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Yields of Maize (*Zea mays* L.) As Affected by Crude Oil Contaminated Soil

O.M. Agbogidi, S.O. Akparobi and P.G. Eruotor
Faculty of Agriculture, Delta State University, Asaba Campus, Delta State, Nigeria

Abstract: A study was carried out during the 2003 and 2004 cropping seasons to investigate the effects of crude oil contaminated soil on the yield of seven maize varieties (Composite suwan 1, Hybrid 3x-yx, AMATZBR w, TZBRSYN w, AMATZBR y, TZBRSYN y and Ozoro local) in two locations (Asaba and Ozoro) in Delta State, Nigeria. Five crude oil concentrations (0.0, 5.2, 10.4, 20.8, and 41.6 mL per maize stand) applied to soil at seven weeks after planting (7 WAP) constituted treatments. The experiment was laid out in a split-split-plot arrangement and replicated four times. Locations of study were allotted the main plots, the crude oil levels, the sub-plots and the maize varieties, the sub-sub-plots. The results indicated that both the fresh grain yields and dry grain yields of the maize across locations and within locations were not significantly affected ($p = 0.05$) by crude oil application to soil up to 5.2 mL but higher levels of the oil contamination significantly ($p = 0.05$) reduced these characters. The Hybrid (3x-yx) variety had the highest fresh and dry grain yields across and within locations hence it should be recommended for planting in Asaba and Ozoro locations of Delta State. Ozoro local had the lowest grain yields among the varieties tested. This study has shown that crude oil contaminated soil has a highly significant effect of reducing the yields of maize. The present study also established varietal differences in maize with response to crude oil thereby providing a basis for future study by plant breeders.

Key words: Crude oil, soil contamination, grain yields, maize

Introduction

Environmental impact of oil exploration and exploitation in a major oil producing country as Nigeria is inevitable. Reported cases of oil spillage in Delta State in particular and Nigeria in general are quite recent (Benka-Coker and Ekundayo, 1995; Ekundayo and Obuekwe, 1997). These spillages may be due to occasional blowouts from oil wells or through leakages of oil pipes, corrosion, sabotage to well heads, oil production operations, engineering drills and others (Okpokwasili and Amanchukwu, 1988; Nwilo, 1998; Agbogidi and Ofuoku, 2005).

Most of the terrestrial ecosystems and shorelines in oil producing communities are important agricultural lands which are under continuous cultivation and any contact with crude oil eventually results in pollution of surrounding farmLands and water resources resulting in soil degradation and damage to the biotic component of the ecosystem (Udo and Opute, 1984; Atuanya, 1987; Amadi *et al*., 1993; Nicolotti and Ellis, 1998; Agbogidi *et al*., 2005a). Oil in soil has been reported to exert adverse effect on soil conditions, microbes and plants (Schwendinger, 1968; Odu, 1977; Rowell, 1977; Anoliefo and Vivioko, 1994; Siddiqui and Adams, 2002; Agbogidi *et al*., 2005b; Agbogidi and Ejemete, 2005). Although work has been conducted on oil pollution effects on the yield of other crops (Udo and Oputa, 1984; Anoliefo, 1991; Agbogidi and Nweke, 2005), there is however, paucity of information on the effects of crude oil contaminated soil on the yield of maize. The present study investigated the effects of crude oil contaminated soil on the yield of maize in Delta State.

Corresponding Author: O.M. Agbogidi, Faculty of Agriculture, Delta State University, Asaba Campus, Delta State, Nigeria Tel: +234805306219

Materials and Methods

Study Locations

The experiment was conducted at the Delta State College of Agriculture Research Farm, Ozoro and at the Research Farm of the Department of Agronomy, Delta State University, Asaba Campus, Asaba. Ozoro lies between latitude 6°30^{1}N and longitude 5°45^{1}E and it is located in a tropical rainforest zone. The area experiences double peak periods of rainfall between June/July and September/October, respectively. The annual mean rainfall is 2800 mm and the mean annual temperature ranges between 29 and 33°C (College of Agriculture Meteorological Station, Ozoro, 2003). Asaba lies between latitude 6°14'N and longitude 6°49'E with an annual temperature (28+6°C), rainfall (1505-1849), relative humidity (69-80%) and monthly sunshine (4.8 h) (Asaba Meteorological Station, 2003).

