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EFFECT OF MUSHROOM (*PLEUROTUS TUBER-REGIUM*) INOCULUMS ON CRUDE OIL POLLUTED SOILS ON STOVER AND GRAIN YIELDS OF MAIZE (*ZEA MAYS* L.) IN NIGER-DELTA, NIGERIA

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ABSTRACT

Pollution of soils by crude oil in Niger-Delta of Nigeria has brought untold hardship to the inhabitants of the region. This study was carried out in 2010/2011 and 2011/2012 to determine the effect of Pleurotus tuber-regium (mushroom) inoculums on crude oil polluted soil on stover and grain yields and as well as cob length and circumference of maize in Emu - Ebendo, Nigeria. The soils were polluted with crude oil at different levels (0 %, 3.0 %, 6.0 % and 9.0 %) by weight of the soil (20 kg) at 0, 2 and 4 weeks duration in the soil. The soils were inoculated with mushroom at 0 g, 150 g, 300 g and 450 g and were incubated for 6 months. The experiment was a 4 x 3 x 4 factorial in a randomized complete randomized design with four replicates. Two (2) seeds of maize were planted. At maturity the maize stalk (stover), cob and grain yield were harvested for stover yield, cob length and circumference and dry grain yield. The results obtained revealed the higher the crude oil application to the soil, the lower the stover yield, grain yields, cob length and cob circumference of maize in the order of 0 % > 3 % > 6 % > 9 %. The application of crude oil at 9% on 0 – 4 weeks of oil duration in the soil, resulted in no stover yield, grain yield, and cob length and cob circumference of maize. The application of different weights of mushroom inoculum to varying levels of crude oil polluted soil significantly (P < 0.05) increased the stover yields, cob's length, cob's circumference and grain yields of maize except at 150 g of mushroom application on 9 % level of crude oil pollution at 4 weeks of oil duration in the soil. Conclusively, the application of mushroom at varying levels in crude oil polluted soil increased the stover and grain yields and as well as of cob length and circumference of maize.

Keywords: Crude oil, soil**,** mushroom, performance characteristics

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INTRODUCTION

The Niger-Delta is the 'home' of crude oil deposit in Nigeria. Crude oil is the major foreign exchange earner earlier in Nigeria which is about 92 % of nation's wealth (CIA World Fact

Book, 2005; Eriemo, 2002). During the process of exploration and exploitation of crude oil, oil spill results from leakages along the pipelines, leakages of oil well heads, mechanical failures, accidental discharge and occasionally sabotage (Benka-Coker and Ekundayo, 1995; Emuh 2009; 2011). This has resulted in posing environmental problems affecting social and economic activities, health, ecological balance and sustainable development in Niger-Delta (Iyoha, 2002). Benka-Coker and Ekundayo (1995), reported that crude oil pollution tend to change the biological, chemical and physical properties of the soil. These soil properties affect germination, growth, development and yield of a crop (Odu, 2000; Emuh, 2009). Similarly, Anoliefo and Vwioko (1994), reported growth retardation in *Capsicum annum* and *lycopersicon esclentum* and attributed it to level of the pollution.

Crude oil contains and releases toxic and environmentally harmful substances and may lead to environmental catastrophe such as pollution of land and water, plant mineral toxicity, menacing human welfare and health through the food chain (Malik, 2004; Iwegbue *et al.*, 2007). Ngodigha (2009) reported that feeding contaminated forages to farm animals resulted in significant depressed feed intake; poor feed conversion efficiency and decrease body weight with increased food intake. Similarly, Ovuru and Oruwari (2005) posited that rabbit fed with crude oil contaminated forages and feeds increased their mortality rates while Nodu *et al*. (2005) reported a significant retardation in puberty attainment. Ngodigha (2009) reported that oil contaminated forages fed to West African Dwarf (WAD) goats altered the blood cell profile with packed cell volume (PCV) and affected their performance. Similarly, Wekhe and Okere (2006) reported that crude oil contaminated feeds fed to cockerels' resulted in vascular dilation and hyperemia, while Otitoju and Onwurah (2007) reported a reduction in fecundity and testerone at 5% and 1% levels of oil contaminated diets fed to Wister albino rats.

In Niger-Delta, oil pollution is a serious environmental problem with attendant effects. There has been a recurrent outcry, which has led to these oil producing communities being vociferous and taking their faith in their hands resulting in communal unrest, rural-urban migration, kidnapping and hostage takings and conflicts in these areas (Emuh, 2009). Attempts at solving this crude oil pollution through chemical means led to immobilization of heavy metals and contaminants while application of amendments transformed them to unavailable forms, thus reducing the nutrient uptake by crops (Chen and Lee, 1997). This method is expensive beyond the resources of resource poor farmers and is environmentally unfriendly. The use of a living organism to reduce or completely eliminate environmental hazard of toxic chemical accumulation is a positive method on soil ecology and production restoration (Alexander, 1994). The use of edible mushroom which is very common in Niger-Delta, grows in cheap medium, produces hypha and mycelium and breaks down substrate or contaminants have been reported (Isikhwemhen *et al.*, 1996; Hamman, 2004). Similarly, Aust *et al.* (2003), Mansur *et al.* (2003) and Stamets (2005) reported that edible mushroom degrades toxic environmental pollutants extra-cellularly and use them as a source of nutrient. Mushroom is a primary decomposer, degrader and recycler of nutrients (Stamets, 2005). Lau *et al*. (2003) reported the use mushroom compost to degrade polycyclic aromatic hydrocarbon (PAH) contaminated soil.

