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Reproductive Capacity of Capsicum sp. as Affected by Crude Oil Pollution in Two Weather Conditions

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ABSTRACT

This study was aimed at investigating the reproductive capacity of *Capsicum annuum* and *C. frutescens* exposed to different crude oil concentrations. The experiment was conducted for two consecutive seasons (rainy and dry season) at the Botanical garden of Ahmadu Bello University, Zaria. The experiment was laid out in a completely randomized block design consisting of three treatments of crude oil polluted soil; control (C) from the pristine area, 50m from point of discharge (M) and 15 m from point of discharge (H). Plant productivity was measured at the end of the experiment for the both seasons. This includes; fruit yield, plant yield, fresh and dry weight matter. Data obtained for plant fresh weight has showed significant differences between the control (CA and CF), and the various level of crude oil pollution (MA, MF, HA and HF). The highest values were obtained in the control 2-6WAT during the rainy season. Crude oil pollution significantly suppressed fruit yield in the MA, MF, HA, and HF treated soils. There was significant difference (P<0.001) in the control and treatments in fruit yield to cadmium toxicity. However, *C. annuum* had more fruit yield than *C. frutescens* at both season. However, it was observed that plants in the rainy season had more yield production than those in the dry season. Although the plants performed well during the rainy season as compared to the dry season, crude oil negatively affects the plants reproductive capacity at both seasons

INTRODUCTION

Oil pollution in the environment has been a major source of concern to the people living in the crude oil-rich-areas. Transportation of crude oil or its products from the point of production to that of processing has resulted in spillage with adverse consequences. Oil blow outs have also occurred during extraction stage and when these happen, the oil empties itself either on the soil or in water bodies while the volatile one escape to the atmosphere [1]. In Nigeria, crude oil production and exploitation is a major source of income providing about 90% of the export earnings and serves as primary raw materials for the chemical industries. The impact on terrestrial environment ranges from aesthetic quality modification to death of sensitive biotic species. One of the environmental challenges posed by oil pollution is the alteration in the physical and chemical nature of the soil which subsequently affects the growth of plants [2].

Crude oil spillage on soil makes it unsatisfactory for plant growth. This is due to insufficient aeration of the soil because of displacement of air from the spaces between the soil particles by crude oil [3]. One of the environmental challenges posed by oil pollution is the alteration in the physical and chemical nature of the soil which subsequently affects the growth of plants [2]. Petroleum hydrocarbon contamination may affect plants by retarding seed germination and reducing height, stem density, photosynthetic rate and biomass or resulting in complete mortality [4].

Many authors have reported the phytotoxic effects of crude oil. They reported that oil-contaminated soil generally causes delayed seed emergence, suggesting that the inhibitory effect could be attributed principally to physical constraints as well as biological harm on the seeds resulting from the physical and chemical characteristics of crude oil. Plants and soil microbes compete for the little nutrient available in soils polluted with crude oil thereby suppressing the growth of plants in such soils [3,5-8].

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Plants are highly susceptible to oil exposure and this may kill them within a few weeks to several months; however there are several species that are capable of growing in soils polluted with hydrocarbons and participate in their degradation through roots which favour the growth of several microorganisms [3]. Thus, with the increasing soil infertility due to the destruction of soil micro-organisms, and dwindling agricultural productivity, farmers have been forced to abandon their land, to seek alternative means of livelihood which may be non-existent. Capsicum is one of the staple produce in Nigeria economy is commonly called "pepper". It can be eaten raw or cooked and mainly used as a spicy ingredient in a range of food. Capsicum contains high amounts of vitamin C and carotene (provitamin A). Yellow and especially green chilies (which are essentially unripe fruit) contain a considerably lower amount of both substances. In addition, pepper is also a good source of most vitamin B, and vitamin B6 in particular [9]. They are very high in potassium, magnesium, and iron.

Pepper is one of the most spices in Benin City, Edo State with residents clamoring for pepper rice or food with pronounced pepper. However, oil production in Ologbo community, Edo State has resulted to low pepper cultivation and or extinction in the area. Hence, the aim of the research work is to comparatively determine the yield production of two species of capsicum to crude oil pollution.

