International Journal of Biological and Pharmaceutical Sciences Archive

ISSN: 0799-6616 (Online)

Journal homepage: https://ijbpsa.com/

(RESEARCH ARTICLE)

The complementary role of the fungus (*Aspergillus niger*) and the corn plant (Zea mays) in improving the efficiency of phytoremediation of soil contaminated with oil residues

Mustafa Ali Saeed Gharab *

Department of Biology, College of Education for Pure Sciences, University of Samarra, Samarra, Iraq.

International Journal of Biological and Pharmaceutical Sciences Archive, 2026, 11(02), 214-223

Publication history: Received on 14 May 2026; revised on 28 June 2026; accepted on 30 June 2026

Article DOI: https://doi.org/10.53771/ijbpsa.2026.11.2.0064

Abstract

This study was conducted in the city of Samarra due to the serious health effects of oil waste-associated soil pollution, which is a prevalent phenomenon that negatively affects the quality of soil and plant growth. The study was conducted to investigate the synergistic mechanism of fungal roots and the root system of plants in the bioremediation process and to analyze the effectiveness of plant bioremediation of soil contaminated with oil waste. Experiments were carried out as described in the section (Study Site and Field Experiment Design).

The inclusion of *Aspergillus niger* fungus, oil residues and *Zea mays maize* in the soil changed its physical and chemical properties throughout the experiment. Treatment (T0P2) recorded the highest conductivity (4.85) dS.m-1, but it decreased to (1.82) dS.m-1 in treatment (T3P2). Treatment (T3P2) had the highest pH value (7.98) whereas therapy (T1P1) gave the lowest value (7.1). The concentration of soluble bicarbonates was greatest in treatment T0P1 (20.81 cmol.L-1) and lowest in treatment T2P1 (14.43 cmol.L-1 Treatment T3P0 showed the most percentage of organic matter (3.50 g.kg-1 soil) whereas the minimum percentage of organic matter was seen in treatment T2P0 (1.25 g.kg-1 soil).

The therapy (T1P1) had the greatest sodium content (56.85 cmol/L), whereas the treatment (T3P1) had the lowest (32.75 cmol/L). Treatment (T1P0) had the maximum plant height (91.55 cm), whereas treatment (T3P0) had the lowest (71.66 cm). Treatment (T1P1) had the highest dry weight at 34 g, whereas treatment (T1P2) had the lowest dry weight at 25 g.

Based on the information above, we may conclude that the fungus *A. niger* has the ability to use, digest, and grow oil waste in order to lessen soil contamination.

Keywords: Bioremediation; Oil residues; Corn (*Zea mays*); Fungus (*Aspergillus niger*)

1. Introduction

The problem of soil pollution by petroleum hydrocarbons is one of the most serious environmental challenges facing ecosystems in the modern era, due to the severe deterioration in the physical, chemical and biological properties of the soil caused by these pollutants [1].

Soil contaminated with petroleum hydrocarbons is one of the biggest environmental challenges, given its high toxicity and bioaccumulation. The modern trend towards "Co-metabolism" stands out as a low-cost and environmentally friendly (Eco-friendly) alternative, as its danger is not limited to being persistent pollutants, but extends to include its direct toxic effects on microorganisms, plants, and ultimately humans through the food chain [2].

* Corresponding author: Mustafa Ali Saeed Gharab

When petroleum derivatives reach the soil, they clog the interstitial spaces, hindering water and air permeability and consequently leading to nutrient imbalances and disruption of normal microbial enzyme activity. Due to the structural complexity of hydrocarbons, Polycyclic aromatic hydrocarbons (PAHs), natural decomposition processes are very slow and insufficient to address the increasing levels of pollution [3].

In response to this dilemma, bioremediation technologies have emerged as a sustainable and highly efficient strategic option. These technologies rely on harnessing the metabolic capabilities of living organisms to break down and convert pollutants into less toxic byproducts such as carbon dioxide and water. The integration of phytoremediation and mycorrhizal systems is one of the most promising approaches; the root system of plants such as corn (*Zea mays*) provides a fertile or rich environment to stimulate microbial activity, while saprophytic fungi such as *Aspergillus niger* contribute, through their powerful enzymatic arsenal, to breaking down complex carbon bonds that are difficult for other organisms to handle [4;5].

