Current Topics in
Plant Biology
Vol. 13, 2012

Original Communication

Assessing the optimum time of utilization of diesel contaminated rice fields after pollution

Isaac Anenya and Albert Kojo Quainoo*

Department of Biotechnology, Faculty of Agriculture, University for Development Studies, Tamale, Ghana

ABSTRACT

The length of time taken to obtain optimum germination and early performance of rice grown on diesel-contaminated soils was investigated. This was meant to inform researchers and farmers of the economic thresholds in using diesel contaminated lands as land is limited in supply in many places of the world and diesel contamination of agricultural lands in most developing countries is an important environmental issue. Soil samples were contaminated at rates of 0 cm³/kg, 12 cm³/kg and 24 cm³/kg and filled into experimental buckets of 10.5 litres capacity. The soil samples were mixed thoroughly to ensure homogeneity before filling the experimental buckets followed by diesel contamination at predetermined dosages. Five rice crops were planted in succession at two weeks interval and the germination percentage and height of seedlings at two weeks after planting determined. Significant difference in germination and plant height was observed when planting was done at the time of pollution. There was no significant difference in germination when seeds were planted at six weeks after contamination. However, the difference in the height of seedlings was significant ($p \leq 0.05$) even when planting was done at eight weeks after soil contamination with diesel. There was a positive relationship between the time of planting after contamination and germination of rice seeds, which depended on the level of contamination ($r^2 = 0.631$ at 12 cm³/kg contamination and $r^2 = 0.644$ at 24 cm³/kg contamination level). For plant height at two weeks after planting, the coefficient of correlation with time of planting after contamination was positive and increased with increased levels of contamination. Rice seeds sown on soils of up to 24 cm³/kg contamination level gave optimum germination when planted at six weeks after contamination but performance of germinated seeds was still significantly low when planting was done even at eight weeks after contamination ($p \leq 0.05$).

KEYWORDS: environment, germination, oil, plant height, seeds, soil

INTRODUCTION

Soil contamination with petroleum, diesel and other petroleum derivatives is a major factor in environmental degradation and it is on its ascendancy as a global menace. This form of pollution is highly toxic, widespread and complex in nature. Major points of soil pollution with diesel are fuel filling stations, car and tractor servicing garages, seaport areas [1] and most importantly mining and distribution sites of diesel and other petroleum products [2]. Heavy use of machinery in agriculture leads to higher consumption of diesel and negligence in transporting, storing and disposing of old or used diesel considerably pollutes the soil [3].

The world has seen dangerous spills and leakages of oil from oil pipes. Oil spills in the Persian Gulf

*Corresponding author
aquainoo@googlemail.com

in January 1991, Gulf of Mexico in June 1979, Trinidad and Tobago in July 1979, Fergana valley in Uzbekistan in March 1992 and BP oil leak in the Gulf of Mexico in June 2010 among others posed great ecological disaster to marine and coastal ecosystems.

Contamination of soils with oil has a remarkable effect on germination, growth and nutrient uptake of crops [4, 5, 6]. Oil products including diesel modify the physicochemical and biological properties of the soil and also limit the productive ability of arable crops [7]. Diesel oil stimulates the multiplication of oligotrophic, copiotrophic actinomycetes while it inhibits the multiplication of *Azotobacter* species and cellulolytic bacteria, regardless of soil type or nitrogen fertilization used [7]. Depending on the degree of contamination, the soil may remain unsuitable for plant growth for months or several years [8].

The advent of commercial oil production in any nation predisposes agricultural lands to contamination with crude petroleum and petroleum derivatives. In light of these, this study is aimed at assessing the germination percentage of rice at varying times after soil contamination with diesel and to assess the performance of rice seedlings grown on contaminated soil. This study is expected to lead to the determination of the economic thresholds of cultivating polluted lands and provide the basis for research into remediation of polluted lands.

MATERIALS AND METHODS

Experimental materials and site

Experimental containers used were plastic buckets of 10.5-litre capacity. Diesel oil was obtained from the filling station which was used to contaminate the soil samples. Rice seeds obtained from the Savanna Agriculture Research Institute (SARI), Nyankpala of the Council for Scientific and Industrial Research (CSIR), Ghana.