MATERIALS AND METHODS

Collection

The *C. annuum* and *C. frutescens* seeds were obtained from the Agricultural Development Project, Benin City, Edo State, Nigeria. Topsoil (0-15 cm) was collected at 50 m from point of discharge and 15 m from point of discharge located in Oredo Flow Station field of the Nigerian Petroleum Development Corporation (NPDC), Ologbo, Benin City. The control was collected at a pristine distance of 500 m. The various soils were transported to the laboratory for physicochemical analysis.

Experimental Site

The experiment was conducted at the Botanical garden Biological Sciences, Ahmadu Bello University, Zaria (long. 7°38'N and lat. 11°11'E).

Seed Nursery

The Capsicum seeds were nursed in the screen house of Biological Sciences, Ahmadu Bello University, Zaria. The seed of *C. frutescens* L. and *C. annum* L. were planted into polybags and watered immediately to soil field capacity and afterwards, every other day for three weeks.

Experimental Setup

Each polythene bag weighed 15 kg of soils. The experiment was laid out in a completely randomized block design consisting of three treatments of crude oil polluted soil; control (C) from the pristine area, 50 m from point of discharge (M) and 15 m from point of discharge (H). Seedlings of relative age were transplanted into the various concentration of crude oil polluted soil. There were two plant *sp.* replicated thrice, one seedling per bag making a total of 54 plants. Plant productivity was measured at the end of the experiment for the both seasons. This includes; fruit yield, plant yield, fresh and dry weight matter. The fruit yield observed was counted after harvesting. The plant fresh weight was by weighing. For the dry weight, the plant samples were oven dried using the Memmert oven at 70°C for 22 hour to a constant weight using the method. This was done for both the dry and rainy season.

Statistics

The data were analyzed using the analysis of variance (ANOVA) technique while Least significant different was used to separate their means. Dendrogram was used to determine any genetic variability in capsicum response while box and whiskers was used to ascertain the range of distribution of plant yield.

RESULTS

Plant Fresh Weight

Tables 1 and 2 shows the effect of crude oil pollution on the fresh weight matter of *C. annuum* and *C. frutescens* during the rainy and dry season. The fresh weight of both Capsicums varies between the various levels of concentrations and between seasons. Data obtained for plant fresh weight has showed significant differences between the control (CA and CF), and the various level of crude oil pollution (MA, MF, HA and HF). The highest values were obtained in the control 2-6WAT during the rainy season **(Table 1)**. Least values were obtained in HA 4WAT and HF 6WAT in crude oil polluted soil. The difference in treatment and control were found to be significant ($P<0.05$).

During the dry season, there were significant differences ($P<0.05$) between the control and various level of crude oil pollution 2-6WAT **(Table 2)**. 4-5 WAT, there was no significant difference in the mean fresh weight of MA, MF, HA and HF respectively. However, there was difference in MA as compared to the other level of crude oil pollution 2-3 WAT ($P<0.05$).

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Table 1. Mean plant fresh weight of *C. frutescens* and *C. annuum* treated with different crude oil concentration during the rainy season. Values are means of 3 replicates ± S.E.

Crude oil Conc.	Plant fresh weight (WAT) Weeks after Transplanting (WAT)					
	1	2	3	4	5	6
CA	0.16 ± 0.05^{a}	0.31 ± 0.04^{a}	0.78 ± 0.05^{a}	1.05 ± 0.13^{a}	1.84 ± 0.25^{a}	2.67 ± 0.25^{a}
MA	0.12 ± 0.04^{a}	0.24 ± 0.03^{b}	0.35 ± 0.03^{b}	0.27 ± 0.08^{b}	0.22 ± 0.03^{b}	0.21 ± 0.02^{c}
HA	0.13 ± 0.02^{a}	0.17 ± 0.03^{c}	0.28 ± 0.04^{b}	0.17 ± 0.04^{c}	0.15 ± 0.04^{b}	0.12 ± 0.01^{de}
CF	0.31 ± 0.13^{a}	0.35 ± 0.04^{a}	0.72 ± 0.04^{a}	1.22 ± 0.16^{a}	1.58 ± 0.40^{a}	1.91 ± 0.32^{b}
MF	0.12 ± 0.04^{a}	0.15 ± 0.01^{c}	0.30 ± 0.06^{b}	0.28 ± 0.03^{b}	0.23 ± 0.02^{b}	0.17 ± 0.02^{cd}
HF	0.11 ± 0.02^{a}	0.15 ± 0.05^{c}	0.27 ± 0.03^{b}	0.24 ± 0.07^{bc}	0.17 ± 0.02^{b}	0.11 ± 0.02^{e}