In Niger-Delta, Emu - Ebendo is an agricultural community, which produces food, forages and pasture crops. Food crops such as maize (*Zea mays* L.) produces stalk which serves as stover for farm animals, green maize cooked for human consumption while the dry grains are processed for human consumption and as well as feeds for farm animals. However, the effect of mushroom on crude oil contaminated soil used to raise food crops, forage and pasture crops is not well known. Thus, the objective of this study is to evaluate the effect of levels on mushroom inoculation on crude oil polluted soil on the stover and grain yields of maize (*Zea mays* L.).

MATERIALS AND METHODS

Description of study area

The experiment was carried out at Emu - Ebendo in Ndokwa West Local Government area of Delta State, Nigeria. Emu - Ebendu is located at 06^0 21^1 06 E and 05^0 40^1 N of the equator. It is an offshore oil producing area in the rain forest region of Niger-Delta. The first study was carried out from December 2010 to May, 2011 and repeated from December 2011 to May 2012.

Soil sampling and analysis

Based on the settlements, oil fields and vegetation, a stratified random sampling was adopted after a reconnaissance soil survey was carried out. The experimental soils were collected at 0 – 20 cm depth with an auger from the twenty locations chosen for sampling. In each point, five soil samples were collected. The soil samples were removed of stones, roots and leaves and bulked, mixed thoroughly, pulverized and air-dried for two weeks and passed through 2mm sieve. The soil was subjected to physical and chemical analysis.

Particle size distribution was determined by Hydrometer method (Bouyoucous, 1951), while the soil pH in water was determined as described by Hendershot *et al.* (1993). Organic carbon was determined using wet oxidation method of Walkey and Black (1934) and converted to organic matter by multiplying with a factor of 1.724 (Allison, 1965). Total nitrogen was determined using modified Kjeldah distillation method as described by Bremner and Mulvaney (1982). Available phosphorus (P) was determined using Bray No 1 as described by Bray and Kurtz (1945) while extracted sodium, calcium and potassium were determined using flame photometer (Udo and Ogunwale, 1986) and Iron (Fe) and Magnesium (Mg) were determined using atomic absorption spectrophotometer. Crude oil sourced from Energia limited was analyzed for its constituents by digestion, using a mixture of concentrated HNO_3 and $HClO_4$ at a ratio of 1:2 and extracted with 0.5m HCl as described by Lacatusu (2000). The crude oil was used to pollute the soil at 0, 3 %, 6 % and 9 % v/wt of the soil (20 kg) at 0, 2 and 4 weeks duration of oil in the soil. The crude oil polluted soils were inoculated with mushroom at 0g, 150 g, 300 g and 450 g. The experimental design was a 4 x 3 x 4 factorial in a randomized complete design with four replicates. These soils were incubated for six months in the green house and sown with maize seeds sourced from Department of Agronomy, Delta State University, Asaba at the rate of two per stand and later thinned to one. At maturity the maize stalk and cob were harvested, bagged and oven dried using oven OV 440 of Gallenkamp at 75 ^{0}C to a constant weight. Thus, the dry matter yield of maize stalk (stover) cob length, cob circumference and grain yield were obtained and subjected to analysis of variance (SAS, 2005) and means that were significantly different were separated using Duncan multiple range test as described by Wahua (1999).

Results

The results of the physical and chemical properties of the soil are presented in Table 1. The result showed that the soil is sandy clay loam in texture with sand fractions as 715 g/kg while silt and clay contents were 59 g/kg and 226 g/kg respectively.

The pH was 6.20 indicating that the soil was slightly acidic. The % total Nitrogen is 0.20 while the available P is 13.45 mg/kg. The exchangeable bases were low, Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} with values of 3.84, 1.20, 0.35 and 0.31 cmolkg $^{-1}$ while Fe^{2+} was 5.53 cmolkg^{-1} (Table 1). This indicates that the soil is low in soil fertility.

The results of the analysis of the crude oil are presented in Table 2. The crude oil is light and less dense with an API gravity of 35.62 and a low specific gravity of 0.862 gcm^{-3} with a viscosity of 0.28 at 38^{0}C (Table 2).

The main effect of stover yield (in g/plant) as influenced by levels of oil pollution (0 %, 3 %, 6 % and 9 %) were 97.46^{a}, 61.91^{b}, 50.89^{b} and 36.99^{c}, duration (0, 2 and 4 weeks) of oil pollution were 63.21^{a}, 62.59^{a}, and 59.64^{a} while the influence of mushroom inoculation (0 g, 150 g, 300 g and 450 g) at stover yield were 41.12^{d}, 54.84^{c}, 69.36^{b} and 79.80^{a} respectively.

