# Effect of Petroleum Products Treatment of Soil on Succinate Dehydogenase and Lactate Dehydogenase Activities in Cowpea (*Vigna unguiculata*) and Maize (*Zea mays*) Seedlings

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*Author's contribution*

*This work was carried out by FIA, who designed the study, wrote the protocol and wrote the first draft of the manuscript. He equally performed the statistical analysis, read and approved the manuscript.*

*Original Research Article*

## ABSTRACT

**Aim:** Most of the land in oil producing area in the Niger delta region of Nigeria is under constant petroleum pollution exposing the soil to the deleterious effect of petroleum hydrocarbons. The effects of petroleum products (kerosene, diesel, engine oil and petrol) treatment of soil at various sublethal concentrations (0.0%, 0.1%, 0.25%, 0.5%, 1.0%, 1.5% and 2.0%) on succinate dehydrogenase and lactate dehydrogenase activities in the leaves of cowpea and maize seedlings were then studied.
**Place and Duration of Study:** This study was conducted in Delta State University, Abraka, Nigeria between April 2007 and August 2011.
**Methodology:** Improved varieties of maize *(Zea mays)* and *Vigna unguiculata* (L) Walp were planted in soil contaminated at different concentrations of six groups of five replicates. Groups 1 to 5 contained 0.1%, 0.25%, 0.5%, 1.0% and 2.0% (v/w) respectively of each of the petroleum products while group six served as control (0.0%). Three seeds were planted in each bag and watered daily.

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The activities succinate dehydrogenase (SDH) and lactate dehydrogenase (LDH) in the leaves of the cowpea and maize seedlings were analysed after four, eight and twelve days after germination.
**Results:** The results indicated that petroleum products treatment of soil resulted in decrease in succinate dehydogenase activity in both cowpea and maize seedlings as well as a corresponding increase in lactate dehydrogenase activity in the two seedlings. The toxic effect of kerosene was more severe than the other products studied. Similarly, Cowpea seedlings were affected more than maize seedlings.
**Conclusion:** Generally, the data indicate that seedlings exposed to petroleum products treated soil tend to move towards anaerobic respiration in a bid to survive under petroleum stress.

## 1. INTRODUCTION

Petroleum compounds have multifarious industrial and domestic uses. They are extensively employed in solvents, dry cleaning fluids quick-products, automobile fuel, household solvents, and lubrication of machines, cosmetics, water proofing agents, cleaning agents and specialty chemicals. [1] These anthropogenic activities have led to the widespread contamination of the environment. Oil spill is the major cause for the high influx of petroleum to the biosphere. [2,3] However, other points of soil pollution with refinery products are petrol stations, garages servicing, tractors and seaports areas. [4] Other areas of concern are mining industries and distribution of petroleum-based products. [5-7] Besides, negligence while collecting or storing refinery products together with unsatisfactory care while disposing of old or used petroleum products leads to considerable pollution of the environment [8].

Various chemicals entering the ecosystem through human activities, either accidentally or by design may cause adverse effects on the biota including deleterious changes, which disrupt metabolic activity at the biochemical levels [9]. When an organism is exposed to polluted medium, a sudden stress is developed for which the organism should meet more energy demand to overcome the toxic stress.

Succinate dehydrogenase is the component of complex II of the respiratory chain that catalyses the oxidation of succinate to fumarate in the Krebs cycle. Flavin adenine dinucleotide (FAD) is also a part of the succinate dehydrogenase active enzyme complex. The oxidation of succinate to fumarate is the only Krebs reaction that takes place in the inner membrane itself as opposed to the other reactions that are catalysed by soluble enzymes. Succinate is the most efficient energy source; therefore its activity is the most efficient method of measuring the vitality of living organisms [10] and can be taken as an indication of the level of the tricarboxylic acid cycle (TCA) activity [11].

Lactate dehydrogenase catalyses the conversion of pyruvic acid to lactic acid in anaerobic condition [12]. To study the strategy of energy production adopted by cowpea and maize seedlings exposed to petroleum products, it is necessary to consider the changes in the activities of succinate dehydrogenase (SDH) and lactate dehydrogenase (LDH).