“Green technology”, also called phytoremediation, reduces the waste in the soil by extracting the poisons from the plants cultivated. Compared to other chemical processes and the trash they create, this is a very excellent and economical approach for cleaning up or removing toxins from the soil [6].

The mycorrhizosphere is the region where plant roots and fungal roots interact and cooperate to help the plant flourish. This knowledge offers up new avenues for dealing with contaminated regions and their restoration. The purpose of this research is to examine and evaluate its function [7].

Microbial remediation is a strategy to get rid of and utilize toxic elements. It has been increasingly employed in recent decades to curb pollution and other environmental challenges. Fungal-based bioremediation techniques have been developed to detoxify the environment by removing toxins and pollutants [8].

There’s been increasing interest in fungus for remediation of oil and other toxic substances in the environment. This is because they have a sophisticated system of enzymes that allows them to break down or modify a large variety of dangerous compounds. Fungi may decompose oil waste, since their strands can form thick layers on the oil and tolerate severe weather [9].

To-do items and actions

See how and where field experiments are established.

They did two tests. First, pure cultures of the fungus *A. niger* were grown in laboratories of the Ministry of Science and Technology.

Chemical and Physical Properties of Experimental Soil Prior to Oil Contamination

Samples of soil were gathered from the Tigris River near Samarra. After removing all the dirt and plant pieces, the samples were placed in the lab to dry out completely. Then they were screened via a two-millimetre screen.

1.1. Soil Texture

Soil texture was estimated using a pipette as described in Miller and Miller.,1987 [10].

1.2. Organic Matter

It was estimated by the wet oxidation method using chromic acid according to the Walkley-Black method described in Page et al. 1982 [11].

1.3. Soil pH

It was estimated using a pH meter according to the description in Tagami and Uchida,2025 [12].

1.4. Soil Electrical Conductivity (EC)

It was measured using a conductivity meter according to the methods described in Tagami and Uchida 2025 [12].

1.5. Dissolved Positive and Negative Ions

The dissolved positive and negative ions in the soil extract were estimated according to the method described in Joly et al.; 2024 [13], and included the following:

- Sodium ions
- Bicarbonate (HCO3)
- Studyed characteristics of the vegetative system in maize under the influence of petroleum residues and the synergistic effect of the fungus *A. niger*:
- Plant height
- The vegetative system's dry weight estimation of the amount of oil in polluted soil.

The percentage of petroleum hydrocarbons was measured at the Ministry of Science and Technology laboratory in Baghdad/Al-Jadriya to determine the removal rate achieved by the treatments used in the experiment, according to the method described by Goutx and Saliot 1980 [14], using a gas chromatography (GC) device.

These are the chemical, physical, and biological features of the study dirt before it was planted.

Unity	**Value**	**Characteristics**	
-	7.3	Soil reaction (pH)	
Decisimens* M^{-1}	2.62	Electrical conductivity (EC)	
gm. kg^{-1} soil	1.8	Organic matter (OM)	
	8.3	Bicarbonate HCO_3	Dissolved negative ions
	25.06	sodium Na^{+2}	Dissolved positive ions
gm. kg^{-1} soil	34.21	Sand	Soil separators Tissue
	39.45	Silver	
	28.11	Clay	
soil mixture			The texture

Treatments used in the experiment:

- T0P0 only Soil
- T0P1 only Soil
- T0P2 only Soil T1P0 Plant only
- T1P1 Plant only
- T1P2 Plant only
- T2P0 Fungus only
- T2P1 Fungus only
- T2P2 Fungus only
- T3P0 Plant + Fungus
- T3P1 Plant + Fungus
- T3P2 Plant + Fungus

