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Effects of Crude Oil Levels on the Growth of Maize (*Zea mays* L.)

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Abstract: Field trials were carried out in 2003 and 2004 cropping seasons to determine the effects of crude oil levels: 0.0 (control), 5.2, 10.4, 20.8 and 41.6 mL on the growth of seven maize varieties: Composite (suwan 1), Hybrid 3x-yx, AMATZBR w, TZBRSYN w, AMATZBR y, TZBRSYN y and Ozoro local at the Teaching and Research Farm of the Delta State University, Asaba Campus and at the Delta State Polytechnic, Ozoro. Nigeria. Crude oil application to soil was carried out at three weeks after planting (3 WAP), 5 WAP and 7 WAP. Significant ($p \geq 0.05$) reductions in plant height, leaf area and stem diameter were observed in maize seedlings grown in 10.4 mL of the oil when compared with seedlings grown in 5.2 mL of oil treatment. All the maize varieties which, received oil treatment at 3 WAP died within 24 h of the application while the plants without crude oil grew normally. Maize varieties subjected to 41.6 mL of the oil died within 2 and 48 h after the treatment. On exposure to 20.8 mL, Composite (suwan 1), Hybrid 3x-yx and Ozoro local died. At 5.2 mL of oil treatment, there was growth enhancement when compared with seedlings in the other treatments including the control. This study has demonstrated that crude oil levels have significant effects on the growth of maize. The study has also established that small amounts of mineral oils or oil products in soil are not harmful but may actually be beneficial to plants.

Key words: Crude oil levels, growth, maize, enhancement, retardation

INTRODUCTION

As one of the cheapest sources of food energy, maize plays a major role in meeting the rising consumption of both food and animal feed in developing countries (FAO, 2002). FAO (2002) maintained that each part of maize including the stalk, leaves, silk, cob and kernels has a commercial value, the kernel being the most useful; hence, Cunard (1971) stated that maize is a universal crop species. Maize is grown in every important agricultural area of the world (Russell and Halluauer, 1980) including the southern part of Nigeria where oil industrial activities are predominant (Agbogidi *et al*., 2005).

Environmental pollution from oil activities in a major oil producing country as Nigeria is inevitable (Agbogidi and Eshegbeyi, 2006). Considering the large quantities of oil reportedly lost to agricultural lands (Ogri, 2001), it has become necessary to investigate the effects of oil spillage on agricultural lands and the crops grown in them. The objective of this study was to evaluate the effects of crude oil levels on the growth of maize.

MATERIALS AND METHODS

The study was carried out at the Teaching and Research Farm of the Delta State University, Asaba Campus, Delta State, during the 2003 and 2004 cropping seasons (latitude 06°14'N, longitude

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06°49'E of the equator) (Asaba Meteorological Station, 2003). The other location was the Delta State Polytechnic, Ozoro. Ozoro lies between latitude 6°13[1]E and longitude 5°33[1]N (College of Agriculture Meteorological Station, Ozoro, 2003). Seven maize varieties: Composite (suwan 1), Hybrid 3x-yx, AMATZBR w, TZBRSYN w, AMATZBR y, TZBRSYN y and Ozoro local were used for the study. The experiment was laid out in a split-split-plot design with three replicates. Between row spacing was 0.75 m and within row spacing was 0.25 m. Two seeds were planted and the maize seedlings were thinned to one plant per hill or stand when seedlings were 12-15 cm tall or at knee level.

The experimental area was hoe-weeded as and when due to enable the plants develop under non-limiting conditions. In order to determine the minimum level of contamination that will cause damage to the plants, low levels of 0.0 (control), 5.2, 10.4, 20.8 and 41.6 mL of crude oil were applied per stand. Six stands of maize plants per sub-sub-plot per treatment were used. The oil was slowly poured from a beaker into the soil around the maize stand (ring application) at 3 WAP. Applications were carried out at 5 and at 7 WAP on fresh sets of maize plants. The volumes of crude oil used were 5.2, 10.4, 20.8 and 41.6 mL/plant. There was a control without crude oil. Growth and development were monitored visually. Data were taken both from the contaminated and uncontaminated sub-sub-plots.