Note: *Means in the same column with same letter(s) are not significantly different (P≥0.05), CA=*C. annuum* in Control, MA=*C. annuum* in Medium polluted soil, HA=*C. annuum* in heavily polluted soil, CF=*C. frutescens* in Control, MF=*C. frutescens* in Medium polluted soil, HF=*C. frutescens* in heavily polluted soil, WAT=Weeks after transplanting

Table 2. Mean plant fresh weight of *C. frutescens* and *C. annuum* treated with different crude oil concentration during the dry season. Values are means of 3 replicates ± S.E.

Crude oil Conc.	Plant fresh weight (g) Weeks after Transplanting (WAT)					
	1	2	3	4	5	6
CA	0.05 ± 0.02^{a}	0.20 ± 0.01^{a}	0.35 ± 0.04^{a}	0.61 ± 0.01^{a}	0.89 ± 0.03^{a}	1.48 ± 0.01^{a}
MA	0.04 ± 0.03^{a}	0.12 ± 0.02^{b}	0.14 ± 0.01^{b}	0.19 ± 0.02^{b}	0.17 ± 0.02^{b}	0.10 ± 0.004^{bc}
HA	0.05 ± 0.004^{a}	0.07 ± 0.04^{c}	0.07 ± 0.01^{c}	0.15 ± 0.003^{b}	0.13 ± 0.03^{b}	0.07 ± 0.01^{c}
CF	0.10 ± 0.01^{a}	0.21 ± 0.02^{a}	0.45 ± 0.03^{a}	0.68 ± 0.02^{a}	1.08 ± 0.01^{a}	1.69 ± 0.04^{a}
MF	0.09 ± 0.02^{a}	0.08 ± 0.02^{bc}	0.11 ± 0.02^{bc}	0.21 ± 0.01^{b}	0.19 ± 0.03^{b}	0.18 ± 0.04^{b}
HF	0.05 ± 0.01^{a}	0.07 ± 0.03^{c}	0.09 ± 0.01^{c}	0.18 ± 0.01^{b}	0.14 ± 0.02^{b}	0.10 ± 0.01^{c}

Note: *Means in the same column with same letter(s) are not significantly different (P≥0.05), CA=*C. annuum* in Control, MA=*C. annuum* in Medium polluted soil, HA=*C. annuum* in heavily polluted soil, CF=*C. frutescens* in Control, MF=*C. frutescens* in Medium polluted soil, HF=*C. frutescens* in heavily polluted soil, WAT=Weeks after transplanting.

Plant Dry Weight

The effect of crude oil pollution significantly reduced (P>0.05) the mean dry weight of *C. annuum* and *C. frutescens* during the rainy and dry season **(Tables 3 and 4).** The highest values were obtained for plants grown in the unpolluted soil (CA and CF). The difference in treatment was also observed to be significant. Crude oil pollution 1–2WAT resulted to no significant difference between the control and various levels of pollution. 5–6WAT at all concentrations resulted in a significant reduction in plant dry weight when compared with the control in both *C. annuum* and *C. frutescens* during the rainy season **(Table 3)**.

Table 4 shows the mean plant dry weight of *C. annuum* and *C. frutescens* planted during the dry season. Crude oil polluted 1WAT had no significant difference at all levels of pollution compared with the control. 2–6WAT showed significant reduction in MA, MF, HA and HF as compared to control (CA and CF), while 6WAT MA and MF were significantly different from HA and MF.

Table 3. Mean plant dry weight of *C. frutescens* and *C. annuum* treated with different crude oil concentration during the rainy season. Values are means of 3 replicates ± S.E.