The interactive effects of levels of crude oil pollution and duration of crude oil pollution on levels of mushroom inoculated soils on grain yield of maize are presented in tables 3, 4, 5 and 6. The stover yield of maize decreased ($P > 0.05$) significantly with increase in the rate of oil application, while the stover yield were ($P = 0.05$) similar at 0 – 4 duration of oil in the soil. The application of mushroom ($P < 0.05$) enhanced the stover yield of maize. At 9 % v/wt application of crude oil, the stover yields (0.00 g) were most significantly depressed at all durations of oil in the soil (Table 3). The stover yield increased with increase in the weight of mushroom inoculum applied to crude oil polluted soil at 0 – 4 weeks durations of oil in the soil (Table 4). Similarly, the stover yield ($P < 0.05$) decreased with increase oil pollution and ($P < 0.05$) increased with increase in mushroom inoculation (0 – 450 g) in crude oil polluted soil (Table 5). The stover yield were ($P < 0.05$) higher at 0% of crude oil pollution at 2 and 4 weeks duration of oil in the soil and at 450 g of mushroom inoculation on 3 % and 6 % v/wt pollution at 2 and 4 weeks duration in the soil than other stover yield (Table 6).

The main effect of cob length (in cm) as influenced by levels of oil pollution (0 %, 3 %, 6 % and 9 %) were 25.59^{a}, 18.24^{ab}, 15.70^{b} and 10.10^{c}, duration of oil in the soil (0, 2 and 4 weeks) were 18.97^{a}, 18.29^{a} and 14.96^{b} while on mushroom inoculated (0 g, 150 g, 300 g and 450 g) soils were 12.91^{c}, 16.37^{b}, $18.70^{ab}$and 20.85^{a} respectively. The interaction effects of levels and duration of crude oil pollution on levels of mushroom inoculated soils on cob length of maize are presented on Tables 7, 8, 9 and 10. The cob length decreased significantly (P < 0.05) with increase in oil pollution at 0 – 4 weeks of oil duration in the soil (Table 7) while the cob length increased significantly (P < 0 05) with increase in weight of mushroom inoculated (0 – 450g) soil at different durations of oil in the soil (Table 8).

The cob lengths decreased with increase in the rate of oil application to the soil while the increased (P < 0.05) with increase in the rate of mushroom inoculation from 0 – 450g at all durations in the soil (Table 9). The cob length harvested in soils at 0% level of crude oil application (control) to the soil were statistically similar (P = 0.05) at the durations of oil in the soil and were significantly higher than cob length harvested in soils at crude oil application of 3 – 9% v/wt (Table 10).

The main effect of cob circumference (in cm/plant) as influenced by levels of oil pollution (0%, 3%, 6% and 9%) were 19.16^{a}, 15.59^{b}, 13.84^{c} and 9.33^{d}, duration (0, 2 and 4 weeks) were 14.85^{a}, 14.62^{a} and 13.95^{a} of crude oil polluted soil on mushroom inoculation were 10.58^{a}, 15.59^{b}, 13.84^{c} and 9.33^{d}respectively. The interaction effects of levels of crude oil pollution, duration of crude oil pollution and levels of mushroom inoculated soils on cob circumference of maize are presented on Tables 11, 12, 13 and 14. At 3 and 6% of oil pollution, the cob's circumference were (P = 0.05) at 0 – 4 weeks duration of crude oil in the soil but was highest (13.40cm) at 4weeks of oil duration (Table 11). The cob circumference (17.93g) was largest at 450g application of mushroom inoculum at 0 week duration of oil in the soil (Table 12). The cob circumference were (P = 0.05) at 450g of mushroom inoculation on 0 – 6% of crude oil polluted soil (Table 13). Cob circumference was most significantly depressed at 0g of mushroom application at 9% of crude oil polluted soil at 0 - 4 weeks duration of oil in the soil and also 150g of mushroom application on 9% of crude oil polluted soil at 4 weeks duration of oil in the soil (Table 14).

The main effect of grain yield (g/plant) as influenced by levels of oil pollution (0%, 3%, 6% and 9%) were 39.86^{a}, 28.35^{b}, 23.09^{c} and 10.23^{d} while the main effect of grain yield (in g/plant) as influenced by 0, 2 and 4 weeks oil duration in the soil were 26.24^{a}, 25.73^{a}, and 24.18^{a}. Similarly, the main effects of grain yield (in g/plant) on mushroom inoculation were 14.98^{c}, 23.53^{b}, 27.94^{b} and 35.24^{a}. The interaction effects of levels of crude oil pollution, duration of crude oil pollution an levels of mushroom inoculated soils on grain yield of maize are presented on Tables 15, 16, 17 and 18. The grain yield decreased significantly with increase in the levels of oil pollution while the grain yields were statistically similar (P = 0.05) on duration of oil in the soil. The grain yield of maize was most significantly depressed at 9% v/wt of oil pollution in the soil with no mushroom inoculation. The grain yield of maize decreased ($P > 0.05$) decreased significantly with increase in oil polluted soil but were similar at ($P = 0.05$) durations of oil pollution