Parameters assessed were plant height (cm), leaf area (cm^2) and stem diameter (cm). Plant height was measured from soil level to terminal bud using a measuring tape. Leaf area was derived from the length and breath measurements of the longest leaf per plant per sub-plot and correction factor value of 0.75 was used to multiply the value of the length times breathe following the procedure of Cunard (1971). The stem diameter was determined with the use of calibrated veneer calipers. Data collected were subjected to analysis of variance and the significant means were separated with the Duncan's multiple range tests using SAS (1996).

RESULTS

There were gradual increases in plant height, leaf area and stem diameter with plant age across locations (Table 1-3, respectively). Significant differences ($p \leq 0.05$) were observed among the varieties

Table 1: Effects of crude oil levels and maize varieties on plant height (cm) across locations (Anwai and Ozoro)

	Level of crude oil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
4 WAP					
Composite (suwan 1)	39.98a	41.06b	39.60a	38.02a	37.01a
Hydrid 3x-yx	40.01a	40.87b	39.54a	38.05a	36.01a
AMATZBR w	41.05a	41.56b	40.21a	40.00a	38.41a
TZBRSYN w	37.41b	38.60c	36.81b	35.16ab	34.01ab
AMATZBR y	36.86b	36.89c	36.08b	35.20ab	34.06ab
TZBRSYN y	35.81b	36.90c	35.02b	34.13ab	33.05ab
Ozoro local	41.09a	43.06a	41.06a	41.00a	40.00a
6 WAP					
Composite (suwan 1)	69.48d	70.46d	69.42d	64.21b	63.12c
Hydrid 3x-yx	80.41c	80.69c	78.13c	73.32b	72.22b
AMATZBR w	92.79b	93.46b	92.04ab	86.96ab	84.28ab
TZBRSYN w	92.92b	93.64b	91.12ab	90.00a	88.41a
AMATZBR y	96.90a	97.08ab	95.06ab	93.46a	90.42a
TZBRSYN y	88.65c	89.08bc	87.52b	83.47ab	81.72ab
Ozoro local	97.09a	100.70a	97.04a	95.40a	91.60a
8 WAP					
Composite (suwan 1)	197.40b	198.52ab	196.03ab	196.00ab	195.41a
Hydrid 3x-yx	194.01b	196.40ab	193.24ab	192.64ab	191.61a
AMATZBR w	202.04a	203.41a	201.16a	200.63a	199.35a
TZBRSYN w	202.83a	204.62a	201.03a	200.20a	199.00a
AMATZBR y	203.98a	204.31a	201.34a	200.00a	198.21a
TZBRSYN y	203.01a	204.00a	203.00a	201.16a	199.50a
Ozoro local	205.64a	208.41a	205.60a	205.18a	204.96a

Means in the same column with the same letter(s) and within the same WAP are not significantly different ($p \geq 0.05$), using DMRT; WAP = Weeks After Planting

Table 2: Effects of crude oil levels and maize varieties on leaf area (cm^2) across locations (Anwai and Ozoro)

	Level of crude oil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
4 WAP					
Composite (suwan 1)	44.26b	46.42ab	44.00ab	43.10ab	42.00ab
Hydrid 3x-yx	45.50b	46.04ab	44.46ab	43.96ab	41.02ab
AMATZBR w	44.96c	47.01ab	44.36ab	43.12ab	41.00ab
TZBRSYN w	44.98c	46.62ab	44.45ab	44.31ab	42.40ab
AMATZBR y	46.65ab	46.96ab	46.06a	45.01ab	43.01ab
TZBRSYN y	42.61d	43.72b	42.17b	42.00b	40.61ab
Ozoro local	48.06a	49.90a	48.01a	47.21a	46.21a
6 WAP					
Composite (suwan 1)	143.30c	143.80c	143.01c	141.07b	140.01b
Hydrid 3x-yx	148.60c	149.01c	146.74c	143.67b	142.02b
AMATZBR w	160.12b	160.67b	156.36b	153.46ab	150.34ab
TZBRSYN w	159.40b	160.43b	158.37b	156.72ab	152.42ab
AMATZBR y	178.80a	178.90ab	168.37b	164.32a	160.21ab
TZBRSYN y	161.41b	164.31b	159.64b	153.47ab	150.36ab
Ozoro local	180.82a	200.01a	180.02a	178.34a	174.41a
8 WAP					
Composite (suwan 1)	310.64d	311.04b	309.38ab	308.41ab	306.36c
Hydrid 3x-yx	341.15c	341.16ab	321.60ab	321.01ab	320.81c
AMATZBR w	344.09c	345.00ab	340.84ab	340.46ab	339.87b
TZBRSYN w	350.52c	351.63a	347.45ab	347.40ab	346.96b
AMATZBR y	388.19ab	389.20	385.64a	385.52ab	385.29a
TZBRSYN y	382.09b	383.30a	376.86a	376.54a	377.00ab
Ozoro local	393.20a	398.41a	391.07a	391.04a	391.00a