The soils of the area developed from the Voltanian sand-stone are moderately drained, have a silty loam texture and are classified as Nyankpala series. Physical and chemical analyses of the top 0 - 20 cm of soil revealed the following properties: sand 47%; silt 40%; clay 16%; organic carbon 0.34%; total N 0.04%; available P (Bray 1) 7.07 mg kg^{-1}; K 89.5 mg kg^{-1}; Ca 497.5 mg kg^{-1}; Mg; 88.5 mg kg^{-1}; CEC 4.69 cmol (+) kg^{-1} and soil pH 5.57.

Viability test

Seeds were tested for viability using the procedure of [5].

Methodology

The plastic buckets were perforated at the bottom to make way for the drainage of excess water from the soil. Garden soil was obtained from the experimental field of the University for Development Studies. The soil contamination with diesel was done by thoroughly mixing the soil in their respective buckets to ensure a homogeneous soil-diesel mixture. 10 kg (dry weight) of soil was treated with 0 cm^3, 120 cm^3, and 240 cm^3 of diesel to obtain 0 cm^3/kg, 12 cm^3/kg and 24 cm^3/kg diesel contamination. Each treatment was replicated five times. The experiment was set up in a randomised complete block design (RCBD) with five replications.

Rice seeds were planted in each bucket at a seeding rate of ten seeds per bucket and watered on daily basis.

Seed germination was monitored and percentage germination recorded using the relationship:

% Germination = Total number of emerged seeds/ Total number of seeds sown X 100

Germination was observed as the emergence of a seed leaf at the soil surface. The heights of emerged plants were measured before removal of plants followed by replanting. Replanting was done at two weeks interval for ten weeks and the germination percentage and plant height determined at each planting session.

Analysis of variance (ANOVA) and correlation analysis were carried out with Genstart (edition 3) and the means separated with least significant difference (LSD) at 5%.

RESULTS

The results obtained from this study are presented as follows.

Viability test

One hundred percent (100%) viability was obtained from the seeds using floatation method.

Germination of rice seeds

Planting on soils contaminated at 0 cm³/kg, 12 cm³/kg and 24 cm³/kg resulted in varying germination rates as shown in Table 1. Germination was recorded at all levels of contamination used in the study. However, germination declined significantly with increased contamination levels when seeds were planted at the time of contamination.

A correlation analysis study of germination on the time of planting revealed that there was a positive relationship between the time of planting after contamination and germination of rice seeds which depended on the level of contamination (r^2 = 0.631 at 12 cm³/kg contamination and r^2 = 0.644 at 24 cm³/kg contamination level). Figure 1 shows a regression of the time of planting after contamination on germination percentage of rice seeds.

Plant height

The effect of diesel on early growth of rice was significant. This is presented in Figure 2. The mean plant height of the control was significantly (LSD = 0.05) greater than the means for plants grown in soil contaminated with 12 cm³/kg and 24 cm³/kg in all successive plantings.

A regression of the time of planting after contamination on plant height reveals that there is a highly positive correlation between the time of planting and plant height. The co-efficient of correlation increased with increasing levels of soil contamination with diesel fuel as shown in Figure 3.

Table 1. Germination of rice seeds planted at various times after soil contamination with diesel.

Soil pollution level (cm³/kg)	Percentage germination of rice after soil contamination (%)				
	Week 0	Week 2	Week 4	Week 6	Week 8
0	96	96	96	96	96
12	74	94	94	94	98
24	10	84	88	94	98
LSD (0.05)	1.49	0.79	1.14	0.96	0.58