(Table 15). Similarly, mushroom inoculation ($P < 0.05$) enhanced grain yield at all durations of oil in the soil (Table 16). The grain yields of maize increased significantly ($P < 0.05$) with increase in the rate of mushroom inoculation from 9% to 0% levels of oil contamination (Table 17). The grain yield increased ($P < 0.05$) with increase in the rate of mushroom inoculation from 0 – 450 g at all durations of oil in the soil save control (Table 18). The grain yield of maize was most significantly depressed at 9% v/wt of oil pollution with no mushroom inoculation. The grain yield of maize decreased ($P > 0.05$) with increase in oil polluted soil but were similar at ($P = 0.05$) at duration of oil in the soil.

Discussion

The result of the soil pH indicates that the soil was slightly acidic. This agreed with the findings of Odu (1996), who reported similar acidic nature on wetlands soil. The low % nitrogen indicates that organic matter is low. This organic matter had a positive relationship with total N, since organic matter constitutes over 70% of soil nitrogen (Agboola et *al.,* 1997; Egbuchua, 2007). These low exchangeable bases could due to the nature of the tropical clay minerals which are mainly kaolinite and are low in exchangeable capacity (FMARD, 2012). Thus, the low soil fertility resulting from soil analysis is in agreement with the findings of Olatunji *et al*. (2007), who reported high leaching, high rainfall and low soil fertility.

The light and less dense crude oil with low API gravity of 35.620 and a low specific gravity of 0.862 gcm^{-3} with a viscosity of 0.28 at 38^0C depicts that the crude oil can float on water and contains a high proportion of the light hydrocarbon fraction and therefore has low impact on the environment (CAPP, 2009). The presence of crude oil with its constituents and effects in the soil needs amendment and rehabilitation. Ogboghodo *et al* (2001) reported rehabilitation of crude oil polluted soil. The higher the crude oil application to the soil the lower the stover yield, grain yields, and cob length and cob circumference of maize may be due to water stress and reduced nutrient up-take. Water is essential for nutrient up-take in the soil. Since oil pollution renders the soil hydrophobic, this tends to reduce the air spaces and water infiltration in the soil, nutrient availability and perhaps reduce the stover yield of maize. This is in tandem with Odu (2000) and Emuh (2009), on crude oil pollution effect on germination, growth, development and yield of crops. Similarly, Anoliefo and Vwioko (1994) reported that a growth retardation in *Capsicum annum* and *lycopersicon esclentum*.

The no stover yield, grain yields, and cob length and cob circumference of maize observed at 9% level at 0 – 4 weeks of oil duration and at 150g of mushroom application at 4weeks duration in the soil agreed with Asuquo *et al.* (2002), who reported no germination at eight percent and greater than eight percent of crude oil polluted soil.

The inoculation of different levels of mushroom in crude oil polluted soil significantly increased the stover yields, cob's length, and cob's circumference and grain yields of maize.

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The different sizes of stover yields, cob's length, and cob's circumference and grain yields of maize indicated that mushroom bio-degraded crude oil polluted soils. This suggests that the varying quantities of mushroom applied could have led to the varying degrees of soils amelioration. The differences in the levels of soil amelioration could have led to the varying degrees of availability of plant growth resources, which culminated in the varying levels of stover yields, cob's length, cob's circumference and grain yields of maize. This agreed with the findings of Oudot (1990) and Stamets (2005), who reported that white rot fungi/mushroom grew optimally in harmful contaminants and detoxified such contaminants. Similarly, Hatvani and Mecs (2003) reported that, shiitake mushroom (*Lentinula edodes*) removed toxic metals from contaminated effluents.

CONCLUSION

The results of the study have revealed that inoculation of mushroom at varying levels in crude oil polluted soil increased the stover and grain yields of maize and as well as the cob length and cob circumference of different sizes. It is recommended that further research should be conducted at higher levels of crude oil pollution and at higher application of mushroom inoculation on the effects on crops.