## 2. MATERIALS AND METHODS

### 2.1 Refined Petroleum Products and Planting Materials

The refined petroleum products of known physical properties were obtained from Warri Refining and Petrochemical Company, Warri, Nigeria .Improved varieties of maize *(Zea mays)* were obtained as single batch from Delta Agricultural Development Project (DTADP) Ibusa Delta State, Nigeria. Improved varieties of *Vigna unguiculata (L)* walp were obtained from International Institute of Tropical Agriculture, IITA, Ibadan, Nigeria. The soil (sand 84%, silt 5.0%, clay 0.4% and organic matter 0.6%, pH 6.1) were obtained from a fallow land in Delta State University, Abraka.

### 2.2 Soil Treatment and Planting of Seeds

One thousand six hundred grams of soil was added to each small size planting bags ($1178.3cm^3$, 15 cm deep) and divided into six groups of five replicates. Groups 1 to 5 contained 0.1%, 0.25%, 0.5%, 1.0% and 2.0% (v/w) respectively of each of the petroleum products

(Kerosene, Diesel, unused engine oil and Petrol) while group six which was treated with petroleum products served as control (0.0%).To the first bag, 1.6 ml of kerosene, corresponding to 0.1%, was added The petroleum product treated soil samples were mixed vigorously with the hand to obtain homogeneity of the mixture. The procedure was repeated for 0.25%, 0.5%, 1.0%, 1.5% and 2.0%. This same procedure was applied to diesel, engine oil and petrol. Each treatment, including control, was replicated five times and consisted of three sown seeds per polythene bag. The treatments were watered every day in order to keep the soil moist. The design of the experiment was completely randomised one.

Seed viability was determined by floatation. Seeds that floated on water were discarded and those that remained at bottom of water were deemed potentially viable. Three seeds were planted in each test bag to an approximate depth of 2cm and under partial shade. During the experiment $80cm^3$ of water was supplied to the set up to keep the soil moist. Germination [indicated by the appearance of epicotyls (for cowpea) and hypocotyls (for maize) above the soil level] records were taken at 4 days interval up to 12 days. Seeds, which failed to sprout after 12 days were regarded as not germinable.

## 2.3 Preparation of Extract and Determination of Succinate Dehydrogenase Activity in the Leaves of Cowpea and Maize Seedlings

The leaves (1.0g) of cowpea seedlings after four days of germination were taken into mortar containing 0.5g of acid washed sand. This was followed by the addition of 5.0ml of 0.05M potassium phosphate buffer, (pH 7.4) and ground with a pestle. The homogenate was filtered through cheesecloth. The filtrate was centrifuged at 1000 xg for 5 minutes at 4°C to sediment the nuclear fraction. The supernatant was further centrifuged at 10,000xg for 30 minutes at 4°C. The supernatant was discarded and pellet resuspended in 80ml of 0.05 M potassium phosphate buffer, (pH 7.4). The resuspended pellet is kept in ice bath for use as source of enzyme. The extraction was repeated for cowpea seedlings after eight and twelve days of germination. This same procedure was adopted for the preparation of extract from maize leaves after four, eight and twelve days of germination in petroleum products treated soil.

SDH catalyzes the oxidation of succinate to fumarate in the presence of FAD, which is subsequently reduced to $FADH_2$. In the presence of cyanide the electrons from $FADH_2$ are picked by 2, 6 dichlorophenolindophenol (DCIP). The reduction of DCIP can be monitored at 600 nm and can be used to follow the reaction over time. The activity of succinate dehydrogenase (SDH) was determined by adding 2.5ml of 0.05M of potassium cyanide and 0.5ml of 0.5M succinate into preincubated cuvette. The tube was covered with paraffin and mixed thoroughly. The change in absorbance was monitored for 30 minutes at 600 nm with an Sp 1800 UV/VIS Spectrophotometer after the addition of 0.5ml of enzyme extract. The blank was prepared by replacing the enzyme extract with distilled water [13]. Succinate dehydrogenate activity was expressed as units and one unit is defined as one mole of dichlorophenolindophenol reduced /minute [13].