Means in the same column with the same letter(s) and within the same WAP are not significantly different ($p \geq 0.05$), using DMRT; WAP = Weeks After Planting

Table 3: Effects of crude oil levels and maize varieties on stem diameter (cm) across locations (Anwai and Ozoro)

	Level of crude oil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
4 WAP					
Composite (suwan 1)	1.01a	1.03a	1.00a	0.94a	0.92a
Hydrid 3x-yx	1.16a	1.18a	1.04a	0.96a	0.94a
AMATZBR w	1.14a	1.15a	1.12a	0.98a	0.92a
TZBRSYN w	1.01a	1.06a	1.00a	0.93a	0.90a
AMATZBR y	1.19a	1.20a	1.02a	0.90a	0.81a
TZBRSYN y	1.14a	1.15a	1.10a	0.94a	0.90a
Ozoro local	1.21a	1.24a	1.08a	1.04a	0.98a
6 WAP					
Composite (suwan 1)	6.53a	6.54a	6.34a	5.42a	5.40a
Hydrid 3x-yx	6.10b	6.12a	6.00a	5.52a	5.46a
AMATZBR w	6.85a	6.86a	6.71a	6.01a	5.84a
TZBRSYN w	6.01b	6.10a	5.89a	5.61a	5.96a
AMATZBR y	6.04b	6.08a	6.00a	5.04a	5.00a
TZBRSYN y	6.23a	6.24a	6.12a	5.68a	5.53a
Ozoro local	6.69a	6.70a	6.64a	6.09a	6.02a
8 WAP					
Composite (suwan 1)	7.88b	7.89a	7.41a	7.40a	7.38a
Hydrid 3x-yx	7.84b	7.86a	7.32a	7.30a	7.28a
AMATZBR w	8.01ab	8.02a	7.36a	7.32a	7.26a
TZBRSYN w	8.10a	8.11a	7.42a	7.41a	7.30a
AMATZBR y	8.04ab	8.05a	7.43a	7.42a	7.34a
TZBRSYN y	7.51b	7.53a	7.42a	7.39a	7.36a
Ozoro local	8.18a	8.21a	8.00a	7.98a	7.97a

Means in the same column with the same letter(s) and within the same WAP are not significantly different ($p \geq 0.05$), using DMRT; WAP = Weeks After Planting at 4, 6 and 8 WAP, respectively (Table 1). The highest mean values of 208.41 cm, 393.41 cm^2 and 8.21 cm for plant height, leaf area and stem diameter were recorded for Ozoro local at 8 WAP, respectively. The lowest leaf area was recorded for TZBRSYN y at 4 WAP, Composite (suwan1) at 6 WAP and at 8 WAP. Although no significant difference at $p \geq 0.05$ was observed in the stem diameter of the seven varieties of maize at 4 WAP, Composite (suwan1), AMATZBR w, TZBRSYN y and Ozoro local were significantly different from Hybrid 3x-yx, TZBRSYN w and AMATZBR y at 6 WAP in the control sub-sub-plots at the 5% level of probability. All the maize varieties which, received oil treatment at 3 WAP died within 24 h of the application while the plants without crude oil grew normally. Maize varieties subjected to 41.6 mL of the oil died within 2 and 48 h after the treatment. On exposure to 20.8 mL, Composite (suwan 1), Hybrid 3x-yx and Ozoro local died. Growth retardation in terms of plant height, leaf area and stem diameter was observed in maize seedlings grown in soils treated with 10.4 mL of the oil and leaf chlorosis was observed. At 5.2 mL of oil treatment, there was growth enhancement when compared with seedlings in the other treatments including the control.

