The Effect of Corn and White Clover Intercropping on Biodegradation of Diesel Oil in Arsenic Contaminated Soil in the Presence of *Piriformospora indica*

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**ABSTRACT**

**Background:** This research was done to evaluate the effect of corn and white clover intercropping on bio-degradation of diesel oil in arsenic (As) contaminated soil in the presence of *Piriformospora indica* (P.indica).  
**Methods:** Treatments included corn planting with three plant density of white clover (0, 20 and 30 seeds per pots) as an intercropping system, As polluted soil (0, 12 and 24 mg/kg soil) and diesel oil (0, 4 and 8 % (W/W) in the presence and absence of P.indica). After 10 weeks, plants were harvested and the soil and plant as concentration was measured using atomic absorption spectroscopy. In addition, the soil microbial activity and the percentage of diesel oil degradation were measured.  
**Results:** The results of this study showed that cultivation of corn in intercropping system with white clover (1:20 seeds corn to white clover) relative to monoculture significantly (P < 0.05) increased the diesel oil degradation in soil by 14.6%. In addition, the soil microbial activity was increased by 13.4%. Plant inoculation with P.indica had additive effect on degradation of diesel oil in the soil.  
**Conclusion:** Plant inoculation and intercropping system can effect on increasing the percentage of diesel oil degradation in As contaminated soil that is an important role in environmental studies.

1. Introduction

Petroleum hydrocarbons are combination of chemical mixtures that are all composed of carbon and hydrogen, so they are called hydrocarbons. These are chemically low soluble or even insoluble in water. Besides carbon and hydrogen which are required to form these compounds, nitrogen and sulfur may also exist in these compounds structures. If these types of petroleum hydrocarbons are added to the environment, by their reaction with molecular oxygen, sulfur or nitrogen oxides and carbon monoxide are produced and enter the atmosphere, thereby polluting atmospheric [1-3].  
Polycyclic aromatic hydrocarbons (PAHs) compositions are composed by imperfect combustion of coal, oil, and gasoline and are utilized variously. For instance naphthalene is used in the production of insecticides, the dyeing industry, explosives, plastics, lubricants; anthracene is utilized in the production of insecticides, the dyeing industry and wood preservatives. Human can be affected differently from petroleum hydrocarbon contamination. some examples of getting contaminated to these oil derivatives at work or home, pesticides, drinking water pesticides, drinking water contaminated with total
petroleum hydrocarbons (TPHs), working, at refineries in which oil is extracted or refined, residing in the areas nearby sites of oil extraction or refining, contact with TPHs contaminated soils as well as utilizing plants contaminated with these compounds or animals feeding on these plants. Likewise, different compounds of petroleum hydrocarbons can influence the human nervous system [4-6].

In many cases soils are contaminated with heavy metals, and contamination of petroleum hydrocarbons with heavy metals can endanger soil quality. Hence, we should seek significant strategies for reducing soil contamination with these compounds. Due to the growing costs and the relatively limited efficiency of regular chemical and physical approaches for remediation of contaminated soils, researchers make attempts to find new methods of soil remediation [7-10]. Thus, there is a need for an economy, sustainable and environmentally friendly way. One of the means embraced tremendously nowadays is phytoremediation. This technique is quite suitable for filtration of large areas of contamination as well as various pollutants in shallow sites, contaminated soils and water surface and subsurface. Actually, this is an innovative and modern approach in which plants play a key role in refining soil, sediments, and surface and groundwater contaminated with heavy metals, organic compounds, and radioactive materials [11-13].

Phytoremediation is presented as an environmentally-friendly way, with negligible, yet inexpensive, side effects on soil refining that is much more economical compared to conventional physical and chemical means to eliminate or reduce the concentration of hazardous pollutants from the soil [14-16]. However, decreasing plant biomass due to heavy metal toxicity can diminish the phytoremediation efficiency [17,18]. Accordingly, using intercropping system or plant inoculation with Piriformospora indica (P.indica) may affect the phytoremediation efficiency [19-21]. Though, they did not consider the simultaneous effect of heavy metal with petroleum hydrocarbons on plant phytoremediation efficiency. Thus, this research was conducted to evaluate the effect of corn and white clover intercropping on biodegradation of diesel oil in a arsenic (As) contaminated soil in the presence of P.indica.

