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Impact of Diesel-Contaminated Soil on the Growth of *Phaseolus vulgaris* as a Test Crop

[1]Ayesa Abayomi Samuel, [1]Yusuf Adedoyin Morenikeji, [1]Ajayi Isaac Iseoluwa, [2]Ajewole Tolulope Olumide, [1]Ayodele Taiwo Oluwatobiloba, [3]Kolawole Opeyemi Saheed, [1]Omoniyi Boluwatife Oluwanifemi, [4]Bamigboye Tolulope Olaseeni and [1]Adeoye Hammed Adeyemi

[1]Department of Biological Sciences, Bamidele Olumilua University of Education, Science and Technology, Ikere, Ekiti, Nigeria

[2]Department of Plant Science and Biotechnology, Federal University Oye-Ekiti, Nigeria

[3]Federal University Kashere, Gombe, Nigeria

[4]Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

Corresponding Author: Abayomi Samuel Ayesa (ayesa.abayomi@bouesti.edu.ng)

ABSTRACT

Background and Objective: The proliferation of diesel contamination in soils is increasing at an alarming rate, posing threats to crop productivity. This study examined the effect of diesel-simulated polluted soil on the growth of *Phaseolus vulgaris* L. **Materials and Methods:** Thirty polythene pots, each containing 5 kg of surface soil, were arranged in a factorial combination of five treatment levels of diesel contamination (0, 10, 20, 30, and 40 g w/w), designated as P1, P2, P3, P4, and P5, respectively. Three seeds of *P. vulgaris* were sown per pot. Growth parameters, including plant height, leaf count, shoot length, root length, and biomass (fresh and dry weights of root and shoot), were measured 4 weeks after emergence (WAE). Experiments were conducted in triplicate (n = 3), results reported as Mean±SE, and analyzed using SPSS 16.0 with Duncan's Multiple Range Test at $p<0.05$. **Results:** Plants grown on highly contaminated soils (P5) exhibited reduced growth, with measurements of plant height (11.7 cm), leaf count (7.0), root length (0.5 cm), and shoot length (11.2 cm), which were lower than all other treatments. Biomass parameters followed the same decreasing trend with increasing diesel concentration. Significant differences were observed among treatments ($P = 0.005$). **Conclusion:** The poor performance of *P. vulgaris* on diesel-contaminated soils may be attributed to restricted water uptake by roots. The control treatment (P1) showed the best growth. These findings highlight the need for careful diesel handling and prompt spill management, as diesel-impacted soils can reduce agricultural productivity, potentially affecting food security and national income.

KEYWORDS

Simulation, diesel, pollution, growth, treatment, biomass

INTRODUCTION

Oil spillage is one of the contentious issues in Nigeria, especially in the contamination of soil. Simulated-polluted soil with crude oil products, especially diesel, are currently a problem in Nigeria[1]. Environmental pollution is a global issue and formed an adverse effect on land and water and has health hazards to

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human, animals, plants and ecosystem[2,3]. Environmental pollution from oil activities in a major oil producing country as Nigeria is inevitable[4]. As previously stated[5], failure of equipment, leakages from pipelines, operational errors are major cause of crude oil (diesel) spill. Many of the oil facilities and operations are located within sensitive habitats including areas vital to fish breeding, sea turtle nesting, mangroves and rainforests[6]. Soil is one of the most important natural resources for food production globally and major geochemical sink of pollutants.

Crude product constitutes majorly to cause of environmental pollution[7]. Diesel is a product from crude oil[8], processing and distribution of petroleum hydrocarbon and use of petroleum products leads to the contamination of the environment. Crude oil has been the engine of Nigeria economy for decadest[9]. Nigeria is one of the established nations dealing with diesel exportation of different kinds, such as bonny light[10]. Various activities in diesel exploration, exploitation, storage and transportation has led to spillage of oil to the environment[11]. Diesel and heavy metals cause harmful effects on the environment. Diesel-contaminated soils poses a serious threat to organisms, endanger human health, promoting the extinction of various plant species and reducing their productivity[12].