Experimental Materials

Two varieties of maize Composite (suwan 1) and Hybrid (3x-yx) were purchased from the Delta State Agricultural Procurement Agency (DAPA), Ibusa, Delta State. Four open- pollinated (OP) AMATZBR w, TZBRSYN w, AMATZBR y and TZBRSYN y were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State and a local variety- Ozoro local purchased as a single batch from Ozoro local market in Delta State. All the maize varieties were treated with apron star 42 before sowing following Obi (1991) against fungi and insects.

The crude oil (light) used had a specific gravity of 0.8334 g cc^{-1} and API of 34.2897 and was sourced from the Nigerian National Petroleum Corporation (NNPC), Warri, Delta State.

Experimental Design and Data Analysis

The experiment was a split-split-plot arrangement with four replicates. Locations of study were allotted the main plots, the crude oil levels, the sub-plots and the maize varieties, the sub- sub-plots. Each sub-sub-plot measured 2.25 m^2. The maize seeds were planted using a spacing of 0.75×0.25 m at a depth of 2-3 cm. A sub-sub-plot contained 24 stands of maize. Two seeds of the maize grains were planted per hole. The seedlings were thinned to one plant per stand at two weeks after planting; when seedlings were 12-15 cm tall or at knee level.

Complete fertilizer (20-10-10) was applied at planting at the rate of 80 kg N ha^{-1}, 40 kg P ha^{-1} and 40 kg K ha^{-1} to ensure optimum seedling establishment and plant growth. The experimental area was hoe-weeded to enable the plants develop under non-limiting conditions. In order to determine the minimum level of contamination to cause damage to the maize plants, low levels of 0, 5.2, 10.4, 20.8 and 41.6 mL levels of the crude oil were applied per maize stand. The oil was slowly poured from a beaker into the soil around the maize stand (ring application) at seven weeks after planting (7 WAP). Spillage of this type was intended to represent what happens in some types of incident.

Data were taken only from the two central rows of the four row plots at 98 Days After Sowing (DAS)/14 Weeks After Planting (WAP) when the cobs were harvested. Parameters measured were fresh grain yields across and within locations and dry grain yields across and within locations. The grains were shelled from the cobs and measured with a measuring scale to get the fresh grain yields. The grains were sun-dried to a moisture content of about 15% following the procedure of Margesin and Schinner (1997) before they were measured to get the grain dry yields. Data collected were subjected to analysis of variance and the significant means were separated with the Duncan's Multiple Range Test (DMRT) using SAS (1996).

Results

The combined effects of oil levels and maize varieties on fresh grain yields and dry grain yields across locations (Asaba and Ozoro) are presented in Table 1 and 2, respectively. Hybrid 3x-yx and

AMATZBR w gave the highest grain fresh weight yields, which differed significantly from the yields of the other varieties tested. With respect to grain dry weights, Hybrid 3x-yx, AMATZBR w and AMATZBR y had grain dry weight that were significantly different (p = 0.05) from the other varieties tested. This result shows that crude oil application to soil reduced the yields of maize. With respect to fresh and dry grain yields, Hybrid 3x-yx had the highest values of 1.81 and 1.42 kg/plant, respectively for the control plants when compared with the values of 1.20 and 0.90 kg/plant in 20.8 mL of the crude oil (Table 1 and 2), respectively.

The fresh grain yields and dry grain yields of the seven maize varieties grown within Asaba and Ozoro locations were not significantly affected by crude oil treatment up to 5.2 mL but higher levels reduced these characters significantly at the 5% level of probability (Table 3 and 4). There was a general reduction in the grain yields by oil pollution levels compared with the yields of the maize grown in the uncontaminated soils and those subjected to 5.2 mL of oil treatment.