1.6. Statistical Analysis:

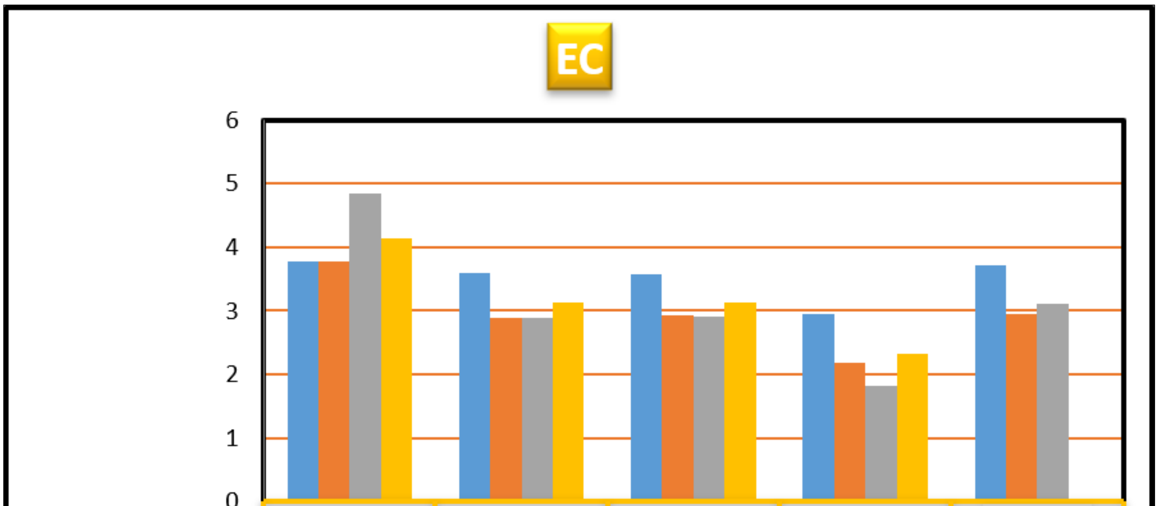
The data was statistically analyzed with Minitab Ver. 17 tools for statistics, particularly the ANOVA test. Duncan's multiple range test was performed to compare the arithmetic mean with the chance level of 0.05 [15], to detect the discrepancies. Graphs might also be created using Microsoft Office Excel 2010.

2. The Lecture and the Results

2.1. The study looked at the biological, chemical, and physical features of dirt

(1)The electrical conductivity (EC) of the earth: Figure (1) shows how the EC changes when oil gets into the soil. The conductivity of treatment (T0P2) was 4.85 dS·m-2, the highest. The conductivity of treatment (T3P2) was 1.82 dS·m-2, the lowest. The results showed that the average amounts of P and T were very different.

If you put different amounts of salt in different places, some salts change into forms that don't dissolve in water because oil leftovers stick to dirt particles. This makes salt less soluble and seals up the soil's pores [16].



	T0	T1	T2	T3	Average P levels
P0	3.78	3.6	3.57	2.95	3.72
P1	3.78	2.89	2.93	2.19	2.94
P2	4.85	2.89	2.9	1.82	3.11
Average T levels	4.13	3.12	3.13	2.32	

Figure 1 Values of (EC)

2.2. pH

It is evident and crucial to see the amount of reactivity and changing oil content as shown in Figure (2) . The lowest value of treatment (T1P1) was 7.01 and the highest value of treatment (T3P2) was 7.98. The findings are shown below and indicate the soil is moderately acidic to slightly alkaline. Also, there were substantial variations in the average P and T values .