Crude oil Conc.	Plant dry weight (g) Weeks after Transplanting (WAT)					
	1	2	3	4	5	6
CA	0.07 ± 0.03^{a}	0.07 ± 0.01^{b}	0.20 ± 0.03^{a}	0.24 ± 0.03^{b}	0.28 ± 0.01^{a}	0.76 ± 0.14^{a}
MA	0.02 ± 0.01^{a}	0.03 ± 0.01^{cd}	0.11 ± 0.02^{bc}	0.07 ± 0.01^{d}	0.05 ± 0.02^{b}	0.04 ± 0.01^{bc}
HA	0.02 ± 0.01^{a}	0.02 ± 0.003^{d}	0.08 ± 0.03^{c}	0.04 ± 0.01^{d}	0.03 ± 0.003^{b}	0.02 ± 0.01^{c}
CF	0.07 ± 0.03^{a}	0.15 ± 0.06^{a}	0.18 ± 0.04^{ab}	0.35 ± 0.08^{a}	0.20 ± 0.02^{a}	0.62 ± 0.27^{a}
MF	0.02 ± 0.01^{a}	0.06 ± 0.02^{c}	0.18 ± 0.08^{ab}	0.12 ± 0.03^{c}	0.08 ± 0.01^{b}	0.05 ± 0.01^{b}
HF	0.02 ± 0.01^{a}	0.01 ± 0.003^{d}	0.07 ± 0.01^{c}	0.05 ± 0.01^{d}	0.03 ± 0.01^{b}	0.02 ± 0.003^{c}

Note: *Means in the same column with same letter(s) are not significantly different (P≥0.05), CA=*C. annuum* in Control, MA=*C. annuum* in Medium polluted soil, HA=*C. annuum* in heavily polluted soil, CF=*C. frutescens* in Control, MF=*C. frutescens* in Medium polluted soil, HF=*C. frutescens* in heavily polluted soil, WAT=Weeks after transplanting.

Table 4. Mean plant dry weight of *C. frutescens* and *C. annuum* treated with different crude oil concentration during the dry season. Values are means of 3 replicates ± S.E.

Crude oil Conc.	Plant dry weight (g) Weeks after Transplanting (WAT)					
	1	2	3	4	5	6
CA	0.06 ± 0.01^{a}	0.08 ± 0.03^{a}	0.11 ± 0.01^{a}	0.23 ± 0.03^{a}	0.11 ± 0.01^{a}	0.18 ± 0.02^{a}
MA	0.01 ± 0.003^{a}	0.02 ± 0.002^{b}	0.05 ± 0.004^{b}	0.07 ± 0.01^{b}	0.04 ± 0.003^{b}	0.03 ± 0.01^{b}
HA	0.01 ± 0.001^{a}	0.03 ± 0.004^{b}	0.04 ± 0.01^{bc}	0.05 ± 0.005^{b}	0.02 ± 0.01^{b}	0.01 ± 0.001^{c}
CF	0.04 ± 0.01^{a}	0.04 ± 0.01^{ab}	0.07 ± 0.01^{ab}	0.16 ± 0.01^{a}	0.10 ± 0.01^{a}	0.14 ± 0.02^{a}
MF	0.04 ± 0.01^{a}	0.03 ± 0.002^{b}	0.02 ± 0.003^{c}	0.05 ± 0.02^{b}	0.02 ± 0.003^{b}	0.02 ± 0.002^{b}
HF	0.03 ± 0.01^{a}	0.02 ± 0.002^{b}	0.01 ± 0.004^{c}	0.02 ± 0.003^{b}	0.01 ± 0.003^{b}	0.01 ± 0.003^{c}

Note: *Means in the same column with same letter(s) are not significantly different (P≥0.05), CA=*C. annuum* in Control, MA=*C. annuum* in Medium polluted soil, HA=*C. annuum* in heavily polluted soil, CF=*C. frutescens* in Control, MF=*C. frutescens* in Medium polluted soil, HF=*C. frutescens* in heavily polluted soil, WAT=Weeks after transplanting.

Yield Production

The effect of crude oil on the amount of fruit yield at the end of the experiment during the rainy and dry season is shown below **(Figure 1)**. Crude oil pollution significantly suppressed fruit yield in the MA, MF, HA, and HF treated soils. There was significant difference (P<0.001) in the control and treatments in fruit yield to cadmium toxicity. However, *C. annuum* had more fruit yield than *C. frutescens* at both season. However, it was observed that plants in the rainy season had more yield production than those in the dry season.