## 2.4 Preparation of Extracts and Determination of Lactate Dehydrogenase Activities in the Leaves of Cowpea and Maize Seedlings

The leaves (2.0g) of cowpea seedlings after four days of germination were homogenized in 10ml of 0.1M Tris-HCl buffer (pH 8.8) containing EDTA using mortar and pestle. The homogenate was filtered through several layers of cheese cloth and the extract was centrifuged for 10 minute at 1,000xg. The supernatant was raised to 20% saturation with solid $(NH_4)_2SO_4$ with constant stirring and left for 20 minutes at $4^0C$. The mixture was centrifuged as before and the precipitate which contained NADH oxidase was discarded with. The crude supernatant obtained at this point was used as the enzyme source. The extraction process was repeated using the leaves of cowpea seedlings after eight days and twelve days. This procedure was adopted for the preparation of extracts from maize seedlings after four, eight and twelve days of germination.

LDH catalyzes the oxidation of lactate to pyruvate in the presence of $NAD^+$, which is subsequently reduced to NADH. The rate of NADH formation at 340 nm is directly proportional to LDH activity [14]. The assay mixture was equilibrated at $37^oC$ contained 1ml of 6 0mM Tris-HCl buffer,( pH 8.8), 0.5ml of 2.0 mM lactic acid, 0.5ml of 6 mM $NAD^+$ and 0.1ml of enzyme extract. The rate of NADH + $H^+$ formation was monitored at 340 nm. The enzyme

activity was assayed with an Sp 1800 UV/VIS Spectrophotometer

## 2.5 Statistical Analysis

The results were expressed as mean + SEM. All results were compared with respect to the control. Comparisons between the test and control were made by using analysis of variance (ANOVA) with the Graph pad Prism, version 5.3.Differences at $p<0.01$ were considered as significant.

## 3. RESULTS

The activities of succinate dehydogenase (SDH) in the leaves of cowpea and maize seedlings after four days of germination in kerosene, diesel, engine oil and petrol treated soil are shown in Fig. 1. In all the concentration tested, kerosene treatment of soil resulted in significant decrease of SDH activities in the leaves of both cowpea and maize seedlings compared with their respective control values. When SDH activities in the leaves of cowpea and maize seedlings were compared, the enzyme activity was slightly lower in the leaves of cowpea seedlings than in the leaves of maize seedlings.

Diesel treatment of soil resulted in significant decrease of SDH activity in the leaves of cowpea seedling in all the concentrations tested. Similarly, diesel treated soil gave rise to a significant decrease of SDH in the leaves of maize seedling across all the concentrations compared with control. When SDH activities in the leaves of cowpea and maize seedlings grown in diesel treatment of soil were compared, the enzyme was higher in the leaves of cowpea seedling at 0.1%, 0.25%, and 2% concentration than in the leaves of maize seedling but slightly lower at other levels of concentrations.

Given the overall concentration tested, engine oil treatment of soil resulted in a significant decrease of SDH activities in the leaves of both cowpea and maize seedlings compared to their respective control value. Nonetheless, the enzyme activity was found to be lower in the leaves of cowpea seedlings than in the leaves of maize seedlings. When compared with control, petrol treatment of soil, in all the concentration tested, resulted in significant decrease in SDH activities in the leaves of cowpea seedlings.

Likewise, in the leaves of maize seedlings, petrol treatment of soil gave rise to a significant

decrease of SDH activities in all the concentration tested relative to control. Nevertheless, SDH activity was lower in the leaves of cowpea seedlings in all the concentration tested than in the leaves of maize seedlings.

The activities of succinate dehydrogenase (SDH) in the leaves of cowpea and maize seedlings after eight days of germination in kerosene, diesel, engine oil and Petrol treated soil are shown in Fig. 1. Kerosene treatment of soil resulted in significant decrease of SDH activities in the leaves of cowpea seedlings compared with control. Similarly kerosene treatment of soil resulted in a significant decrease of SDH activities in the leaves of maize seedlings at the various concentration levels. Nonetheless, SDH activity was found to be significantly lower in the leaves of cowpea seedlings in the entire concentration tested.

Diesel treatment of soil resulted in a significant decrease of SDH activities in the leaves of cowpea seedlings compared with control. Likewise, diesel treatment of soil led to a significant decrease of SDH activity in the leaves of maize seedlings across the concentration tested compared with control. By way of comparing SDH activities in the leaves of cowpea and maize seedlings grown in diesel treated soil, the enzyme activity was found to be significantly higher in the leaves of cowpea seedlings at 0.25% concentration, but lower at other concentrations.