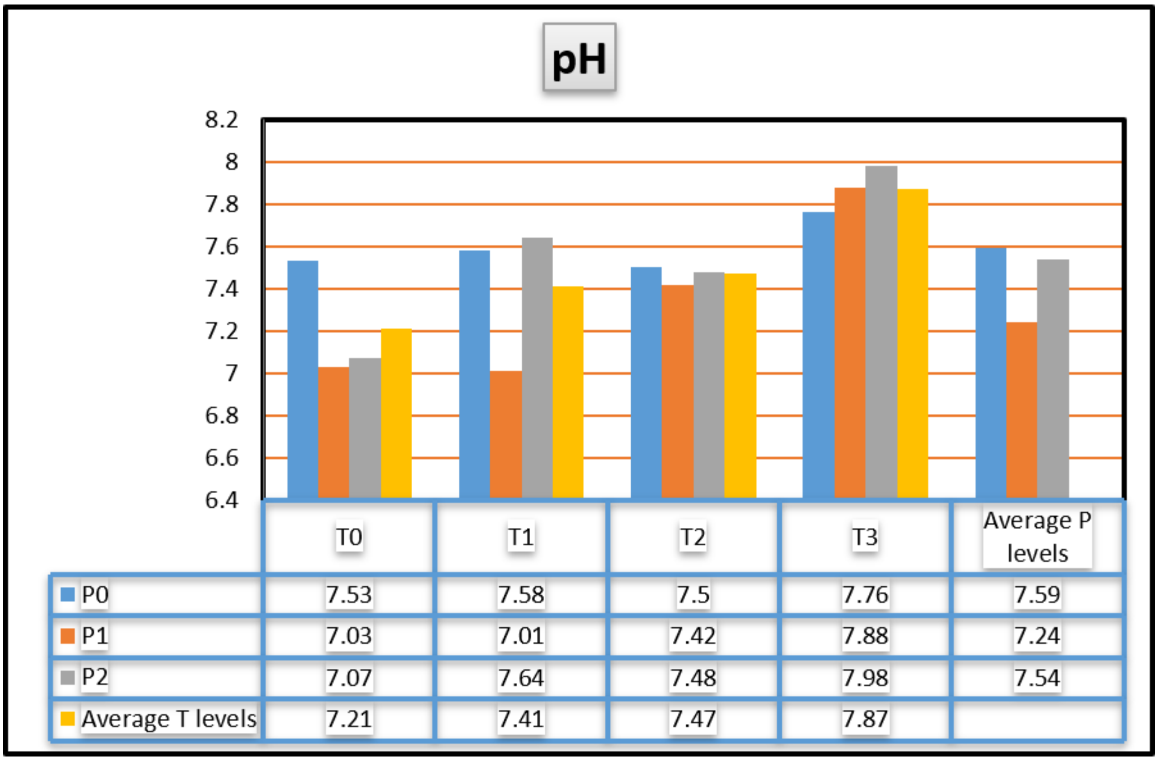


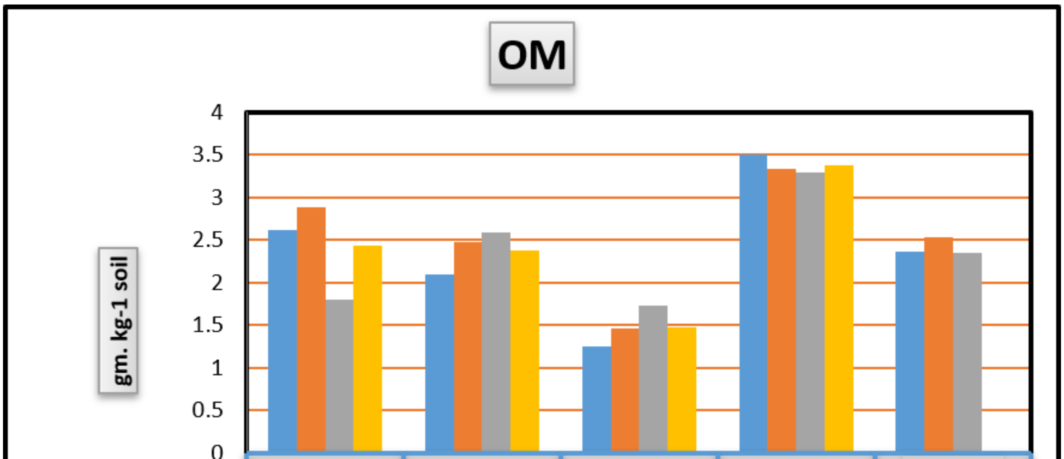
Figure 2 pH values

2.3. Soil Organic Matter (OM)

Findings in Figure (3) show that treatment (T2P0) had the least amount of organic matter (1.25 g/kg^{-2} soil), while treatment (T3P0) had the most at (3.50 g/kg^{-3} soil). All of the control factors came back in the low range because oil remains in the soil made it less porous, made it harder for air to flow through, and decreased the amount of nitrogen that was available. The results showed that the average P levels and average T levels were very different.