2. Materials and Methods

Treatments included corn (Z. mays L.Cv. 704) planting (corn as a main crop and white clover as an intercrop) with three plant density of white clover (0, 20 and 30 seeds per pots) as an intercropping system and the simultaneous pollution of soil that was As (at the rates of 0, 12 and 24 mg/kg soil) and diesel oil (0, 4 and 8 % (W/W) in the presence and absence of P.indica. This research was done as a factorial experiment in the layout of randomized completely block design with three replications. Selected some physic-chemical properties are shown in Table 1.

### 2.1. Soil Preparation and Plant Cultivation

To do this experiment, the soil was polluted with As at the mentioned rates and incubated for two weeks to equilibrium. After that, The As polluted soil was polluted with diesel oil (at the rates of 0.4 and 8% W/W) and incubated for two weeks to equilibrium.

Three days after seed germination on filter paper, the corn seedlings (as a main crop) and white clover (as an intercrop) were transferred into 5 kg plastic pots (two seedlings in each pot) as a monoculture and intercropping system and filled with the treated soil. Two fungal plugs of 10 mm in diameter were placed at a distance of 1 cm below the corn and white clover seedlings in the soil at sowing time. P. indica was obtained from the soil biology of water and soil research institute. P. indica was cultured in Petri dishes on a modified Kafer medium. During the plant growth, soil moisture was maintained at the field capacity (FC). After 10 weeks of plant growth, plant roots and stems were harvested, washed with tap water, rinsed with deionized water and oven-dried at 55°C for 72h. After that, the samples were digested with HCl 2 N and the As concentration in extracted solution was measured using atomic absorption spectroscopy (AAS) (PerkinElmer 3030; PerkinElmer, Wellesley, MA, USA) [22].

### 2.2. Chemical Analysis

The soil microbial respiration was measured according to the Besalatpour et al. (2011) method [23]. Accordingly, soil samples of different treatment were incubated for one week at 25°C in 250-ml glass containers closed with rubber stoppers. The CO2 produced was trapped in NaOH solution and the excess in alkali was then titrated with HCl.

In addition, the total concentration of soil hydrocarbon (TPHS) were determined using the GC-MS with a Delsi DI 200 chromatograph equipped with a direct injection port and an FID detector at 340°C according to the Besalatpour et al. (2011) [23]. The carrier gas was helium under 0.08 MPa and the column was a CP Sil 5 CB (Chrompack) capillary column (50 m by 0.32 mm, film thickness 0.25 μm).

### 2.3. Statistical Analysis

A completely block randomized design in three replications was used. The statistical analyses of data were performed using the ANOVA procedure by SAS V. 9.1 software. Differences between means were evaluated using the least significant difference (Duncan test). The 0.05 probability value was used to determine the significant difference.

### 3. Results and Discussion

The greatest soil As concentration belonged to the soil under cultivation of corn and white clover intercropping

| Table 1: Selected Physicochemical Properties of Soil |
|-----------------------------------------------|
| Characteristic | Unit | Amount |
|----------------|------|--------|
| Soil texture   |      | Silt loam |
| pH             |      | 7.1    |
| EC             | ds/m | 1.2    |
| Pb available   | mg kg⁻¹ | ND* |
| Cd available   | mg kg⁻¹ | ND   |
| As available   | mg kg⁻¹ | ND    |
| Organic carbon | %    | 0.2    |
| CaCO₂         | %    | 5      |

*ND: Not detectable by atomic absorption spectroscopy (AAS)
(1:30 corn to white clover) that was polluted with the greatest level of diesel oil, while the lowest that was observed in the soil under corn monoculture system that was polluted with 12 mg As/kg soil and 4% (W/W) diesel oil (Table 2).

Increasing soil pollution to diesel oil from 0 to 4% (W/W), increased the soil As concentration by 11.3% (Table 2). The results of the study of Mehrabadi et al. (2014) about the increasing soil and plant heavy metal concentration with increasing soil pollution to petroleum hydrocarbons confirm our results clearly [24]. In this regards, Askary et al. (2012) showed that simultaneous pollution of soils to heavy metals and petroleum pollutants had additive effect on increasing soil heavy metals availability [25].