Engine oil treatment of soil resulted in a significant decrease of SDH activity in the leaves of cowpea seedlings in all the concentration tested. Similarly, engine oil treated soil gave rise to a significant decrease of SDH activity in the leaves of maize seedling across the concentration tested relative to control. Comparing the activities of SDH in the leaves of cowpea and maize seedlings grown in engine oil treatment of soil, it was found to be significantly lower in the leaves of cowpea seedling in all concentrations than in the leaves of maize seedlings.

In all the concentrations tested, petrol treatment of soil resulted in significant decrease of SDH activity in the leaves of both cowpea and maize seedlings relative to their respective control value. Nonetheless, the activities of SDH appeared to be slightly lower in the leaves of cowpea seedlings than in the leaves of maize

seedlings at 0.1%, 0.5%, 1%, 1.5% and 2% concentrations of petrol in soil.

The activities of succcinate dehydrogenase (SDH) in the leaves of cowpea and maize seedlings grown in kerosene, diesel, engine oil and petrol treated soil after twelve days of germination are shown in Fig. 1. In all the concentrations tested, kerosene treatment of soil resulted in significant (p<0.01) decrease of SDH activity in the leaves of cowpea seedlings compared with control. Likewise, kerosene treatment of soil resulted in a significant (p<0.01) decrease in SDH in the leaves of maize seedlings. Comparing the activities of SDH in the leaves of cowpea seedling and maize seedlings, it was observed that SDH was significantly lower (p<0.01) in virtually all the levels of concentration in the leaves of cowpea seedlings than in the leaves of maize seedlings.

Diesel treatment of soil resulted in a significant (p<0.01) decrease of SDH activity in the leaves of cowpea seedling in all the concentrations tested. Similarly, diesel treatment of soil gave rise to a significant (p<0.01) decrease of SDH activity in the leaves of maize seedling across all the concentration compared with control. By way of comparing SDH activities in the leaves of cowpea and maize seedlings grown in diesel treatment of soil, the enzyme was significantly (p<0.01) lower in the leaves of cowpea seedlings at concentrations above 0.5% than in the leaves of maize seedlings.

In all the concentrations tested, engine oil treatment of soil resulted in a significant decrease of SDH activity in the leaves of cowpea seedlings compared with control. Also, engine oil treatment of soil gave way to a significant (p<0.01) decrease of SDH activity in the leaves of maize seedling at the various concentration levels. Nonetheless, the enzyme was found to be significantly lower in the leaves of cowpea seedling than in the leaves of maize seedlings in all the concentrations tested.

When, compared with control, petrol treatment of soil, in all the concentrations tested, brought about a significant (p<0.01) decrease of SDH activity in the leaves cowpea and maize seedlings. However, SDH activity was found to be significantly lower in the leaves of cowpea seedlings at 0.1%, 0.25% and 1.0%-2% concentrations than in the leaves of maize seedlings.

The activities of lactate dehydrogenase (LDH) in the leaves of seedlings of cowpea and maize grown in kerosene, diesel, engine oil and kerosene treatment of soil after four days of germination are shown in Fig. 2. Kerosene treatment of soil resulted in significant decrease of LDH activities in the leaves of cowpea seedlings compared with control. Likewise, kerosene treatment of soil resulted in a significant decrease of LDH activities in the leaves of maize seedling in all the concentrations tested. Slight decreases were found at 1% and 1.5%. No significant differences existed in the activities of LDH in the leaves of cowpea and maize seedlings when compared.

Diesel treatment of soil resulted in significant decrease of LDH activities in the leaves of cowpea seedlings at all the concentration tested except 1% and 1.5% concentration where slight decrease of LDH was found. Similarly, diesel treatment of soil resulted in decrease in LDH activity in maize seedling except at 1% and 1.5%. When compared, the activities of the LDH in the leaves of cowpea seedlings were not significantly different from that of maize seedlings. Engine oil treatment of soil resulted in significant decrease of LDH activities in the leaves of cowpea seedlings at all concentrations except at 1.5% concentration, which had a slight increase in the activity of the enzyme. Similarly, engine oil treatment of soil treated soil gave rise to a significant decrease of LDH activities in all the concentrations tested except 1.5% compared with control.