As the amount of organic matter in the earth grows, it becomes better at absorbing heavy metals. To put it another way, there is a link between the amount of organic matter in the soil and the heavy metals that can be absorbed.

The year 2023: Li and others

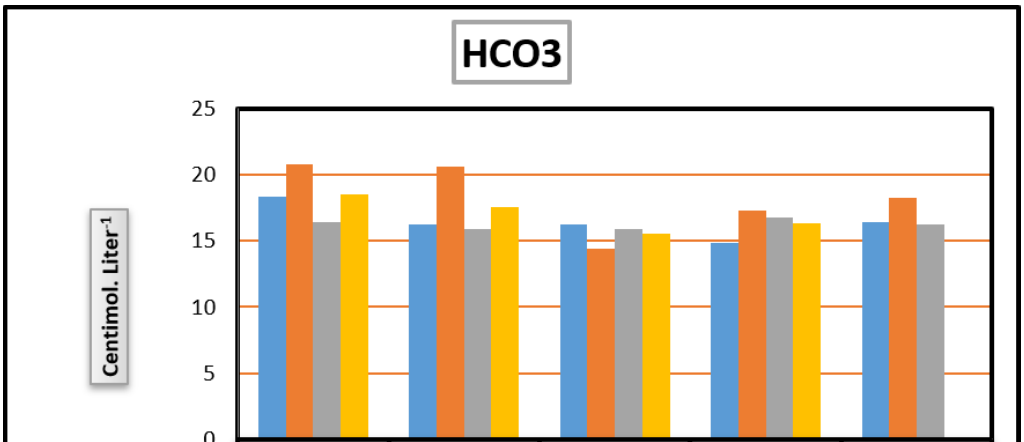


	T0	T1	T2	T3	Average P levels
P0	2.62	2.09	1.25	3.5	2.36
P1	2.88	2.48	1.46	3.33	2.53
P2	1.8	2.59	1.72	3.29	2.35
Average T levels	2.43	2.38	1.47	3.37	

Figure 3 Levels of organic matter (OM) in soil

2.4. Amount of dissolved negative ions (HCO3)

Figure 4 illustrates the effects of adding varying quantities of oil waste to the soil on the quantity of dissolved negative ions. At 20.81 cmol L-1, the treatment known as T0P1 contained the highest amount of dissolved bicarbonate. Treatment T2P1 had the lowest quantity (14.43 cmol L^{-1}). This might be because the addition of oil waste to the soil may have fixed the existing ions and transformed them into forms that are difficult for plants to use [17].