In addition, intercropping system and its population density had significant effect on increasing soil As concentration. Accordingly, increasing white clover population density from 1:20 to 1:30 in intercropping system significantly (P < 0.05) increased the soil As concentration by 13.4%. Baghaie et al. (2018) investigated the heavy metal phytoremediation of corn and white clover cultivation in monoculture and intercropping system and concluded that intercropping system has positive effect on increasing Pb phytoremediation efficiency [26]. However, they did not consider the role of other soil pollutant such as petroleum hydrocarbons on the changes of heavy metals availability. Liu et al. (2013) investigated the heavy metal concentration in maize monoculture and intercropping with different legume species and reported that legumes caused a greater effect on heavy metal concentration in maize and peanut was a potential intercrop for enhancing heavy metal extraction from soil, that is similar to our results. Generally, Intercropping of maize with legumes is an alternative to maize monoculture and has a number of advantages compared to monoculture systems [27]. Li et al. (2010) studied the metal mobilization and production of short-chain organic acids by rhizosphere bacteria associated with a Cd/Zn hyper-acculumating plant and concluded that plant root exudate due to intercropping system had significant effect on increasing soil heavy metal availability [28].

In addition, corn inoculation with P. indica in monoculture and intercropping system had significantly (P < 0.05) increased the soil As concentration.

The results of this study showed that corn inoculation with P. indica in monoculture and intercropping system significantly (P < 0.05) increased the soil As concentration in the soil that was polluted with 4% (W/W) diesel oil by 9.7% and 13.1%, respectively. Increasing soil As concentration may be related to the role of P. indica fungus on increasing plant root exudate that help to increase soil heavy metal solubility Gill et al. (2016) investigated the role of P. indica on plant resistance to abiotic stress and concluded that plant inoculation with P. indica can decrease the negative effect of soil pollution and thereby increase the plant biomass. Accordingly increasing plant biomass may increase the plant root exudate that increases the solubility of soil As [29]. On the other hand, Wu et al. (2018) reported that P. indica could enhance phosphorous sorption by plants, thereby increasing the plant biomass by incrementing the acid phosphatase activities and organic acids in the plants, which was in turn associated with the higher plant resistance to abiotic stresses [30].

The greatest corn As concentration has belonged to the inoculated plants with P. indica that cultivated in the soil polluted with 24 mg As/kg soil and 8% (W/W) diesel oil (Table 3), while the lowest that was measured in the plants grown in the As-polluted soil (12 mg As/kg soil) without any pollution with diesel oil. Increasing soil pollution to As significantly (P < 0.05) increased the plant As concentration in corn and white clover intercropping system that could be related to the increasing of soil As solubility. Increasing soil As solubility and thereby increase plant As concentration was reported by researchers. Mottaghi et al. (2015) reported that intercropping system is a useful method for heavy metal phytoremediation from contamination Soils [31]. Mansouri et al. (2017) investigated the effect of soil pollution to As on phosphorus, iron, zinc and manganese concentrations in soil and corn plant and concluded that increasing soil pollution to As significantly (P < 0.05) increased and decreased the As and nutrient elements, respectively [32]. However, they did not consider the role of other pollutant such as petroleum hydrocarbons on the changes heavy metal availability. The white clover As concentration showed the similar results (Table 4).

The presence of P. indica had significant (P < 0.05) effect on increasing corn and white clover As concentration. Based on the results of this study, the greatest plant As concentration was belonged to the inoculated plants with P. indica.

### Table 2: Effects of corn and white clover intercropping, heavy metal and diesel oil on soil As concentration (mg/kg soil) in the presence and absence of P. indica

| Corn to white clover ratio | Diesel oil (% W/W) | Soil As concentration (mg/kg soil) |
|----------------------------|-------------------|-----------------------------------|
|                            | P. indica(+)      | P. indica(-)                      |
|                            | 0                 | 12                                | 24 | 0      | 12 | 24 |
| 1:0                        | 0                 | ND**                             | 10.02v* | 21.12n | ND | 10.12u | 21.51k |
|                            | 4                 | ND                               | 10.11u | 21.34m | ND | 10.26g | 21.72i |
|                            | 8                 | ND                               | 10.24l | 21.49l | ND | 10.38s | 21.85h |
| 1:20                       | 0                 | ND                               | 10.18u | 21.39j | ND | 10.37s | 22.01f |
|                            | 4                 | ND                               | 10.34y | 21.53k | ND | 10.54c | 22.18e |
|                            | 8                 | ND                               | 10.57r | 21.78i | ND | 10.62n | 22.44c |
| 1:30                       | 0                 | ND                               | 10.39s | 21.65j | ND | 10.53r | 22.31d |
|                            | 4                 | ND                               | 10.51r | 21.78i | ND | 10.87p | 22.56b |
|                            | 8                 | ND                               | 10.84p | 21.99g | ND | 11.73o | 22.78a |