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APPENDIX

Table 1: Physical and chemical properties of Emu -Ebendo soil

Parameters	**Values**
Physical properties	
Sand (g/kg)	715
Silt (g/kg)	59
Clay (g/kg)	226
Chemical properties	
pH (H_2O)	6.20
Organic matter	1.82
Total N (%)	0.20
Available P (mg/kg)	13.45
Fe (Mg/kg)	5.53
Ca^{2+} (cmol kg^{-1})	3.84
Mg^{2+} (cmol kg^{-1})	1.20
Na^{+} (cmol kg^{-1})	0.31
K^{+} (cmol kg^{-1})	0.35
H^{+} (cmol kg^{-1})	1.27
Al^{3+} (cmol kg^{-1})	3.86

Table 2: Characteristics of the crude oil

Parameters	Measured Values
Crude oil	
Specific gravity (g/cm^{-3})	0.862
Api gravity (g/cm^{-3})	35.620
Viscosity at 38^{o}C	0.28
Gas oil ratio	85.46
Carbon (%)	80.18
Hydrogen (%)	13.50
Sulphur (%)	1.35
Nitrogen (%)	0.30
Oxygen (%)	0.62

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Table 3: Stover yield of (*Zea mays* L.) maize (g/plant) as influenced by levels of crude oil pollution and duration of contamination

Duration of crude oil contamination (wks)	Levels of crude oil contamination (%)			
	0	3	6	9
0	95.25[a] ±0.03	39.25[b] ± 0.01	28.40[b] ± 0.04	00.00[c] ± 0.00
2	97.14[a] ± 0.05	38.25[b] ± 0.02	27.88[b] ± 0.01	00.00[c] ± 0.00
4	99.36[a] ± 0.03	37.25[b] ± 0.06	37.25[b] ± 0.04	00.00[c] ± 0.00
Mean	98.25 ± 0.04	38.25 ± 0.03	31.18 ± 0.03	00.00 ± 0.00

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 4: Stover yield (g/plant) of (*Zea mays* L.) maize as influenced by levels of mushroom inoculation and duration of crude oil pollution

Duration of crude oil pollution (wks)	Weight of mushroom inoculum (g)			
	0	150	300	450
0	41.48[d] ±0.02	50.07[c] ±0.04	73.14 [ab] ± 0.04	80.14[a] ± .04
2	40.82[d] ± 0.02	57.58[c] ± 0.03	71.50[b] ± 0.03	80.49[a] ± 0.03
4	41.08[d] ±0.04	48.88[c] ± 0.03	68.51[b] ± 0.03	78.76[a] ± 0.03
Mean	41.13 ± 0.04	52.18[c] ± 0.03	71.05 ± 0.03	79.79 ± 0.03

Values with similar letter superscript are not significantly different at 5% level of Probability at Duncan Multiple Range test

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Table 5: Stover yield (g/plant) of maize (*Zea mays* L.) as influenced by levels of mushroom (*Pleurotus tuber-regium*) inoculation and level of crude oil pollution

Level of crude oil contamination (%)	Weight of mushroom inoculum (g) 0	150	300	450
0	$98.25^{a} \pm 0.04$	$98.16^{a} \pm 0.03$	$96.19^{a} \pm 0.03$	$97.22^{a} \pm 0.04$
3	$38.25^{d} \pm 0.03$	$58.19^{c} \pm 0.03$	$70.76^{b} \pm 0.04$	$80.45^{a} \pm 0.04$
6	$27.99^{d} \pm .03$	$40.45^{cd} \pm 0.03$	$60.94^{b} \pm 0.03$	$74.21^{b} \pm 0.03$
9	$0.00^{e} \pm 0.00$	$22.57^{de} \pm 0.02$	$56.31^{c} \pm 0.03$	$67.31^{b} \pm 0.03$
Mean	41.12 ± 0.03	54.84 ± 0.04	71.05 ± 0.03	79.82 ± 0.04

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 6: Effect of mushroom (*Pleurotus tuber-regium*) application on levels and duration of crude oil pollution on stover yield (g/plant) of maize

Duration of oil in the soil (wks)	Levels of crude oil contamination (v/wt)	Weight of mushroom inoculum (g) 0	150	300	450
	0	$98.25^{a} \pm 0.03$	$98.41^{a} \pm 0.03$	$97.83^{a} \pm 0.06$	$97.22^{a} \pm 0.04$
0	3	$39.25^{c} \pm 0.01$	$59.12^{bc} \pm .04$	$70.76^{ab} \pm 0.05$	$81.30^{a} \pm 0.03$
	6	$28.40^{c} \pm .04$	$40.32^{c} \pm 0.01$	$64.12^{b} \pm 0.04$	$74.21^{ab} \pm .04$
	9	$0.00^{d} \pm 0.00$	$34.41^{c} \pm 0.02$	$59.84^{bc} \pm .02$	$67.84^{b} \pm .05$
	0	$97.14^{a} \pm 0.05$	$98.22^{a} \pm 0.00$	$94.54^{a} \pm 0.01$	$97.60^{a} \pm 0.05$
2	3	$38.25^{c} \pm 0.02$	$58.19^{bc} \pm 0.01$	$74.21^{ab} \pm 0.03$	$80.23^{a} \pm 0.04$
	6	$27.88^{c} \pm 0.01$	$40.61^{c} \pm 0.06$	$60.94^{b} \pm 0.05$	$76.35^{ab} \pm .02$