Table 1: Fresh grain yield (kg/plant) as affected by different levels of crude oil across locations (Asaba and Ozoro)

	Level of oil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
Composite (suwan 1)	1.34d	1.25b	1.20a	1.00a	0.52b
Hydrid 3x-yx	1.81a	1.68a	1.36a	1.20a	0.86a
AMATZBR w	1.75a	1.56ab	1.21a	1.12a	0.71a
TZBRSYN w	1.51c	1.46ab	1.20a	1.01a	0.63ab
AMATZBR y	1.69b	1.50ab	1.30a	1.10a	0.70a
TZBRSYN y	1.68b	1.54ab	1.24a	1.11a	0.58ab
Ozoro local	1.28d	1.20b	1.00a	0.86ab	0.46b

Means in the same column with the same letter (s) are not significantly different (p = 0.05), using DMRT

Table 2: Dry grain yield (kg/plant) as affected by different levels of crude oil across locations (Asaba and Ozoro)

	Level of oil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
Composite (suwan 1)	0.71d	0.65b	0.60c	0.54ab	0.37b
Hydrid 3x-yx	1.42a	1.02a	0.94a	0.90a	0.66a
AMATZBR w	0.97b	0.90a	0.84ab	0.82a	0.51ab
TZBRSYN w	0.94b	0.84ab	0.64c	0.54ab	0.50ab
AMATZBR y	0.97b	0.86ab	0.72b	0.63ab	0.64a
TZBRSYN y	0.89c	0.82ab	0.70b	0.62ab	0.48ab
Ozoro local	0.70d	0.64b	0.56c	0.50b	0.36b

Means in the same column with the same letter (s) are not significantly different (p = 0.05), using DMRT

Table 3: Fresh grain yields (kg/plant) as affected by application of different crude oil levels in Asaba and Ozoro

	Crude oil levels in soil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
Asaba location					
Composite (suwan 1)	1.70a	1.67a	0.80c	0.78bc	0.76b
Hybrid 3x-yx	1.86a	1.85a	1.43b	1.30a	0.90a
AMATZBR w	1.80a	1.73a	1.47ab	1.31a	0.95a
TZBRSYN w	1.40b	1.37b	0.93c	0.90b	0.88ab
AMATZBR y	1.70a	1.67a	1.60a	1.30a	0.98a
TZBRSYN y	1.67a	1.57a	1.13b	0.90ab	0.86ab
Ozoro local	1.57a	1.52a	0.80c	0.70c	0.64c
Ozoro location					
Composite (suwan 1)	1.77a	1.75a	1.60a	1.05ab	0.68c
Hybrid 3x-yx	1.90a	1.87a	1.46ab	1.42a	0.98a
AMATZBR w	1.77a	1.45b	1.04b	1.00ab	0.87ab
TZBRSYN w	1.42b	1.18b	1.41b	1.02ab	0.80ab
AMATZBR y	1.78a	1.64a	1.50a	1.14ab	0.90a
TZBRSYN y	1.82a	1.68a	1.54a	1.30a	1.01a
Ozoro local	1.63a	1.58a	1.46c	1.30a	0.81ab

Means in the same column with same letter(s) are not significantly different (p = 0.05), using DMRT

Table 4: Dry grain yields (kg/plant) as affected by application of different crude oil levels in Asaba and Ozoro

	Crude oil levels in soil (mL)				
Maize varieties	0	5.2	10.4	20.8	41.6
Asaba location					
Composite (suwan 1)	1.03a	1.00b	0.64b	0.50b	0.26d
Hybrid 3x-yx	1.07a	1.03b	0.79ab	0.64b	0.61c
AMATZBR w	1.02a	1.00b	0.60b	0.51b	0.50c
TZBRSYN w	1.03a	1.00b	0.96a	0.79a	0.43d
AMATZBR y	1.08a	1.05a	0.90a	0.80a	0.64c
TZBRSYN y	1.09a	1.01b	0.84a	0.69a	0.50c
Ozoro local	0.92a	1.10a	0.41c	0.39c	0.34d
Ozoro location					
Composite (suwan 1)	1.05a	1.02b	0.41c	0.31c	0.29d
Hybrid 3x-yx	1.17a	1.13a	0.98a	0.83a	0.80a
AMATZBR w	1.04a	1.01b	0.93a	0.90a	0.84a
TZBRSYN w	1.04a	1.07a	0.67b	0.80a	0.74b
AMATZBR y	1.10a	1.13a	0.92a	0.66b	0.60c
TZBRSYN y	1.10a	1.04a	0.90a	0.50b	0.45d
Ozoro local	1.00a	0.86c	0.40c	0.37b	0.30d