*Data with the similar letters are not significant (P > 0.05), **ND: Not detectable by AAS*
Generally, inoculated plant with *P. indica* can enhance the plant biomass (Table 5) and plant resistance to abiotic stresses such as heavy metals or petroleum hydrocarbons. Increasing plant biomass can stimulate the soil microorganism activities that can increase soil heavy metals availability. However, the role on plant root exudate on low organic acid secretion and consequently decreasing soil pH cannot be ignored. Increasing soil heavy metal availability with redesigning soil pH is reported by researchers. On the other hand, applying white clover as an intercrop in corn cultivation had a significant effect on increasing plant phytoremediation efficiency. Nascimento et al. (2006) mentioned that low organic acids can affect on desorption of heavy metals from contamination soils and thereby increase heavy metal solubility. However, they concluded that increasing heavy metal solubility depends on the heavy metal type, as, the results of their studies showed that soil as solubility was not affected by low organic acids [34]. It is noteworthy that these researchers did not consider the simultaneous effect of soil contamination with heavy metals and petroleum hydrocarbons [34].

The greatest percentage of diesel oil degradation was observed in the soil with the highest level of diesel oil that was not polluted with As and under cultivation of corn and white clover intercropping system, while the lowest that was measured in the soil with the greatest and lowest level of As and diesel oil concentration, respectively (Table 6).

Increasing soil pollution with As significantly (*P*<0.05) decreased the degradation of diesel oil in soil. Based on the results of this study, with increasing soil pollution with As from 0 to 12 mg As/kg soil, the degradation of diesel oil in soil was decreased by 13.9%. Xie *et al.* (2016) investigated the effect of heavy metals pollution on soil microbial diversity and plant genetic variation and reported that heavy metal pollution is a serious global environmental problem that alter the population of soil microbial activity [35]. Accordingly, decreasing soil microbial activity (Table 7) has negative effect on degradation of diesel oil in soil.

According to the results of some studies, petroleum hydrocarbons at low concentration can be introduces as a carbon sources for increasing soil microbial activities that can help to degrade the petroleum hydrocarbons.

Al-Hawash studied the microbial degradation of petroleum hydrocarbons in the environment and reported that petroleum hydrocarbons can be used as a carbon source for increasing soil microbial activates [36]. In this regard, Besalutpour *et al.* (2011) reported the similar results. Based on the results of their study petroleum hydrocarbon at the low concentration can be used as a carbon source for soil microbial activities [23].

The result of our study showed that increasing in heavy metal concentration has prevented the using of petroleum hydrocarbons as a carbon source by soil microorganisms and reduced the percentage of petroleum hydrocarbon degradation in soil. For instance, with increasing soil pollution with diesel oil from 0 to 4 and 8 % (W/W) the

### Table 3: Effects of corn and white clover intercropping, heavy metal and diesel oil on corn As concentration (mg/kg) in the presence and absence of *P. indica*

| Corn to white clover ratio | Diesel oil (% W/W) | Soil As concentration (mg/kg soil) | *P indica* (+) | *P indica* (-) |
|---------------------------|-------------------|-----------------------------------|---------------|---------------|
|                           |                   | 0       | 12     | 24           | 0       | 12     | 24           |
| 1:0                       | 0                 | ND**    | 9.51w  | 21.56k       | ND     | 9.77u  | 22.05h       |
|                           | 4                 | ND      | 9.65v  | 21.72j       | ND     | 9.86t  | 22.11g       |
|                           | 8                 | ND      | 9.78u  | 21.97l       | ND     | 9.93s  | 22.55c       |
| 1:20                      | 0                 | ND      | 9.78u  | 22.00h       | ND     | 10.04t | 22.11g       |
|                           | 4                 | ND      | 9.82r  | 22.19g       | ND     | 10.21p | 22.24f       |
|                           | 8                 | ND      | 10.34  | 22.55c       | ND     | 10.65m | 22.78b       |
| 1:30                      | 0                 | ND      | 10.11q | 22.11g       | ND     | 10.35o | 22.39e       |
|                           | 4                 | ND      | 10.36o | 22.32e       | ND     | 10.44n | 22.41d       |
|                           | 8                 | ND      | 10.67m | 22.73b       | ND     | 10.81l | 23.89a       |

*Data with the similar letters are not significant (P > 0.05). **ND: Not detectable by AAS.*