Petrol treatment of soil resulted in significant decrease of LDH activities in the leaves of cowpea seedlings except 2% concentration level compared with control. In maize seedlings grown in petrol treated soil, the activities of LDH decreased significantly in all the concentrations tested except at 1.5% relative to the control. When the activities of LDH in the leaves of cowpea and maize seedlings grown in petrol treatment of soil were compared, it was significantly lower in the leaves of cowpea seedling at 1.5% than in the leaves of maize seedlings. Also, LDH was significantly higher at 2% in the leaves of cowpea seedling than in the leaves of maize seedling.

The activities of lactate dehydrogenase (LDH) in the leaves of cowpea and maize seedlings after eight days of germination in kerosene, diesel, engine oil and Petrol treated soil are shown in Fig. 2. Kerosene treatment of soil resulted in

significant decrease of LDH activities in the leaves of cowpea seedling at 1% 1.5% and 2% compared with control. LDH activities were also found to decrease significantly in the leaves of cowpea seedling at 0.1% and 0.25% concentrations compared with control. Similarly, kerosene treatment of soil resulted in significant decrease of LDH activities in the leaves of maize seedlings at 0.1%and 0.25% concentrations relative to the control, but there was a significant increase in the activity of LDH at 1%, 1.5% and 2.0% concentrations. When the activities of LDH in the leaves of cowpea and maize seedlings were compared, no significant difference existed between them. Nonetheless, it was slightly lower in the leaves of cowpea seedlings than in the leaves of maize seedlings.

Diesel treatment of soil resulted in significant decrease of LDH activities at 0.1%, 0.25% and 2% in the leaves of cowpea seedlings compared with control. However, there was a significant increase of LDH activities in the leaves of cowpea seedlings at 1% and 1.5% concentrations relative to control. Similarly, diesel treatment of soil resulted in significant increase of LDH activities in the leaves of maize seedlings at 1%, 1.5% and 2.0% concentrations of diesel in soil compared with control, but the LDH activity showed a significant decrease at 0.1%, 0.25% and 2% concentrations of diesel in soil. Engine oil treatment of soil resulted in significant increase of LDH activities in the leaves of both cowpea and maize seedlings at 1% and 1.5% concentrations compared to their respective control values. However, LDH activities decreased significantly at 0.1%, 0.25% and 2% concentration in the leaves of both cowpea and maize seedlings compared to their control values. When the activities of LDH in the leaves of cowpea and maize seedlings grown in engine oil treatment of soil were compared, it was found slightly lower in the leaves of cowpea seedlings than in the leaves of maize seedlings.

Petrol treatment of soil resulted in significant decrease of LDH activities in the leaves of cowpea seedlings at all the concentrations except at 2.0% concentration. In maize seedling, petrol treatment of soil resulted in significant decrease of LDH activities in the leaves at 0.1%, 0.25% and 2% compared with control. However, LDH activities showed a significant increase at 1.5%. When the activities of LDH in the leaves of cowpea and maize seedlings grown in petrol

treatment of soil were compared, there appeared to be no significant difference between them.

The activities of lactate dehydrogenase (LDH) in the leaves of cowpea and maize seedlings after twelve days of germination in kerosene, diesel, engine oil and petrol treated soil are shown in Fig. 2. Kerosene treated soil resulted in significant increase of LDH activity in the leaves of cowpea seedlings in all the concentrations tested compared to the control. Correspondingly, kerosene treated soil resulted in significant (p<0.01) increase of LDH activity in the leaves of maize seedling at all concentrations tested compared with the control. Comparatively, the activity of the enzyme was significantly (p<0.01) lower in the leaves of cowpea seedlings than in the leaves of maize seedling at each tested concentration, except at 0.1% concentration. In all the concentrations tested, diesel treatment of soil resulted in significant increase of LDH activity in the leaves of cowpea seedling compared with control.