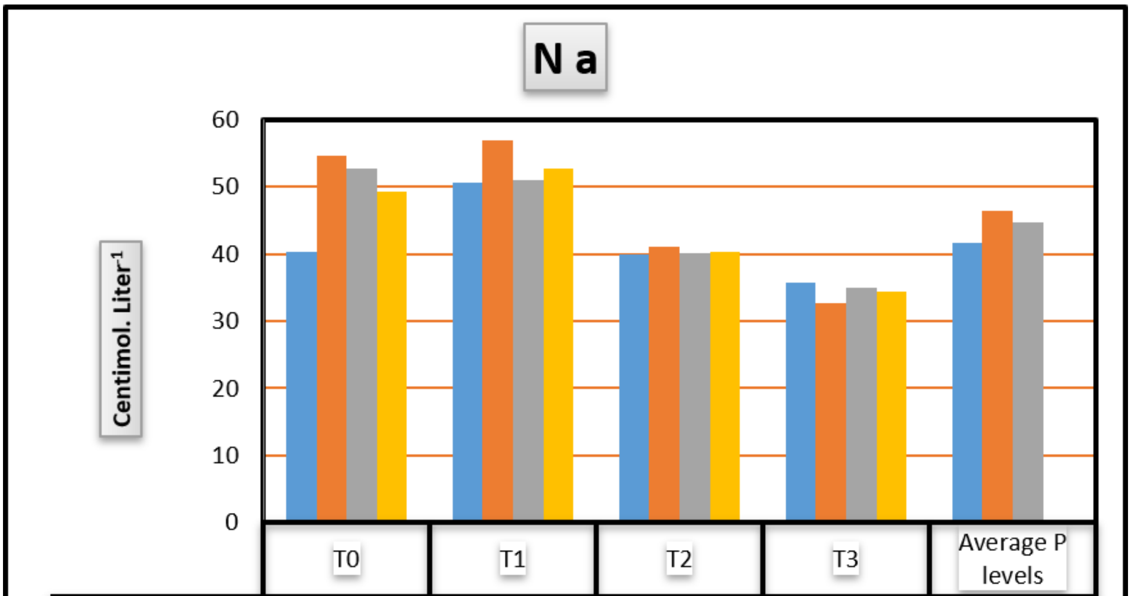


	T0	T1	T2	T3	Average P levels
P0	18.32	16.25	16.2	14.82	16.39
P1	20.81	20.59	14.43	17.32	18.28
P2	16.45	15.88	15.89	16.78	16.25
Average T levels	18.52	17.54	15.5	16.3	

Figure 4 Values of (HCO3).

2.5. The amount of positive ions (Na) that are dissolved.

The results in Figure 5 show that there is more salt in the land right now. The treatment (T1P1) had the most sodium (56.85 cmol L^{-2}), while the treatment (T3P1) had the least, at 32.75 cmol L^{-2}. The results were also very different based on the mean P and mean T levels.



	T0	T1	T2	T3	Average P levels
P0	40.25	50.61	39.82	35.67	41.58
P1	54.65	56.85	41.04	32.75	46.32
P2	52.72	50.9	40.09	34.96	44.66
Average T levels	49.2	52.78	40.32	34.46	

Figure 5 Values of dissolved positive ions (Na)

2.6. What OIL Residues Do to Plant Height

Figure (6) shows significant differences in plant height. The highest height was recorded in treatment (T1P0) at (91.55) cm, while the lowest height was recorded in treatment (T3P0) at (71.66) cm. The results indicate significant differences between the average P levels and the average T levels.

This is attributed to the varying proportions of oil residues in the soil, which reduced the availability of nutrients and water to the plant with increasing application levels. This negatively impacted the average plant height [18].

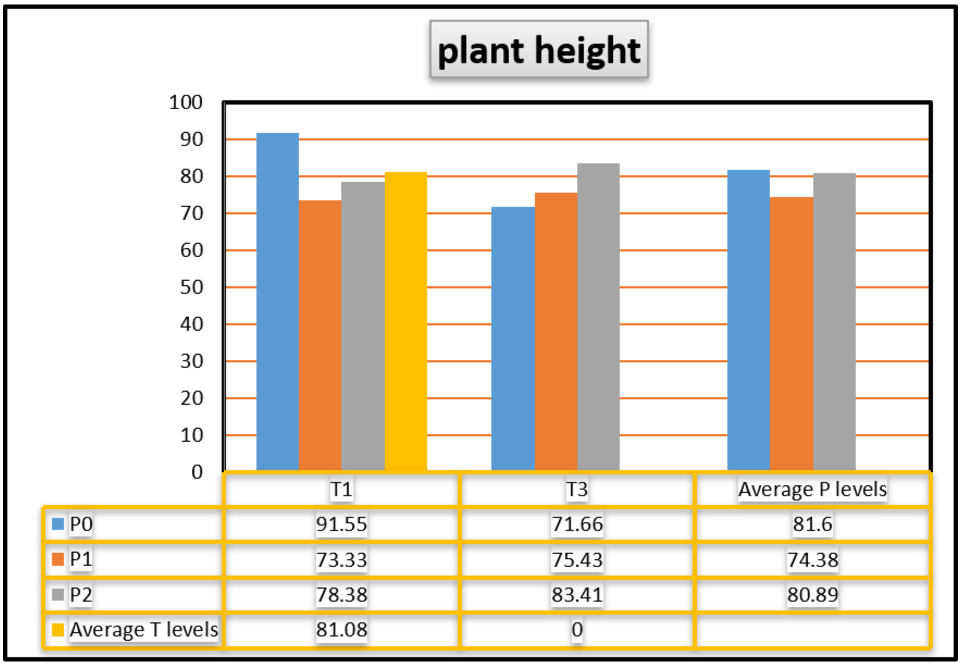


Figure 6 Plant Height

2.7. Dry Weight of the Vegetative Body

The findings shown in Figure (7) demonstrated that the vegetable body dry weight decreased with increasing the amount of oil residues. It was just 25 grams therefore the lightest of all of the treatments. Reduced water uptake from the oiled layers or the layers below might result in decreased dry matter yields for plants growing in oil-contaminated soils [19;20].

