils using growth parameters such as plant height and leaf number. There was a progressive increase in stem height for the control cowpeas in both soil types. Udo and Fayemi (1975) observed that growth of plants seeded in crude oil polluted soil was generally retarded and leaf chlorosis resulted coupled with dehydration of the plants indicating water deficiency. The study showed that there was a significant difference in growth between crude oil treated plants and plants with water used as control. Also, Gill *et al.* (1992) observed a positive relationship between degree of growth retardation and concentration in crude oil contaminated soil while Odjegba and Sadiq (2002) noticed a significant reduction in heights of seedlings for all levels of treatment relative to the control. The low seedling emergence and plant height in this study may have been due to the use of unweathered bonny light crude oil, classified as a class A crude oil which is highly toxic to biota, fish and man. It contains the lighter, more volatile and most phytotoxic components of crude oil (Rhykerd *et al.*, 1998). Exposure of seeds to this crude oil fraction may have reduced emergence and also reduced the plant height relative to the control; this being in accordance with the study of Spiares *et al.* (2001).

However, soil type significantly affected leaf number and plant height. Cowpea sown in loamy sandy soil was observed to have more leaves and higher stem heights in comparison to sand soils. This may have been due to the increased organic matter present in the loamy sand soil which may have induced increased production of leaves and increased stem height in the plants. Akinyosoye (1976) observed that cowpeas seeded in rainforest soils tend to produce too many leaves and a reduced number of seeds. A positive correlation was observed between reduction in protein content and crude oil concentration. Seventy five mililitter treatments in both soils could not be analyzed for protein content as both died before harvest due to increased crude oil phytotoxicity. Soil type however did not significantly affect protein content in the plants. Analysis of leaf chlorophyll content did not show any specific pattern, as chlorophyll values of cowpea plant grown in soils with some crude oil treatments were higher than in the controls. This is at variance with the study of Odjegba and Sadiq (2002), who observed that chlorophyll levels in the fresh leaves of plants grown in spent engine oil-treated soils was lower than those of the control.

CONCLUSION

Crude oil pollution had a significant effect on the emergence and growth of cowpea in both soil types. However, the effect on germination was more profound on cowpea planted in loamy sand soil of the Fadama (i.e., soil from the wetland/lowland) which is most prevalent in swampy areas of the Niger Delta where much of the crude oil pollution occurs. The low bulk density of the Fadama soil coupled with the crude oil treatment greatly reduced water infiltration and oxygen diffusion. This study therefore demonstrated that the effect of crude oil spillage will be much more devastating to vegetation especially crop plants in areas of loamy sand soils with a higher silt and clay contents. It also showed that the loamy sand soil is not a good medium for the cultivation of cowpea since the plant produced too many leaves at the detriment of seeds compared to the more sandy soils which were more tolerated by the plants. Similarly, crude oil pollution has been found to have economic implications on growth and yield of agricultural crops. In order to stem the high tide of oil spillage in our environment there is need to create more awareness on the harvoc of oil spillage on the agricultural sector of the economy. Besides, laying of oil pipelines should reasonably be far away from farmlands.

REFERENCES

Adams, R.S. and Ellis, 1960. Some physical and chemical changes in the soil brought about by unsaturation with natural gas. J. Soil Sci. Am., 24: 41-44.

Agbenin, J.O., G. Lombin and J.J. Owonubi, 1990. Effect of boron and nitrogen fertilization on cowpea nodulation mineral nutrition and grain yield. Fertilizer Res., 22: 71-78.

Akinyosoye, V.O., 1976. Senior Tropical Agriculture. Macmillan Publishers Ltd., London and Basingstoke, ISBN: 9780333192399, Pages: 199.

Atlas, R.M., 1977. Stimulated petroleum biodegradation. Crit. Rev. Microbiol., 5: 371-386.

Atuanya, E.L., 1987. Effects of waste engine oil pollution on physical and chemical properties of soil: A case study of waste oil contaminated Delta soil in Bendel State, Nigeria. J. Applied Sci., 5: 55-176.

Baker, J.M., 1970. The effect of oil on Plants. Environ Pollt., 1: 27-44.

Baldwin, I.L., 1922. Modification of the soil flora induced by applications of crude petroleum. Soil Sci., 14: 465-475.