### Table 4: Effects of corn and white clover intercropping, heavy metal and diesel oil on white clover As concentration (mg/kg) in the presence and absence of *P. indica*

| Corn to white clover ratio | Diesel oil (% W/W) | Soil As concentration (mg/kg soil) | *P indica* (+) | *P indica* (-) |
|---------------------------|-------------------|-----------------------------------|---------------|---------------|
|                           |                   | 0       | 12     | 24           | 0       | 12     | 24           |
| 1:0                       | 0                 | ND**    | 8.74v  | 16.82m       | ND     | 9.12v  | 17.31j       |
|                           | 4                 | ND      | 8.81x  | 16.95l       | ND     | 9.55s  | 17.56i       |
|                           | 8                 | ND      | 9.08w  | 17.13k       | ND     | 9.71t  | 17.87h       |
| 1:20                      | 0                 | ND      | 9.01w  | 17.18k       | ND     | 9.78t  | 19.11v       |
|                           | 4                 | ND      | 9.23u  | 17.37j       | ND     | 9.87q  | 19.46e       |
|                           | 8                 | ND      | 9.38t  | 17.59i       | ND     | 10.36o | 19.83d       |
| 1:30                      | 0                 | ND      | 31     | 17.38j       | ND     | 10.12p | 20.15c       |
|                           | 4                 | ND      | 9.34t  | 17.81h       | ND     | 10.32o | 20.74b       |
|                           | 8                 | ND      | 9.50s  | 18.28g       | ND     | 10.65n | 21.31a       |

*Data with the similar letters are not significant (P > 0.05). **ND: Not detectable by AAS.*
Table 5: Effects of corn and white clover intercropping, heavy metal and diesel oil on corn plant biomass (g) in the presence and absence of *P. indrica*

| Corn to white clover ratio | Diesel oil (% W/W) | Soil As concentration (mg/kg soil) |
|----------------------------|-------------------|------------------------------------|
|                            |                  | *P. indrica (+)*                    | *P. indrica (-)*                     |
|                            |                  | 0  | 12  | 24  | 0  | 12  | 24  |
| 1:0                        | 0                | 4.85e | 4.77h | 4.69l | 4.81g | 4.70k | 4.65m |
|                            | 4                | 4.76f | 4.70k | 4.64m | 4.73j | 4.64m | 4.600 |
|                            | 8                | 4.70k | 4.63n | 4.58p | 4.69f | 4.60o | 4.56q |
| 1:20                       | 0                | 4.92c | 4.84f | 4.80g | 4.87d | 4.80g | 4.74i |
|                            | 4                | 4.88d | 4.80 | 4.75h | 4.81g | 4.73j | 4.70k |
|                            | 8                | 4.84f | 4.75h | 4.72j | 4.77f | 4.70k | 4.65m |
| 1:30                       | 0                | 4.98a | 4.89d | 4.85e | 4.92c | 4.86e | 4.80g |
|                            | 4                | 4.95b | 4.85e | 4.84f | 4.87d | 4.80g | 4.73i |
|                            | 8                | 4.91c | 4.80g | 4.75h | 4.81g | 4.75h | 4.70k |

*Data with the similar letters are not significant (P > 0.05)*

diesel oil degradation in non Pb-soil increased by 14.3 and 18.6%, respectively. However, with increasing soil As pollution from 0 to 12 and 24 mg As/kg soil, the degradation of diesel oil in soil decreased by 9.3 and 13.3%, respectively.

Plant inoculation with *P. indrica* significantly (*P < 0.05*) increased the degradation rate of diesel oil in soil, as, the greatest soil degradation rate of diesel oil in soil was observed in the soil under cultivation of corn inoculated with *P. indrica* in intercropping system.

The results of this research showed that plant inoculation with *P. indrica* can diminish the negative effect of soil pollution with As on degradation of diesel oil in soil, as, corn inoculation with *P. indrica* significantly increased the degradation percentage of diesel oil in As-polluted soil (24 mg As/kg soil) by 13.3%. This increasing rate can be related to the role of *P. indrica* on increasing plant resistance to abiotic stresses and thereby increase the soil microbial activity that help to degradation of diesel oil in soil. Increasing in corn biomass via decreasing AS- bio-transfer and increasing microbial activity in the soil under cultivation of plant inoculated with *P. indrica* in monoculture and intercropping system confirm our results clearly. Mohd et al. (2017) reported that *P. indrica* mediated protection of host from arsenic toxicity [37]. In addition, they suggested that *P. indica* protects the plants from As toxicity (that is similar to our results) via three mechanisms: by decreasing the As concentration in the plant, bio-transformation of the toxic arsenic salts into insoluble particulate matter and modulating the antioxidative system of the host cell [37].