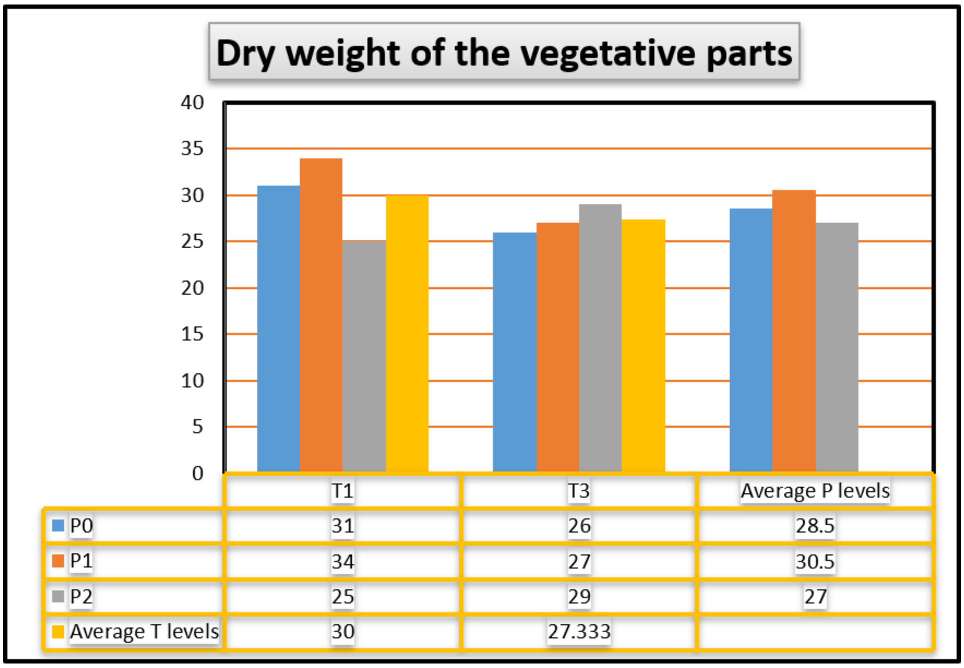


Figure 7 Dry weight of the vegetative parts

3. Conclusion

In this study, the synergistic effect of the use of both *A. niger* and *Zea mays* in combination on the phytoremediation of soil contaminated with oil residues was observed, as reflected by the improvement of the soil physico-chemical characteristics and plant growth parameters of the different treatments. The results do support the idea that fungal activity in concert with the plant root systems can be more effective in reducing the concentration of hydrocarbons and enhancing soil quality than can either the fungal activity or the plant root systems alone. In conclusion, this bioremediation strategy is an environment-friendly and economical solution that can be used to restore contaminated soil, and it has the potential to benefit society through environmental health and agricultural productivity enhancement; future studies should seek to scale up the use of this method and optimize it for various field conditions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Mohanta, S., Pradhan, B., & Behera, I. D. (2024). Impact and remediation of petroleum hydrocarbon pollutants on agricultural land: a review. Geomicrobiology Journal, 41(4), 345-359.

[2] Sakshi, Singh, S. K., & Haritash, A. K. (2019). Polycyclic aromatic hydrocarbons: soil pollution and remediation. International Journal of Environmental Science and Technology, 16(10), 6489-6512.

[3] Elijah, A. A. (2022). A review of the petroleum hydrocarbons contamination of soil, water and air and the available remediation techniques, taking into consideration the sustainable development goals. Earthline Journal of Chemical Sciences, 7(1), 97-113.

[4] Wojtowicz, K., Steliga, T., Kapusta, P., & Brzeszcz, J. (2023). Oil-contaminated soil remediation with biodegradation by autochthonous microorganisms and phytoremediation by maize (*Zea mays*). Molecules, 28(16), 6104.