Equally, diesel treatment of soil resulted in significant (p<0.01) increase of LDH activity in the leaves of maize seedling compared with control. Comparatively, the activity of the enzyme was significantly (p<0.01) lower in the leaves of cowpea seedlings than in the leaves of maize seedlings at diesel concentration greater than 0.25%. At the various concentrations tested, engine oil treatment of soil resulted in significant increase of LDH activities in the leaves of both cowpea and maize seedlings compared to their respective control values. When the activities of LDH in the leaves of cowpea and maize seedlings grown in engine oil treatment of soil were compared, it was found to be significantly (p<0.01) lower in the leaves of cowpea seedlings than in the leaves of maize seedling at diesel concentrations higher than 0.25%.

Petrol treatment of soil resulted in significant increase of LDH activity in the leaves of cowpea seedling in all the concentrations tested relative to control value. Similarly, petrol treatment of soil resulted in significant increase of LDH activity in the leaves of maize seedling in all the concentrations tested relative to control value. Comparing the activities of LDH in the leaves of cowpea and maize seedlings, it was found to be significantly lower in the leaves of cowpea seedlings than in the leaves of maize seedlings.
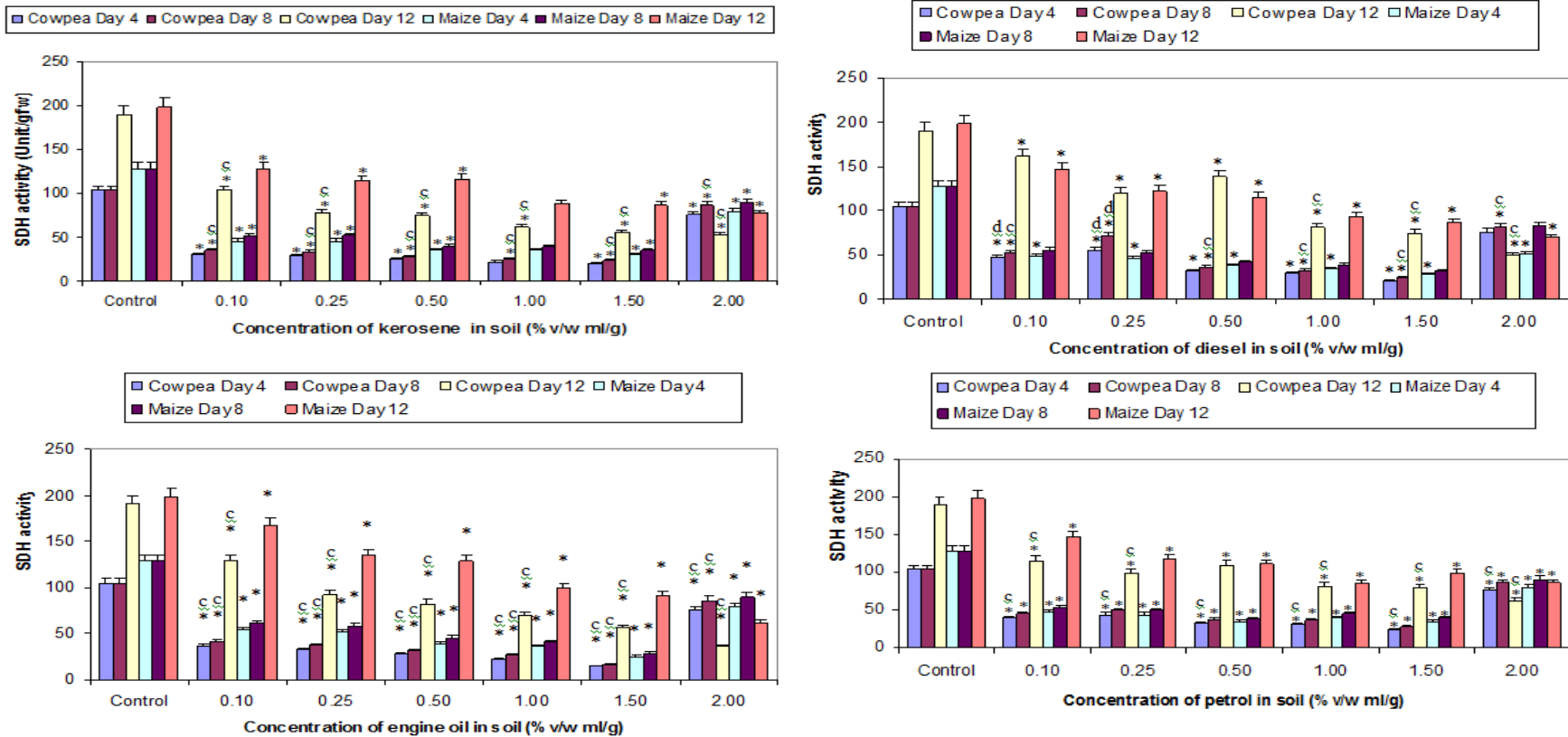
**Fig. 1. Effect of concentration of petroleum products on SDH activities in leaves of cowpea and maize after four, eight and twelve days of germination. \*Significantly lower as compared to control; ⁺Significantly lower as compared to engin oil; ⁺⁺Significantly lower as compared to kerosene; ᵉSignificantly higher relative to control; ᵃSignificantly lower relative to other petroleum products; ᵇSignificantly higher relative to other petroleum products; ᶜSignificantly lower in cowpea relative to maize seedlings; ᵈSignificantly higher in cowpea relative to maize seedlings**
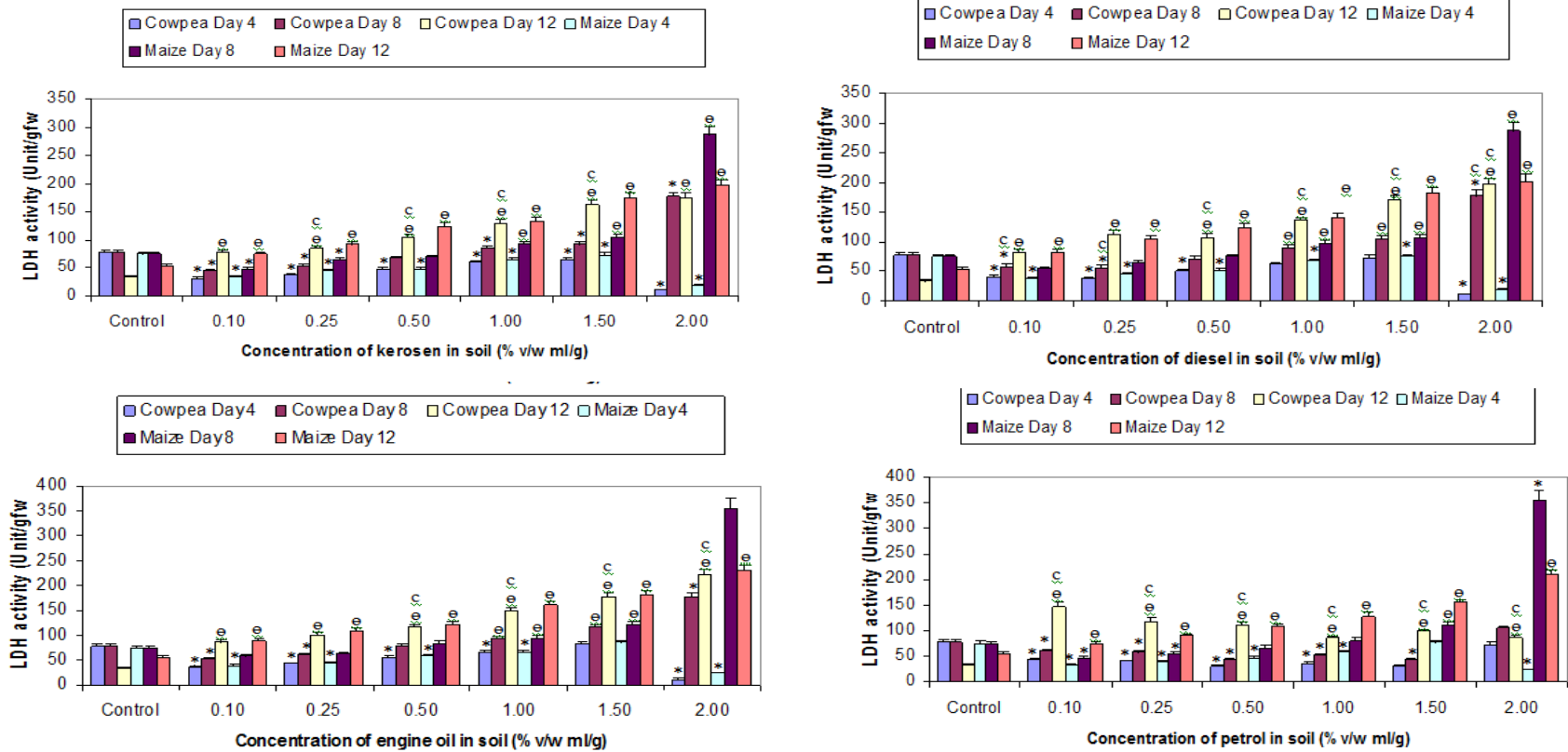
**Fig. 2. Effect of concentration of petroleum products on LDH activities in leaves of cowpea and maize after four, eight and twelve days of germination. *Significantly lower as compared to control; +Significantly lower as compared to engin oil; ++Significantly lower as compared to kerosene; eSignificantly higher relative to control; aSignificantly lower relative to other petroleum products; bSignificantly higher relative to other petroleum products; cSignificantly lower in cowpea relative to maize seedlings; dSignificantly higher in cowpea relative to maize seedlings**