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	9	$0.00^{d} \pm 0.00$	$33.31^{c} \pm 0.04$	$56.31^{bc} \pm 0.03$	$67.80^{b} \pm .03$
	0	$99.36^{a} \pm 0.03$	$97.85^{a} \pm 0.05$	$96.20^{a} \pm 0.02$	$96.84^{a} \pm 0.03$
4	3	$37.25^{c} \pm 0.06$	$57.26^{bc} \pm 0.04$	$67.31^{b} \pm 0.03$	$79.82^{ab} \pm .05$
	6	$27.69^{c} \pm .04$	$40.42^{c} \pm 0.02$	$57.76^{bc} \pm 0.04$	$72.07^{ab} \pm .04$
	9	$0.00^{d} \pm 0.00$	$0.00^{d} \pm 0.00$	$52.78^{bc} \pm 0.05$	$66.29^{b} \pm 0.00$

Values with similar letter superscript are not significantly different at 5% level of probabilities using Duncan Multiple Range test

Table 7: Mean cob length (cm/plant) of maize (*Zea mays* L.) as influenced by levels of crude oil pollution and duration of crude oil pollution

Duration of crude of (wk)	Crude oil contamination in percentage (%)			
	0	3	6	9
0	$24.50^{a} \pm 0.01$	$14.30^{b} \pm 0.04$	$11.20^{c} \pm 0.05$	$00.00^{d} \pm 0.00$
2	$25.20^{a} \pm 0.03$	$18.60^{b} \pm .02$	$12.40^{c} \pm 0.03$	$00.00^{d} \pm 0.00$
4	$25.36^{a} \pm 0.01$	$13.10^{bc} \pm .06$	$10.29^{c} \pm 0.03$	$00.00^{d} \pm 0.00$
Mean	25.02 ± 0.02	15.33 ± 0.04	11.29 ± 0.04	00.00 ± 0.00

Values with same letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 8: Effect of levels of mushroom (*Pleurotus tuber-regium*) inoculation and duration of crude oil pollution on maize (*Zea mays* L.) mean cob length (cm)

Duration of oil in the soil (wk)	Weight of mushroom inoculum (g)			
	0	150	300	450
0	$12.50^{c} \pm .03$	$20.00^{a} \pm 0.04$	$20.51^{a} \pm 0.04$	$22.90^{a} \pm 0.04$
2	$14.05^{c} \pm 0.03$	$17.91^{b} \pm 0.06$	$18.69^{ab} \pm 0.02$	$21.16^{a} \pm 0.06$
4	$12.19^{c} \pm 0.03$	$12.32^{c} \pm 0.03$	$16.92^{b} \pm 0.04$	$18.49^{ab} \pm .03$
Mean	12.91 ± 0.03	16.74 ± 0.04	18.71 ± 0.03	20.85 ± 0.04

Values with similar letter superscript are not significantly different at 5% level of Probability at Duncan Multiple Range test

Table 9: Mean cob length of maize (*Zea mays* L.) (cm/plant) as influenced by levels of mushroom (*Pleurotus tuber-regium*) inoculation and levels of crude oil contamination in the soil

Level of crude oil contamination (%)	Weight of mushroom inoculum (g)			
	0	150	300	450
0	$25.02^{a} \pm 0.02$	$24.42^{a} \pm 0.04$	$24.71^{a} \pm 0.03$	$24.88^{a} \pm 0.05$
3	$15.33^{bc} \pm 0.04$	$17.47^{b} \pm 0.04$	$19.54^{b} \pm 0.03$	$20.67^{a} \pm 0.03$
6	$11.29^{c} \pm 0.03$	$14.84^{c} \pm 0.03$	$17.10^{b} \pm 0.04$	$19.64^{b} \pm 0.04$
9	$0.00^{d} \pm 0.00$	$8.73^{cd} \pm 0.05$	$13.47^{c} \pm 0.03$	$18.19^{b} \pm 0.05$
Mean	14.94 ± 0.03	16.36 ± 0.04	18.70 ± 0.03	20.84 ± 0.04

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

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Table 10: Influence of mushroom (*Pleurotus tuber-regium*) inoculum on levels and duration of crude oil polluted on maize (*Zea mays* L.) cob length (cm/plant)

Duration of oil in the soil (wks)	Levels of crude oil contamination (v/wt)	Weight of mushroom inoculum (g) 0	150	300	450
	0	24.50[a] +0.01	25.10[a] + 0.05	24.92[a] + 0.04	25.40[a] + 0.04
0	3	14.30[c] +0.04	19.60[bc] + .04	20.60[ab] +0.03	23.30[a] + 0.03
	6	11.20[c] + .05	18.90[c] + 0.02	18.30[b] + 0.04	22.10[ab]+0.06
	9	0.00[d] + 0.00	16.40[c] + 0.03	18.20[bc] +0.05	20.80[b] + 0.04
	0	25.20[a] +0.03	24.90[a] + 0.05	23.80[a] + 0.01	24.10[a] + 0.07
2	3	18.60[c] +0.02	18.61[bc] + 0.07	20.40[ab] + 0.01	21.30[a] + 0.06
	6	12.40[c] +0.03	13.81[c] + 0.06	18.44[b] + 0.02	20.62[ab] +0.05
	9	0.00[d] + 0.00	09.80[c] + 0.04	12.11[bc] +0.03	18.60[b] + 0.06
	0	25..36[a] 0.01	23.25[a] + 0.01	25.40[a] + 0.04	25.15[a] + 0.04
4	3	13.10[c] +0.06	14.20[bc] +0.01	17.61[b] + 0.03	17.40[ab] + .00
	6	10.29[c] + 0.03	11.82[c] + 0.02	14.56[bc] +0.05	16.21[ab]+ .01
	9	0.00[d] + 0.00	0.00[d] + 0.06	10.10[bc] + .04	15.19[b] + 0.05