Means in the same column with same letter(s) are not significantly different (p = 0.05), using DMRT

Discussion

The observed reduction in both the fresh and dry grain yield of plants grown in the soils amended with 10.4, 20.8 and 41.6 mL of the oil could be due to water stress and nutrient supply of the plant consequent upon oil treatment. This observation is in line with the findings of De Jong (1980) who reported that reduction in the dry matter yield of cereals was due to lack of intake of nutrients resulting from nutrient immobilization consequent on the adulterated nature of the soil following crude oil application to soil. Since uptake of water and salts (ions) is carried out by the roots, the plants grown in oil treated soils could have suffered morphological and anatomical aberrations. Crude oil application to soil could have caused an obstruction to the xylem and phloem vessels of the seedlings thereby inhibiting translocation of both photosynthates and water throughout the plant body and subsequently, the observed reduced yields.

It may also be argued that the considerable decrease in other growth variables including the number of leaves and leaf area of the test plants with increased concentrations of the oil reduced the photosynthetic rates of the plants hence a corresponding decrease in both the fresh and dry weight yields of the grains. Epstein (1972) reported that the mesophyll cells of the leaves finally receive mineral ions absorbed initially by the roots. This could have caused a reduction in leaf growth and development and consequently the yields. It is also logical to reason that impaired photosynthesis in the maize plants subjected to higher levels of oil could have led to a reduction in the assimilates accumulated in the seeds and cobs and thus led to low grain weight yield for all the levels of crude oil applied with the exception of the plants grown in soils amended with 5.2 mL of the oil and the experimental plants. Oil has been shown to physically act by absorbing light wavelengths essential for photosynthesis (Baker, 1970a).

There could have also been a potential breakdown of photosynthetic apparatus in leaves following the crude oil application to soil which occurred because of blocked leaf transpiration leading to dramatic increased leaf temperature and or direct adverse effects of oil penetration into the leaf tissues destroying cellular integrity and hence photosynthetic ability of the plants. Because yields corresponds to the amount of photosynthates stored by plants (Larson and Hanway, 1976), it is logical to reason that any factor, which directly or indirectly affects photosynthetic process, starch formation and storage affects yields. This observation is in line with the findings of Baker (1970b), Jaja and Barber (1999) and Odjegba and Sadiq (2002). Amadi *et al.* (1993) reported that yield depression

in maize to be below 10% in soil polluted with crude oil when no nutrient supplementation or remediation is done. In same vein, reduction in the dry matter yields of forest fruit trees subjected to oil treatment had been reported by Agbogidi and Ejemete (2005), Agbogidi and Ofuoku (2005) and Agbogidi and Eshegbeyi (2006). This finding also corresponds with earlier findings of De Jong (1980) who reported that the total above ground production of cereals was significantly affected by crude oil pollution of soil. He further maintained that even very small amounts of oil (less than 0.2% by weight) in the 0-03 or 0-09 cm depth reduced yields considerably. Yield reduction in maize following oil pollution is a threat to food security to the generality of the Nigeria's population. This is because; maize is regarded as one of the staple foods in Nigeria. It is grown in almost all the ecological zones including the Niger Delta area where oil activities are prominent.

Variations in the soil properties of the two locations could have also led to the observed differences in the yield of the maize in Ozoro and Asaba locations. This observation is in line with the findings of (Ogeh *et al*., 2001) who recorded yield reduction in maize in an exhaustively cropped alfisol in South Western Nigeria.

Conclusively, this study has shown that crude oil contaminated soil has a highly significant effect of reducing the yields of maize. The present study also established varietal differences in maize with response to crude oil thereby providing a basis for future research work by plant breeders.

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