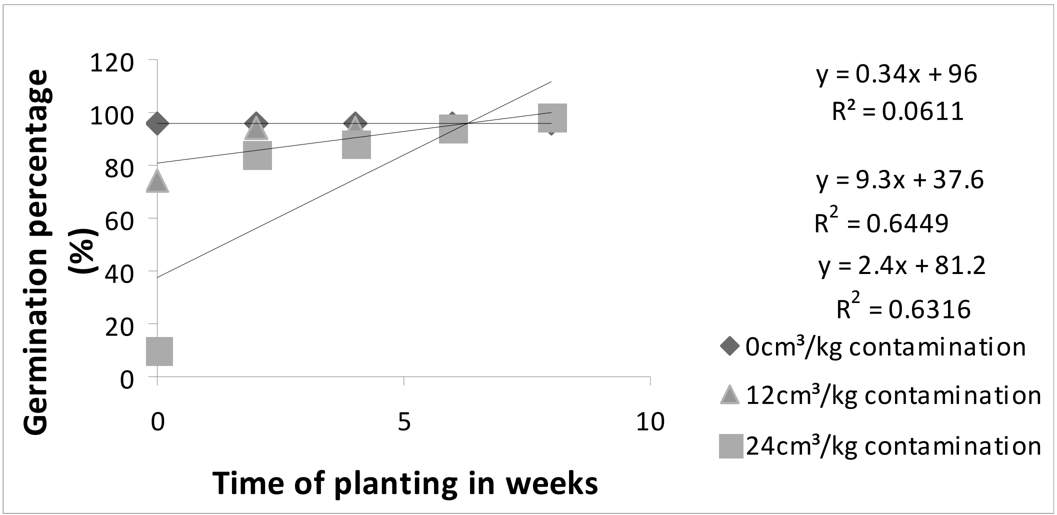

Figure 1. Linear relationship between germination of rice seeds and time of planting after soil contamination.

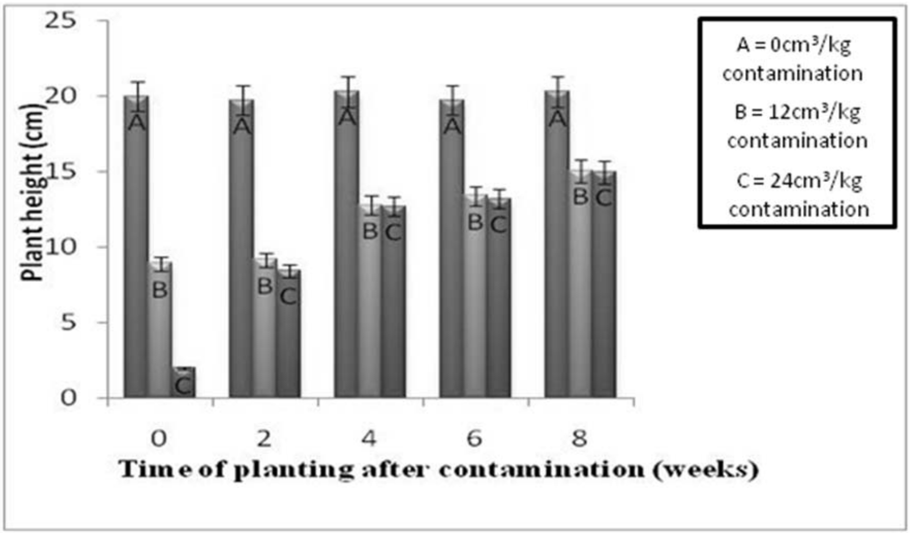

Figure 2. Effect of diesel contaminated soil on rice seedlings two weeks after planting.

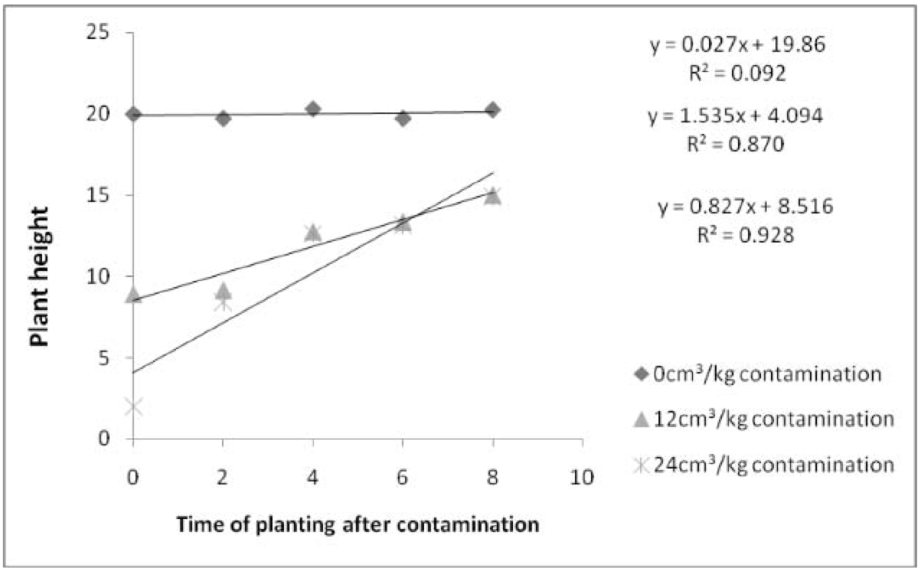

Figure 3. Linear relationship between plant height at two weeks after planting and time of planting after contamination.