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 11: Effect of maize (*Zea mays* L.) cob circumference (in cm) as influenced by levels of crude oil pollution on duration of crude oil pollution

Duration of crude oil (wks)	Percentage of Crude oil contamination (%)			
	0	3	6	9
0	19.10[a] ±0.04	13.20[b] ± 0.01	10.10[b] ± 0.03	00.00[c] ± 0.00
2	19.24[a] ± 0.01	12.80[b] ± 0.06	09.90[b] ± 0.04	00.00[c] ± 0.00
4	19.30[a] ± .04	13.40[b] ± 0.05	10.00[b] ± 0.03	00.00[c] ± 0.00
Mean	19.21 ± 0.03	13.13 ± 0.04	10.00 ± 0.03	00.00 ± 0.00

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 12: Effect of levels of mushroom (*Pleurotus tuber-regium*) inoculation and duration of crude oil pollution on maize (*Zea mays* L) mean cob circumference (cm)

Duration of oil in the soil (wks)	Weight of mushroom inoculum (g)			
	0	150	300	450
0	10.16[c] ± 0.02	14.51[b] ± 0.00	16.36[ab] ±0 .04	17.93[a] ± 0.004
2	10.45[c] ± 0.07	14.51[b] ±0.00	15.94[b] ± 0.03	17.65[a] ±0.003
4	10.68[c] ± 0.04	11.47[bc] ±0.00	16.14[b] ± 0.03	17.52[a] ± 0.06
Mean	10.44 ± 0.04	13.49 ± 0.00	16.15 ± 0.03	17.70 ± 0.03

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 13: Effect of levels of mushroom (*Pleurotus tuber-regium*) inoculation and levels of crude oil pollution on maize (*Zea mays* L.) mean cob circumference (cm)

Level of crude oil contamination (%)	Weight of mushroom inoculum (g) 0	150	300	450
0	19.21[a] ± .03	19.13[a] ± 0.04	19.19[a] ± 0.04	19.09[a] ± 0.02
3	13.13[bc] ± 0.04	14.14[b] ± 0.03	16.37[a] ± 0.03	18.72[a] ± 0.04
6	10.00[c] ± 0.03	13.28[b] ± 0.03	14.96[b] ± 0.03	17.13[a] ± 0.04
9	0.00[d] ± 0.00	7.44[c] ± 0.03	14.07[b] ± 0.05	15.83[ab] ± 0.04
Mean	10.58 ± 0.03	13.49[c] ± 0.03	16.15 ± 0.04	17.69 ± 0.04

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 14: Influence of mushroom (*Pleurotus tuber-regium*) inoculum on levels and duration of crude oil polluted soil on maize (*Zea mays* L.) cob circumference (in cm)

Duration of oil in the soil (wks)	Levels of crude oil contamination (v/wt)	Weight of mushroom inoculum (g) 0	150	300	450
0	0	19.10[a] ± 0.04	19.21[a] ± 0.03	19.43[a] ± 0.05	18.90[a] ± 0.02
	3	13.20[c] ± 0.01	14.22[bc] ±0.02	16.60[ab] ± 0.04	19.10[a] ± 0.03
	6	10.10[c] ±0.03	13.52[c] ± 0.04	15.12[b] ± 0.03	17.90[ab] ± 0.04
	9	0.00[d] ± 0.00	11.11[c] ± 0.05	14.30[bc] ± 0.04	15.80[b] ± 0.05
2	0	19.24[a] ± 0.01	18.92[a] ± 0.02	19.24[a] ± 0.03	19.25[a] ± 0.03
	3	12.80[c] ± 0.06	14.30[bc] ± 0.01	15.81[ab] ± 0.02	18.43[a] ± 0.05
	6	09.90[c] ± 0.04	13.61[c] ± 0.04	14.80[b] ± 0.04	16.80[ab] ±0.03

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	9	0.00[d] ± 0.00	11.20[c] ± 0.03	13.91[bc] ± 0.05	16.10[b] ± 0.01
	0	19.30[a] ± 0.04	19.25[a] ± 0.06	18.90[a] ± 0.03	19.14[a] ± 0.02
4	3	13.40[c] ± 0.05	13.90[bc] ± 0.04	16.71[b] ± 0.03	18.62[ab] ± 0.04
	6	10.00[c] ± 0.03	12.72[c] ± 0.01	14.96[bc] ± 0.04	16.70[ab] ± 0.05
	9	0.00[d] ± 0.00	0.00[d] ± 0.00	14.00[bc] ± 0.05	15.60[b] ± 0.06