Phaseolus vulgaris L., is one of the most important directly consumed food legume in the world. It has a tremendous variability (>40,000 varieties). Among major food crop, it has one of the highest levels of variation in growth habit, seed characteristics (size, shape, colour), maturity, and adaptation. It belongs to the family Fabaceae, the crop has edible leaves often used in soups preparation as well as the high protein content of the seeds, which makes it a valuable food for domestic consumption and as export crop[13,14]. Beans are also one of the best non-meat sources of iron, providing 23-30% of the daily recommended levels[15] from a single serving. Consumption of beans is high mostly because they are a relatively inexpensive food. For the poor of the world, they are a means of keeping malnutrition at bay[16].

Exposure of plants to diesel and heavy metal poisoning has been reported to produce Reactive Oxygen Species (ROS) and other free radicals which induce oxidative stress and cause lipid peroxidation[17]. Even at an early stage, it can cause a reduction in cell proliferation and growth. Various researchers have reported activation of lipid peroxidation in plants exposed to different pollutants[18]. Several plant species have also been shown to have elevated peroxidase activities in response to increased pollutant concentrations[19]. Petroleum oil pollution usually results in damage to the soil microorganisms and plants, together with an increase in soil organic carbon, and reduction in soil nitrates and phosphorus, thus imposing a condition that impairs oil degradation in the soil[20,21].

It is crystal clear that the Niger Delta area of Nigeria experiences rising oil spillage and gas flaring. In view of this, the soil ecosystem has been disturbed, while rivers and farmlands are not excluded. The level of famine, drought, and poverty has increased in areas experiencing this menace of oil spillage. Hence, the need for the prevention of ecosystem degradation. The purpose of this study is to determine effect of diesel pollution of *P. vulgaris* germination and growth rate with reference to the effect on the biochemical characteristics of beans. The objective of this study were to investigate the performance of *P. vulgaris* grown on diesel contaminated soil, investigate the effect of diesel-contaminated soil on the biomass of the cultivated beans., determine the viability of *P.vulgaris* grown on diesel-contaminated soil and determine the tolerance of different concentration of diesel-contaminated soil on *P. vulgaris*.

MATERIALS AND METHODS

Study area: The study was conducted in the Screen House of Bamidele Olumilua University of Education, Science and Technology, Ikere, Ekiti in the South-Western part of Nigeria. It is located within Latitude 7°29′42.0″N and Longitude 5°10′25.3″E. The research study was carried out between July and August, 2024.

Experimental design: The experiment was conducted in a Screen House of Bamidele Olumilua University of Science, Education and Technology, Ikere Ekiti, Nigeria in accordance with the modified method described by Adewole and Aboyeji. The soil samples were subjected to five treatments with three replicates in a complete randomized design.

Collection of seed and soil: Bulk surface soil samples (0-15 cm) were collected from an area in the University, air-dried for three days, sieved using 2 mm sieve and analyzed using standard methods. Bean seeds suitable for planting were also collected from the nearby market.

Contamination of soil samples: Twenty polythene pots with drainage holes at the bottom, each containing 5 kg of surface soil, were randomly placed in Screen House using factorial combination of five treatment levels (0, 10, 20, 30 and 40 g) of diesel and designated P1, P2, P3, P4 and P5, respectively. The soil samples were put inside planting bags, homogenized by stirring using a glass rod, wetted with distilled water and allowed to equilibrate for three days.

Seedling: Three seeds of kidney beans were planted in diesel polluted soil per plot. The bean stands were regularly watered throughout the growing stage. The beans plants were thinned to two stands per pot at two weeks after planting (WAP). The thinned stands were retained inside the pots from which they were removed so as to put back into the soil what might have been taken up by the plant within the first two weeks of growth.

Measurement of gowth parameters: Fortnightly, growth parameters of beans such as plant height and leaf count were measured till 28 days when the experiment was terminated. After termination, the root and shoot length and weight of the plants were carried out using thread and ruler and weighing balance of all 20 samples, respectively. The roots were separated from the plant and then measurement was taken. After the weight of the fresh plant was carried out, it was then oven dried for 48 hrs at 80°C in order to carry out the dry weight of the samples.