Brantley Jr., B.B., 1992. McGraw-Hill Encyclopedia of Science and Technology. McGraw-Hill, USA., pp: 496-497.

Campbell, W.J. and M.C. Vavrek, 1999. Development of an emergence index of sensitivity to applied oil (year 2). Louisiana Applied and Educational Oil Spill Research and Development Program, OSRADP Technical Report Series No. 99-001.

De Jong, E., 1980. The effect of a crude oil spill on cereals. Environ. Pollut., 22: 187-196.

Doust, H. and E. Omatsola, 1990. Niger Delta. In: Divergent/Passive Margin Basins, Edwards, J.D. and P.A. Santogrossi (Eds.). AAPG Memoir, USA, pp: 239-248.

Duke, J.A., 1981. Handbook of Legumes of World Economic Importance. 1st Edn., Plenum Press, New York.

Ekundayo, E.O., T.O. Emede and D.I. Osayande, 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.

Gee, G.W. and J.W. Bauder, 1986. Particle Size Analysis. In: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, Klute, A. (Ed.). American Society of Agronomy, Madison, WI., pp: 383-411.

Gill, L.S., H.G.K. Nyawuame and A.O. Ehikhametalor, 1992. Effects of crude oil on the growth and anatomical features of *Chromolaena odorata* (L.) K. and R. Chromolaena Odoranta Newslett., 6: 1-6.

Hutchinson, T.C. and W. Freedman, 1978. Effects of experimental crude oil spills on subarctic boreal forest vegetation near Norman Wells, N.W.T., Canada. Can. J. Bot., 56: 2424-2433.

Kulke, H., 1995. Nigeria. In: Regional Petroleum Geology of the World, Part II: Africa, America, Australia and Antarctica, Kulke, H. (Ed.). Gebruder Borntraeger Publ., Berlin, Germany, pp: 143-172.

McLeod, E., 1982. Feed the Soil. Organic Agriculture Research Institute, Graton, CA., USA., Pages: 209.

Nwachukwu, J.I., A.F. Oluwole, O.I. Asubiojo, R.H. Filby, C.A. Grimm and S. Fitzgerald, 1995. A Geochemical Evaluation of Niger Delta Crude Oils. In: Geology of Deltas, Oti, M.N. and G. Postma (Eds.). A.A. Balkema Publ., Rotterdam, The Netherlands, pp: 287-300.

Odjegba, V.J. and A.O. Sadiq, 2002. Effect of spent engine oil on the growth parameters, chlorophyll and protein levels of *Amaranthus hybridus* L. Environmentalist, 22: 23-28.

Opeolu, B.O., 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.

Pandey, R.K., 1987. A Farmer's Primer on Growing Cowpea on Riceland. International Rice Research Institute (IRRI), Los Banos, Philippines, ISBN-13: 9789711041694, pp: 5-10.

Rhykerd, R.L., D. Sen, K.J. McInnes and R.W. Weaver, 1998. Volatilization of crude oil from soil amended with bulking agents. Soil Sci., 163: 87-92.

Rowell, M.J., 1977. The Effect of Crude Oil Spills on Soils. A Review of Literature. In: The Reclamation of Agricultural Soils after Oil Spills, Toogood, J.A. (Ed.). University of Alberta, Edmonton, pp: 1-33.

Sharma, G.K., C. Chandler and L. Salemi, 1980. Environmental pollution and leaf cultivar variation in kadzu (*Puereria lobata* Willd.). Ann. Bot., 45: 77-80.

Spiares, J.D., K.E. Kenworthy and R.L. Rhykerd, 2001. Emergence and height of plants seeded in crude oil contaminated soil. Texas J. Agric. Nat. Resour., 13: 37-46.

Thomas, D., 1995. Niger Delta oil production, reserves, field sizes assessed. Oil Gas J., 93: 101-104.

Udo, E.J. and A.A. Fayemi, 1975. Effects of oil pollution of soil on germination, growth and nutrient Uptake of corn. J. Environ. Qual., 4: 537-540.

Whiteman, A.J., 1982. Nigeria: Its Petroleum Geology, Resources and Potentials. Vol. 1, Graham and Trotman Publisher, London, UK., ISBN-13: 9780860102649, Pages: 394.