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 15: Effect of levels of crude oil pollution and duration of crude oil contamination soil on maize (*Zea mays* L.) grain yield (in g/plant)

(wks)	0	3	6	9
0	41.25[a] ± 0.05	11.44[b] ± 0.04	7.31[bc] ± 0.06	00.00[d] ± 0.00
2	41.44[a] ± 0.03	11.43[b] ± 0.02	7.31[bc] ± 0.00	00.00[d] ± 0.00
4	41.06[a] ± 0.04	10.86[b] ± 0.05	6.75[c] ± 0.01	00.00[d] ± 0.00
Mean	41.25 ± 0.04	11.24 ± 0.04	7.06 ± 0.02	00.00[d] ± 0.00

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

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Table 16: Effect of levels of mushroom (*Pleurotus tuber-regium*) inoculation and duration of crude oil pollution on maize (*Zea mays* L.) grain yield (g/plant)

Duration of oil in the soil (wks)	Weight of mushroom inoculum (g)			
	0	150	300	450
0	15.00[d] ± 0.04	25.13[bc] ± 0.06	29.63[b] ± 0.04	35.63[a] ± 0.04
2	15.19[d] ± 0.01	24.00[c] ± 0.04	32.13[b] ± 0.04	35.44[a] ± 0.03
4	14.63[d] ± 0.03	21.56[c] ± 0.03	26.06[b] ± 0.03	35.40[a] ± 0.04
Mean	14.94 ± 0.03	23.56[c] ± 0.04	27.94 ± 0.04	35.49 ± 0.04

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

Table 17: Effect of grain yield of maize (g/plant) as influenced by levels of mushroom (*Pleurotus tuber-regium*) inoculation on level of crude oil contaminated soil

Level of crude oil contamination	Weight of mushroom inoculum (g)			
(%)	0	150	300	450
0	41.25[a] ± 0.04	39.75[a] ± 0.04	39.19[a] ± 0.03	39.18[a] ± 0.03
3	11.63[d] ± 0.04	28.50[b] ± 0.05	33.94[a] ± 0.03	39.38[a] ± 0.04
6	7.13[d] ± 0.03	21.56[c] ± 0.05	29.63[b] ± 0.05	35.63[a] ± 0.04
9	0.00[e] ± 0.00	4.31[e] ± 0.03	9.94[d] ± 0.04	27.38[b] ± 0.03
Mean	15.00 ± 0.03	23.53 ± 0.04	28.17 ± 0.04	35.39 ± 0.03

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test

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Table 18: Effect of grain yield (g/plant) of maize (*Zea mays* L.) as influenced by levels of mushroom (*Pleurotus tuber-regium*) inoculation on levels and duration of crude oil polluted soil

Duration of oil in the soil (wks)	Levels of crude oil contamination (v/wt)	Weight of mushroom inoculum (g) 0	150	300	450
	0	41.25^{a} ±0.05	39.75^{a} ± 0.07	39.38^{a} ± 0.02	38.81^{a}± 0.03
0	3	11.44^{c}± 0.04	29.63^{bc}± 0.06	37.31^{ab}± 0.03	39.19^{a} ± 0.05
	6	07.31^{c}± 0.06	24.19^{c}±0.007	29.81^{b} ± 0.06	36.75^{ab}±0.04
	9	0.00^{d} ± 0.00	06.75^{c} ± 0.04	12.00^{bc} ±0.04	27.94^{b} ± 0.02
	0	41.44^{a}± 0.03	39.56^{a} ± 0.06	39.38^{a} ± 0.05	39.56^{a} ± 0.01
2	3	12.56^{c}± 0.02	28.69^{bc}± 0.05	33.00^{ab}± 0.04	38.25^{a} ± 0.04
	6	07.13^{c} ± 0.0	21.56^{c} ± 0.04	28.69^{b} ± 0.04	34.13^{ab}± 0.06
	9	0.00^{d} ± 0.00	06.19^{c} ± 0.01	11.44^{bc}± 0.03	27.19^{b} ± 0.01
	0	41.06^{a} 0.04	39.94^{a} ± 0.00	38.63^{a} ± 0.01	39.38^{a} ± 0.04
4	3	10.88^{c}± 0.05	27.00^{bc}± 0.04	31.69^{b} ± 0.02	37.89^{ab}± 0.02
	6	06.75^{c}± 0.01	19.13^{c} ± 0.04	27.75^{bc}± 0.05	33.94^{ab}± 0.02
	9	0.00^{d} ± 0.00	0.00^{d} ± 0.05	06.19^{bc}± 0.05	27.00^{b} ± 0.05

Values with similar letter superscript are not significantly different at 5% level of probability at Duncan Multiple Range test