Statistical analysis: Each experiment was conducted in triplicate (n = 3). Results were expressed as Mean±Standard error. Data were analyzed using SPSS version 16.0. Heavy metal concentrations in control and experimental groups were compared using Duncan's Multiple Range Test at a significance level of $p<0.05$.

RESULTS

Plant height: The effect of diesel simulated polluted soil on the growth of *Phaseolus vulgaris* for a period of 28 days were studied on weekly basis (Table 1). Figure 1 shows the effect of diesel simulated polluted soil on the growth performance of *Phaseolus vulgaris*. The highest value recorded for plot height in week 1 was in *Phaseolus vulgaris* grown on P1 (8.4 cm) followed by P2 (6.7 cm) and the least plot height was recorded for P3 (6.2 cm) (Table 1). Likewise week 2, P1 had the highest plot height (16.7 cm) and the least value was recorded in P5 with (9.3 cm) (Table 1). For week 3, P1 had the highest plant height (19.7 cm) and the least value was recorded in P5 with (10.2 cm). In week 4, P1 had the highest plant height (22.2 cm) and the least value was recorded in P5 with (11.7 cm). The plant height showed significant differences along the columns at p = 0.5 (Table 1).

Average fresh weight: The effect of diesel simulated polluted soil on the fresh weight and dry weight of *P. vulgaris* for period of 28 days studied per plant pot (Table 2). The highest value recorded for fresh root and shoot weight was in *phoseolus vulgaris* grown on P1 (1.7 g) and P1 (31.9 g) and the least value for fresh root and shoot weight was recorded for P5 (0.2) and P5 (2.1) (Table 2).The highest value recorded for dry root and shoot weight was in *phoseolus vulgaris* grown on P1 (1.1 g) and P1 (18.23 g) and the least plot for dry root and shoot weight was recorded for P5 (0.01 g) and P5 (0.5 g) (Table 2).

Fig. 1: *Phaseolus vulgaris* grown on diesel contaminated soil

Table 1: Effect of different concentration of diesel contaminated soil on plant height

Pots	Week 1	Week 2	Week 3	Week 4
P1	8.4^{d}	16.7^{e}	19.7^{e}	22.2^{e}
P2	6.7^{c}	12.7^{d}	14.9^{d}	17.6^{d}
P3	6.2^{a}	12.1^{c}	13.9^{c}	15.6^{c}
P4	6.3^{ab}	11.7^{b}	11.8^{b}	12.2^{ab}
P5	6.3^{ab}	9.3^{a}	10.2^{a}	11.7^{a}

P1: Soil contaminated with 0 g of diesel with control, P2: Soil contaminated with 10 g of diesel, P3: Soil contaminated with 20 g of diesel, P4: Soil contaminated with 30 g of diesel, P5: Soil contaminated with 40 g of diesel and Means of same letter showed no significant differences at p = 0.05

Table 2: Effect of different concentration of diesel contaminated soil on average fresh weight (g) of all plant samples in each pots respectively

Pots	FRW (g)	FSW (g)	DRW (g)	DSW (g)
Pot 1	1.7^{d}	31.9^{e}	1.1^{d}	18.23^{e}
Pot 2	0.6^{c}	9.0^{d}	0.12^{c}	1.6^{d}
Pot 3	0.4^{b}	6.4^{c}	0.04^{b}	1.2^{c}
Pot 4	0.2^{a}	2.9^{b}	0.04^{b}	0.6^{ab}
Pot 5	0.2^{a}	2.1^{a}	0.01^{a}	0.5^{a}

P1: Soil contaminated with 0 g of diesel with control, P2: Soil contaminated with 10 g of diesel, P3: Soil contaminated with 20 g of diesel, P4: Soil contaminated with 30 g of diesel, P5: Soil contaminated with 40 g of diesel. Means of same letter showed no significant differences at p = 0.05, FRW: Fresh root weight, FSW: Fresh shoot weight, DRW: Dry root weight and DSW: Dry shoot weight