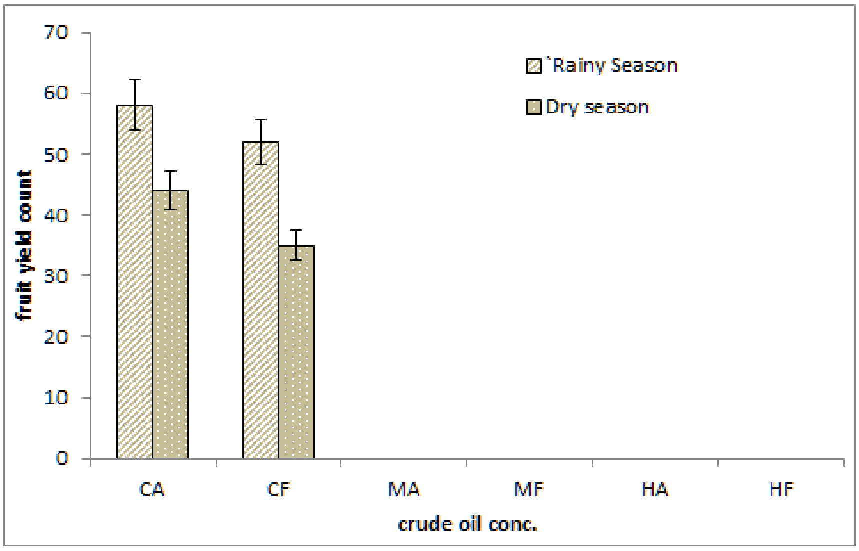

Figure 1. Plant fruit yield of *C. frutescens and C. annuum* treated with different crude oil concentration during the rainy and dry season.

DISCUSSION

The present study demonstrated the response of *C. annuum* and *C. frutescens* yield to the effect of crude oil pollution during the rainy and dry season respectively. Oil pollution of soil leads to build up of essential (organic C, P, Ca, Mg) and non-essential (Mg, Pb, Zn, Fe, Co, Cu) elements in soil and the eventual translocation in plant tissues [10]. Soils polluted with crude oil result in the soil remaining unsuitable for crop growth. The disruption of soil physical properties by crude oil with anaerobic and hydrophobic condition was found largely responsible for reduction in plant fresh weight [9]. Smith et al. [10] also reported stomatal closure and decrease in leaf, stem and root dry weight in poorly aerated soils as was also reported in this study. Crude oil pollution significantly (P<0.05) reduced the plants biomass matter with increase in concentration **(Tables 1-4)**. This agrees with the previous work reported by Ohanmu et al. [1] that plant growth in the crude oil polluted soil decrease with increased concentration. This may be due to increased phytotoxicity above the tolerance limit of the plant. However, this reduction was more pronounced during the dry season and was plant dependent.

The plants dry weight reduction was more pronounced in the dry season than the rainy season. These results are supported by previous studies in Nigeria where the effect of crude oil has been used in different plants [11-13]. The low dry matter weight caused by oil pollution of plants lead to the non-productivity in MA, MF, HA and HF as compared to the control which produced fruit yield.

The yield of a crop is a complex trait affected by genetically controlled physiological components [14]. Crude oil contamination of soil has been reported to cause reduction in the germination, growth and their performance and even yield [15,16]. Oil contamination of soil has also been shown to limit normal diffusion processes thereby reducing the availability of the level of some nutrients in the soil [17].

The low dry matter weight caused by oil pollution of plants lead to the non-productivity in MA, MF, HA and HF as compared to the control which produced fruit yield. The yield of a crop is a complex trait affected by genetically controlled physiological components [14]. Crude oil contamination of soil has been reported to cause reduction in the germination, growth and their performance and even yield [15,16]. Oil contamination of soil has also been shown to limit normal diffusion processes thereby reducing the availability of the level of some nutrients in the soil [17].

CONCLUSION

The phytochemical analysis of the fruits yield was not determined due to the fact that there was no yield at the end of the experiment in the MA, MF. HA and HF crude oil polluted soils at both seasons. However, *C. annuum* and *C. frutescens* could be used as a bio-indicator and phyto-remediation of environmental pollution in a given area.

RECOMMENDATION

Further studies should be carried out at lower concentrations to determine the phytochemical analysis of the fruits *C. annuum* and *C. frutescens* in crude oil polluted soils to ascertain any possible translocation to the fruits.

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