DISCUSSION

The high plant mortality in three weeks old maize was probably due to the contact of the oil with a large percentage of the photosynthetic leaf surfaces of the vegetation and the penetration of the oil into the plant tissue. This finding corresponds with the report of Klingman (1961) that oil applied to roots can move up to the leaves and oil applied to leaves can move down into roots. The observed yellowing of leaves resulted in loss of photosynthetic ability and general physiological weakening of the plants causing the three weeks old maize plants from all the varieties tested to succumb. Cessation of growth or stunting, wilting and withering may all be attributed to one or a combination of these stress conditions. Agbogidi and Eshegbeyi (2006) noted that symptoms of oil pollution in soil were typical of extreme nutrient deficiency in plants while McKee (1995) reported that nutrient deficiency symptoms could be directly proportional to water uptake.

The observed luxurious growth in five weeks old maize plants, which received 5.2 mL of oil indicated enhancement of growth (fertilizer effect). Growth stimulation of a variety of plants as a result of the presence of crude oil seems to be a fairly usual phenomenon. Following the Torrey Canyon oil pollution in Brittany, Stebbings (1970) reported that stands of *Agropogon pungens*, *Jucus maritimus*, *Scripus maritimus* and *Festuca rubra* were extremely vigorous. Baker (1970) had earlier reported that crude oil stimulated growth in *Pucinellia maritiam* and *Festuca rubra.* It is possible for growth stimulation to be effected in the 5.2 mL treatment due to uptake of nutrients especially nitrogen obtained from decomposed soil micro-organisms such as bacteria, fungi, etc., which were killed by oil applied to the soil. The significant effect of treatment 5.2 mL over the higher levels agrees with earlier results of Gudin and Syratt (1975) who reported that it is possible for oil in the soil to be degraded and release nitrogen and other mineral nutrients later on for plant use. Baker (1970) posited that enhancement of growth may be related to the ability of the plants to metabolise hydrocarbons while Kolattukudy (1979) reported that some plants can oxidise many hydrocarbons and their derivatives which occur naturally in them. Makcin (1980) reported that crude oil rapidly killed the salt marsh *Distichlis spicata* but later, they completely repopulated the area and produced lust growth, which he thought might be due to fertilization from oil decomposition products. Odu (1981) also stated that crude oil pollution up to 1% could easily be degraded by natural rehabilitation in soils as the oil could be expected to increase organic matter in the soil and improve the fertility, physical and chemical properties of the soil. Udo and Oputa (1984) maintained that oil in the soil leads to an increase in the uptake of manganese and iron in plants. In the same vein, Bamidele and Agbogidi (2000) reported growth stimulation for aquatic macrophytes in the presence of 12.5% water-soluble fraction of crude oil while Agbogidi and Eshegbeyi (2006) recorded growth stimulation in *Dacryodes edulis* at 2.08% of crude oil application to soil.

Plant Height

Significant differences ($p \leq 0.05$) existed in the effect of oil pollution levels and plant height. The observed reduction in the height of maize plants subjected to higher doses of the oil confirmed the findings of Rowell (1977) who reported that growth retardation is possible with oil pollution of soil due to insufficient aeration caused by displacement of air from pore spaces. De Jong (1980) reported on the evidence of growth retardation as a result of increased demand for oxygen by oil decomposing organisms. The observed inhibition of plant height in maize seedlings grown in soils treated with 20.8 mL of the oil corresponds with the report of Asuquo *et al*. (2002) on okra and fluted pumpkin. Reduction in growth following crude oil pollution could be attributed to a disruption in aeration and biological properties of the soil. Plant height as a plant growth character and yield index is vital for maize. This is because, the taller a plant, the higher the amount of light energy absorbed by such plant and invariably, the higher the rate of photosynthesis and consequently the amount of assimilates produced by the leaves.