Table 3: Effect of different concentration of diesel contaminated soil on the root and shoot length

Pots	Root length (cm)	Shoot length (cm)
Pot 1	1.7^{e}	20.5^{e}
Pot 2	1.3^{d}	16.3^{d}
Pot 3	0.8^{c}	14.8^{c}
Pot 4	0.6^{ab}	11.6^{ab}
Pot 5	0.5^{a}	11.2^{a}

P1: Soil contaminated with 0 g of diesel with control; P2: Soil contaminated with 10 g of diesel, P3: Soil contaminated with 20 g of diesel; P4: Soil contaminated with 30 g of diesel, P5: Soil contaminated with 40 g of diesel and Means of same letter showed no significant differences at p = 0.05

Root and shoot length: The effect of different concentration of diesel contaminated soil on the root and shoot length of *P. vulgaris* studied per plant pots was presented in Table 3. P1 had the highest root and shoot length of 1.7 and 20.5 cm, while the lowest value was recorded in P5 with 0.5 and 11.2 cm, respectively (Table 3) The plant height showed significant differences along the columns at p = 0.5 (Table 3).

Table 4: Effect of different concentration of diesel contaminated soil on the number of leaves seen on plant on different pots

Pots	Week 1	Week 2	Week 3	Week 4
Pot 1	6[c]	16[c]	21[d]	24[d]
Pot 2	4[b]	8[b]	16[c]	14[c]
Pot 3	4[b]	7[ab]	13[ab]	12[b]
Pot 4	3[a]	6[a]	13[ab]	7[a]
Pot 5	3[a]	6[a]	12[a]	7[a]

P1: Soil contaminated with 0 g of diesel with control, P2: Soil contaminated with 10 g of diesel, P3: Soil contaminated with 20 g of diesel, P4: Soil contaminated with 30 g of diesel, P5: Soil contaminated with 40 g of diesel and Means of same letter showed no significant differences at p = 0.05

Leaf number: The effect of diesel simulated polluted soil on the number of leaves of *P. vulgaris* for period of 28 days was presented in Table 4. The highest value recorded for plot number of leaves in week 1 was in *P. vulgaris* grown on P1 (6) followed by P2 (4) and the least plot number of leaves was recorded for P5 (3) (Table 4). Likewise week 2, P1 had the highest number of leaves (16) and the least value was recorded in P4 and P5 with (6) (Table 4). For week 3, P1 had the highest number of leave (21) and the least value was recorded in P5 with (12). In week 4, P1 had the highest number of leaves (24) and the least value was recorded in P4 and P5 with (7) (Table 4).

DISCUSSION

The present study investigated effects of diesel contaminated soil on the growth of *P. vulgaris*. The study found that diesel contamination significantly reduces plant height, root length, and leaf count. This aligns with studies by Ekundayo *et al.*[22] and Okonokhua *et al.*[23] who reported that petroleum hydrocarbon contamination inhibits plant growth by creating anoxic conditions in the soil and reducing nutrient availability. The significant reduction in plant height, biomass, and root development suggests that diesel contamination can severely hinder crop productivity[22]. This implies potential food insecurity in regions where agricultural lands are affected by petroleum pollution. Farmers in such areas may experience reduced yields and income losses.

Diesel contamination adversely affected biomass accumulation. The observed reductions in fresh and dry weights suggest that diesel negatively impacts the physiological processes of the plant, such as photosynthesis and nutrient uptake. The decrease in fresh and dry weights observed in the study is consistent with findings[24] showed that crude oil pollution and spent engine oil adversely impacted various plant parameters, including total leaf area, plant height, stem girth, total biomass and crop yield in *Vigna unguiculata*. Adenipekun *et al.*[25], who noted reduced biomass production in plants grown in oil-contaminated soils. These studies attributed the reductions to toxic effects on plant metabolic activities, such as photosynthesis and nutrient uptake.