## 4. DISCUSSION

Earlier reports had indicated that petroleum in soil caused displacement of air in the pore spaces [15,16] which culminate in oxygen tension cum hypoxia in exposed plants [17,18]. This may result in changes in energy metabolism, vis-à-vis an alteration in the activity of respiratory enzymes such as lactate dehydrogense and succinate dehydrogenase [12].

Succinate dehydrogenase is component of complex II of the respiratory chain that catalyzes the oxidation of succinate to fumarate in the Krebs cycle [19]. It is the most efficient energy source in the cell [10,20]. Therefore, inhibition of succinate dehydrogenase activity suggests a decrease in rate of energy generation by the cell. Previous report indicated that heavy metals induced a decrease in succinate dehydrogenase activity [12]. This is in agreement with the present investigation in which refined petroleum products caused a decrease in succcinate dehydrogenase activity after four, eight and twelve days of germination (Fig. 1). Moreover, the toxic effect of kerosene was more pronounced compared to the effect of other refined petroleum products. The high degree of toxicity of kerosene had been documented [21]. Similarly, the vulnerability of cowpea seedlings to petroleum hydrocarbon compared to maize seedlings was apparent (Fig. 1). The higher toxic effect of refined petroleum product on cowpea compared to maize had been attributed to the fact that cowpea seedlings have the ability to absorb hydrocarbon from the soil more than maize seedlings [22,23].

The findings of the present study indicate that the time-dependent effect of petroleum products on LDH activity of tissues of cowpea and maize seedlings was varied or inconsistent (Fig. 2). However, the observed increase in LDH activity, especially at day eight, is consistent with similar toxicant mediated increase in lactate dehydrogenase activity which has been reported earlier [12]. The increase in lactate dehydrogenase activity may reflect an increase dependence on anaerobic carbohydrate metabolism by the leaves of the respective seedlings after sustained exposure to reduced oxygen supply. Thus, the non availability of oxygen, the inhibition of succinate dehydrogenase activity and simultaneous elevation of lactate dehydrogenase activity may

suggest a bias toward the anaerobic glycolytic pathway. The reciprocal relationship between succinate dehydrogenase activity and lactate dehydrogenase activity had been reported previously [12,24]. Similar to succinate dehydrogenase activity, kerosene seems to affect both cowpea and maize seedlings more than the other refined products, though not significant. In addition, the response of maize seedlings was significantly (P<0.01) higher relative to cowpea seedlings (Fig. 2). This may be predicted on the backdrop of starchy seeds ability to undergo fermentative respiration [25]. Generally, it is obvious that refined petroleum product, most especially kerosene could impose anaerobiosis in exposed plant.

## 5. CONCLUSION

In conclusion, it is pertinent to say that the refined petroleum products inhibited succinate dehydrogenase activity in both cowpea and maize seedlings. The degree of inhibition was higher in cowpea than in maize seedlings. Moreover, kerosene affected the seedlings more than the other three petroleum products. However, the refined petroleum products increased the activity of lactate dehydrogenase. This increment was more in kerosene exposed seedlings relative to other petroleum products. This suggests that the simultaneous decrease in succinate dehydrogenase activity and increase in lactate activity predisposes petroleum products exposed plant to anaerobic carbohydrate metabolism.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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