Table 6: Effects of corn and white clover intercropping, heavy metal and diesel oil on the percentage of diesel oil degradation in soil in the presence and absence of *P. indrica*

| Corn to white clover ratio | Diesel oil (% W/W) | Soil As concentration (mg/kg soil) |
|----------------------------|-------------------|------------------------------------|
|                            |                  | *P. indrica (+)*                    | *P. indrica (-)*                     |
|                            |                  | 0  | 12  | 24  | 0  | 12  | 24  |
| 1:0                        | 0                | NC* | NC  | NC  | NC  | NC  | NC  |
|                            | 4                | 52.3f | 50.5p | 45.6r | 45.8r | 44.1s | 40.5t |
|                            | 8                | 70.2f | 67.5h | 64.3j | 66.5i | 64.2j | 62.1k |
| 1:20                       | 0                | NC  | NC  | NC  | NC  | NC  | NC  |
|                            | 4                | 54.6m | 52.5n | 51.30 | 50.2p | 48.3q | 45.5r |
|                            | 8                | 73.5c | 72.7d | 71.7e | 70.2f | 68.4q | 67.5h |
| 1:30                       | 0                | NC  | NC  | NC  | NC  | NC  | NC  |
|                            | 4                | 55.8l | 54.3m | 51.9o | 54.2m | 52.7n | 51.6o |
|                            | 8                | 75.8a | 74.3b | 72.6d | 74.6b | 73.1c | 70.9f |

*Data with the similar letters are not significant (P > 0.05), **NC: Not calculated*

Table 7: Effects of corn and white clover intercropping, heavy metal and diesel oil on soil microorganism activity (mg-C-Co/kg soil) in the presence and absence of *P. indrica*

| Corn to white clover ratio | Diesel oil (% W/W) | Soil As concentration (mg/kg soil) |
|----------------------------|-------------------|------------------------------------|
|                            |                  | *P. indrica (+)*                    | *P. indrica (-)*                     |
|                            |                  | 0  | 12  | 24  | 0  | 12  | 24  |
| 1:0                        | 0                | 9.27w* | 9.00y | 8.78z | 9.03y | 8.71z | 8.47z |
|                            | 4                | 11.39p | 11.21q | 11.00s | 11.29q | 11.16r | 11.00s |
|                            | 8                | 14.41f | 14.23g | 14.01l | 14.15h | 14.00s | 13.82j |
| 1:20                       | 0                | 9.47u | 9.28w | 9.11x | 9.34v | 9.19x | 9.00y |
|                            | 4                | 11.78m | 11.56n | 11.44o | 11.55n | 11.32p | 11.11r |
|                            | 8                | 14.71b | 14.52d | 14.27g | 14.55d | 14.32f | 14.12h |
| 1:30                       | 0                | 9.53f | 9.43u | 9.22w | 9.48u | 9.29w | 9.11x |
|                            | 4                | 12.12k | 12.00l | 11.73m | 11.78m | 11.54n | 11.32p |
|                            | 8                | 14.84a | 14.75b | 14.62c | 14.85c | 14.55d | 14.42e |

*Data with the similar letters are not significant (P > 0.05)*
4. Conclusion

The results of this study showed that corn and white clover intercropping system had significant effect ($P<0.05$) on increasing the percentage of diesel oil degradation in soil. Accordingly, the presence of *Pindica* had significantly ($P<0.05$) on degradation of diesel oil in the soil. In addition, inoculation of corn with *Pindica* significantly ($P < 0.05$) increased the plant As concentration and plant biomass, respectively. Increasing the plant density of white clover as an intercrop significantly ($P < 0.05$) increased the As phytoaccumulation efficiency. However, soil physico-chemical condition can affect on the changes in heavy metal availability that is necessary to be considered in the future studies. Given that there is a problem of contamination of heavy metals and petroleum hydrocarbons in industrial areas of the country, it is necessary to study the simultaneous effect of other heavy metals and petroleum. In addition, it is necessary to consider the crop management in the polluted area.

Authors’ Contributions

A.H.B., and A. G.J. designed the manuscript and have role in performing the experiment, data collection and data analysis; R.S., has help in biological processes of the experiment, all the authors read and approved the final manuscript.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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