[5] Humada, Y. H., Abdullah, R. M., & Hussein, F. K. (2024). Study of heritability estimates and their genetic variability for yield traits and its components in yellow maize (*Zea mays L.*). Magna Scientia Advanced Research and Reviews, 12(02), 224-234.

[6] Sharma, J. K., Kumar, N., Singh, N. P., & Santal, A. R. (2023). Phytoremediation technologies and their mechanism for removal of heavy metal from contaminated soil: An approach for a sustainable environment. Frontiers in plant science, 14, 1076876.

[7] Nugent, A. (2023). Impacts of Urbanization and Drought on Soil Microbial Communities (Doctoral dissertation, University of California, Irvine).

[8] Tomer, A., Singh, R., Singh, S. K., Dwivedi, S. A., Reddy, C. U., Keloth, M. R. A., & Rachel, R. (2021). Role of fungi in bioremediation and environmental sustainability. In Mycoremediation and environmental sustainability: Volume 3 (pp. 187-200). Cham: Springer International Publishing.

[9] Vaksmaa, A., Guerrero-Cruz, S., Ghosh, P., Zeghal, E., Hernando-Morales, V., & Niemann, H. (2023). Role of fungi in bioremediation of emerging pollutants. Frontiers in Marine Science, 10, 1070905.

[10] Miller, W. P., & Miller, D. M. (1987). A micro-pipette method for soil mechanical analysis. Communications in soil science and plant analysis, 18(1), 1-15.

[11] Page, A.L.; R.H. Miller, and D. R. Keeney (1982). Methods of soil analysis. Part (2). 2nd ed. Madison, Wisconson, USA. PP:1159.

[12] Tagami, K., & Uchida, S. (2025). Fundamental study on measurement of soil pH and electrical conductivity in batch tests for the determination of soil-soil solution distribution coefficient. Nuclear Engineering and Technology, 57(3), 103269.

[13] Joly, M., Marlet, M., Barreau, D., Jourdan, A., Durieu, C., Launay, J., & Temple-Boyer, P. (2024). Monitoring of ammonium and nitrate ions in soil using ion-sensitive potentiometric microsensors. Sensors (Basel, Switzerland), 24(22), 7143

[14] Goutx, M., & Saliot, A. (1980). Relationship between dissolved and particulate fatty acids and hydrocarbons, chlorophyll a and zooplankton biomass in Villefranche Bay, Mediterranean Sea. Marine Chemistry, 8 (4), 299-318.

[15] Al-Rawi, Khash'a Mahmoud and Abdulaziz Mohammed Khalaf (2000), Design and Analysis of Agricultural Experiments, Dar Al-Kutub Foundation for Printing and Publishing, College of Agriculture, University of Mosul, Ministry of Higher Education and Scientific Research – Republic of Iraq.

[16] Alzamel, N. M., Taha, E. M., Bakr, A. A., & Loutfy, N. (2022). Effect of organic and inorganic fertilizers on soil properties, growth yield, and physiochemical properties of sunflower seeds and oils. Sustainability, 14(19), 12928.

[17] Konur, O. (2021). Bioremediation of Petroleum Hydrocarbons in Contaminated Soils: A Review of the Research. Petrodiesel Fuels, 995-1013.

[18] Odiyi, B. O., Giwa, G. O., Abiya, S. E., & Babatunde, O. S. (2020). Effects of Crude Oil Pollution on the Morphology, Growth and Heavy Metal Content of Maize (*Zea mays Linn*.). Journal of Applied Sciences & Environmental Management, 24(1).

[19] Humada, Y. H., Abdullah, R. M., & Hussein, F. K. (2025). Genetic Relationship Analysis to Evaluate the Performance of Several Pure Strains and their Individual Hybrids between the RAPD-PCR Indicators in the Yield Traits of Yellow Corn (*Zea mays L*.). Jordan Journal of Biological Sciences, 18(1).

[20] Li, Q., Wang, L., Fu, Y., Lin, D., Hou, M., Li, X., ... & Wang, Z. (2023). Transformation of soil organic matter subjected to environmental disturbance and preservation of organic matter bound to soil minerals: a review. Journal of Soils and Sediments, 23(3), 1485-1500.