Root length was significantly reduced in diesel-treated pots. The control group had the longest roots, while P5 had the shortest roots. The number of leaves per plant was significantly higher in the control group compared to the treated pots. Diesel contamination reduced leaf production, particularly at higher concentrations. The stunted root growth in diesel-contaminated soils indicates that diesel contamination disrupts natural plant cycles such as flowering and fruiting, as well as having a toxic effect on root elongation. This could be due to the hydrophobic nature of diesel, which creates a barrier to water and nutrient absorption. Stunted root growth in the study is supported by Adesina and Adelasoye[26], who found that petroleum products increase the levels of certain elements, such as iron and zinc, to toxic levels, which inhibit root elongation and subsequent crop performance. Kayode *et al.*[27] also noted that oil contamination alters soil structure, reducing water and oxygen penetration, thereby impairing root growth.

In the study, *P. vulgaris* grown in diesel contaminated soil showed sign of pest attack on the leaf. Symptoms like yellowing leaves and increased pest susceptibility suggest oxidative stress and weakened plant immunity, likely caused by toxic hydrocarbons and heavy metals in the diesel. Yellowing of leaves and pest susceptibility were observed in the study are indicative of oxidative stress caused by the reactive oxygen species (ROS) generated in diesel-contaminated soils. This is consistent with findings by Kaur *et al*.[18], who noted that ROS cause lipid per-oxidation and protein oxidation, leading to visible stress symptoms in plants.

The findings align with Osibemhe *et al*.[28], who noted that diesel contamination reduces soil fertility by altering its physical and chemical properties leading to higher daily maximum surface temperatures in hydrocarbon-contaminated soils compared to uncontaminated areas. Similarly, Ossai *et al*.,[29] highlighted that oil contamination reduces microbial activity and organic matter decomposition, further compounding nutrient deficiencies in plants. Diesel contamination alters soil properties, such as aeration, nutrient availability, and water retention, rendering the soil unsuitable for agriculture. Over time, this could lead to land degradation, requiring costly remediation efforts or abandonment of farmland. The presence of toxic hydrocarbons and heavy metals in diesel-contaminated soil poses potential risks to human health[30]. Crops grown in such soils may bioaccumulate harmful substances, which could enter the food chain, impacting consumers' health.

The results clearly indicate a dose-dependent relationship, with higher diesel concentrations causing more severe effects on all growth parameters. The dose-dependent relationship observed in the study, where higher diesel concentrations caused more severe effects, agrees with findings by Masakorala *et al*.[31]. Similarly, Sagaya *et al*.[32] reported a significant oil-dose dependent reduction in the germination, growth, fruiting and Leaf Anatomy of *Abelmoschus caillei*. These studies emphasized that the toxic effects of diesel contamination increase with concentration due to higher hydrocarbon content and associated toxicity. The study therefore emphasizes the need for stricter regulations on the handling, storage, and transportation of petroleum products to minimize accidental spills.

CONCLUSION

The study investigated the impact of diesel contamination on the growth and development of *P. vulgaris* (common bean). Diesel contamination in soil occurs through spills and leakages, often in agricultural and industrial areas, introducing hydrocarbons and toxic compounds that affect soil quality and plant health. Therefore, there is a need to carefully transport diesel, and when a container carrying the diesel breaks down, spillage of diesel oil should be totally avoided. More so, quick response to oil spillage during an accident should be taken seriously. This also sounds a serious warning to oil pipeline vandals to desist from such act owing to the fact that diesel impacted soil may reduce agricultural produce, which will in turn lead to shortage of food and reduced national income. The findings highlight the urgency for governments and environmental agencies to enforce stricter policies on petroleum handling. Communities near oil facilities should also be educated on the risks of improper handling and disposal of petroleum products. The study underscores the need for further research into cost-effective and sustainable remediation strategies for diesel-contaminated soils.

SIGNIFICANCE STATEMENT

This study demonstrates that diesel-contaminated soil significantly inhibits the growth and biomass of *Phaseolus vulgaris*, highlighting its sensitivity to petroleum pollution. The findings emphasize the environmental risk of diesel spills on agricultural productivity and the need for strict pollution control and soil remediation strategies.

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