Leaf Area

The observed reduction in the leaf area at higher levels of oil application may be attributed to the fact that crude oil application to soil created conditions that limited water supply to the plants. Cutler *et al*. (1987) reported that water stress limits leaf development primarily through a reduction in cell size rather than cell number in *Nicotiana tabacum* and *Gossypium arboreum*. The reduction and depression in the leaf area of maize plants grown in the higher levels of oil probably led to a reduction in photosynthesis as the surface area of the leaves were reduced. Leaf area depression following stressed conditions (presence of crude oil) has been reported for melon (Anoliefo, 1991), hot pepper and tomatoes (Anoliefo and Vwioko, 1994), aquatic macrophytes (Bamidele and Agbogidi, 2000) and *Amaranthus hybridus* (Odjegba and Sadiq, 2002). Oil pollution has been reported to physically act by absorbing light wavelengths essential for photosynthesis (Baker, 1970; Odjegba and Sadiq, 2002). The considerable reduction in the leaf area could indicate that leaf stomata were grossly affected by crude oil. The observed significant reduction between the degree of leaf area reduction and concentration of crude oil in the soil further confirmed earlier reports of Sharma *et al.* (1980). The reduced leaf area following crude oil application to soil may also imply leaf shrinkage and Baker (1970) attributed it to a reduction or delay in cell expansion. Differential changes in the rate of leaf growth may be associated with anatomical and morphological change caused by the oil (Agbogidi *et al*., 2005). Baker (1970) noted that oil pollution of soil affects physiological processes such as leaf initiation and leaf area expansion, photosynthetic ability, root activity, partitioning of nutrients and photosynthates between various plant organs.

The significant increase in the leaf area of plants exposed to low amount of the oil (5.2 mL) showed that little amount of the oil in the soil stimulated greater leaf area. This can be interpreted in part as a physiological adaptation adopted by the plant to increase surface area of the leaves for greater photosynthetic rates. It also suggested greater cell size, enhanced cell expansion and enlargement made possible by higher nutrient availability. This observation corresponds with the findings of Wilkins (1985) and McKee (1995) that enhanced plant parameters indicate higher nutrient availability. Similar observation of increased leaf area in the presence of light doses of oil contamination has been made by Evans (1973), Winter *et al.* (1976), Cutius and Lauchi (1986), Bamidele and Agbogidi (2000). Nasamu (1996) had also reported a significant stimulation in the growth characters of *Xanthosoma sagittifolium* at 6-12% (w/w) pollution.

The root rot, stem rot, drying of lower leaves, growth stunting and super-stunting, leaf burnt and falling of leaves from the base, differential changes in the rate of leaf initiation and leaf growth as well as reduced root activity in maize plants exposed to higher oil levels could be attributed to the adulterated structure of the soil or higher crude oil assimilation by plants of higher concentration levels applied to the soil. Leaves are the sources or sites of assimilate where food materials are manufactured and transported to the sinks (the seeds and other parts of the plant body). If the conditions in the sources are favourable, the rate of photosynthesis is enhanced and consequently, the yield of the plant. For example, increased number of leaves and larger surfaces of leaf area allow for greater photosynthetic surfaces, which can lead to higher photosynthetic rates and consequently, better yield (Wilkins, 1985; Cutius and Lauchi, 1986). If the leaf areas are negatively affected as a result of crude oil pollution of soil, the growth and yield of the maize would be significantly reduced. Larson and Hanway (1977) had earlier reported reduced corn production following exposure to stressed environmental conditions.

Stem Diameter

There was a consistent increase in the stem diameter of maize plant grown in the uncontaminated soil (0.0) and 5.2 mL of oil treatment, respectively throughout the sampling period and both deferred significantly ($p \leq 0.05$) from those of other treatments. The higher levels of soil contamination (10.4, 20.8 and 41.6 mL), respectively, continued to diminish in collar girth as plants were observed to dehydrate indicating water deficiency due to an increase in soil toxic levels. Similar results were obtained by Odu (1981) who reported that adverse effects of oil on soil is due to certain conditions which make nutrients for plant growth unavailable to plants. Poor growth as observed in the present study may be due mainly to the difficulties in the absorption of water and nutrients by roots as well as toxicity of the oil components. Petroleum products have been shown to impact an inhibitory effect on plant growth and development in various ways (Gill *et al.*, 1992). The poorer growth of maize plants exposed to higher doses of the crude oil conforms to the reports of Asuquo *et al.* (2002) who reported that the performance of okra and fluted pumpkin plants after germination in terms of stem diameter was seriously affected by crude oil pollution of soil. This poor growth could be attributed to the alteration caused by oil application to soil, which could have affected below ground processes that are vital for photosynthetic system. Some of these processes include absorption of mineral nutrients and water (Wilkins, 1985).

This study has demonstrated that crude oil levels have a significant effect on the growth of maize. The study also established that small amounts of mineral oils or oil products in soil are not harmful but may actually be beneficial to plants.

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