DISCUSSION

Germination of rice seeds

Generally, diesel contaminated soils affected the germination rates of the rice seeds in terms of level of contamination and time of planting after contamination. During the first four weeks after planting, there was significant difference between the levels of contamination on the germination of the rice seeds. However, from week 6 to week 8, there were no significant differences in the germination rates (Table 1). Except the controlled treatment which recorded no germination difference across the weeks, the other treatments recorded either constant or progressive increase in germination after the initial low germination rates of 74% and 10% for 12 cm³/kg and 24 cm³/kg contamination levels respectively (Table 1).

The results showed that diesel oil contamination of soil inhibits the germination of rice. The degree of inhibition is dependent on the level of contamination and the time of planting after pollution has occurred. The results indicated that rice can tolerate diesel contamination of soil by germinating successfully in contamination levels between 0 cm^3/kg and 24 cm^3/kg. It has been observed that percentage germination decreased with increased level of soil contamination with diesel. Kirk *et al*. [9] recorded that four species belonging to the *poacea* family germinated successfully in different levels of petroleum hydrocarbon contamination. It was further recorded that percentage germination decreased as the level of contamination increased [9]. Ogbo [8] reported that 1% diesel contamination did not significantly reduce seed germination in *Zea mays* and *Sorghum bicolor* but did in *Arachis hypogaea* and *Vigna unguiculata* ($P<0.05$). A total inhibition of germination in *Sorghum bicolor* and *Vigna unguiculata* at 4.00% level of diesel contamination was also noted. The findings of this study are also in agreement with the work of Adam and Duncan [10] who reported reductions in the germination rates of several plant species.

This result indicated that percentage germination of rice seeds in contaminated soil depended on the time of planting after contamination of the soil has occurred. Seed germination on polluted soil is positively correlated to the time of planting after contamination. This correlation increased with the level of contamination (Figure 1). At 0 cm^3/kg, 12 cm^3/kg and 24 cm^3/kg contamination level the correlation co-efficient between the time of planting and germination of rice seed was 0.061, 0.631 and 0.644 respectively (Figure 1). This observation can be attributed to the fact that diesel degraded in the soil with time after contamination. Anoliefo and Edegbai [11] attributed the lethal effect of petroleum products such as diesel on plants to hydrocarbons present in such fuels. Diesel oil has a negative effect on the biochemical and physicochemical characteristics of soils [12, 13]. The effect could also be attributed to the formation of polar compounds dissolved in water that could penetrate the seed coat, exerting polar necrosis [10, 14]. According to Terge [15] the presence of oil and level of contamination in the soil affected germination and subsequently, the growth of plants in such soils.

Observations made in this study show that fresh diesel had coagulatory effect on the soil, binding the soil particles into water impregnable soil blocks which probably impaired water percolation and oxygen diffusion. Atuanya [12] stated that seeds sown in such soil failed to germinate. However, the contamination levels used in this study could not totally inhibit rice germination (Table 1).

Plant height

Generally, except the control, there was progressive reduction in plant height as the concentration of diesel contamination increased from 0 cm^3/kg to 24 cm^3/kg within treatment weeks. This was highest in week 0 and lowest in week 8 (Table 1). According to Udo and Fayemi [4, 5, 6], early growth and establishment of rice plants is inhibited by diesel in the soil which confirmed this study. This study showed significant difference in the height of rice plants between the control and treated plants. From week 2 to week 8 there was no significant difference in plant height at 12 cm^3/kg and 24 cm^3/kg contamination levels. This may be attributed to the degradation of the diesel product with time.

The correlation coefficients between the height of plants and the time of planting after contamination are 0.092, 0.870 and 0.928 for 0 cm^3/kg, 12 cm^3/kg and 24 cm^3/kg contamination levels respectively (Figure 3). Relevant literatures contain evidence suggesting that refinery products including diesel are toxic to plants [10, 4, 16, 17].

Growth retardation was observed in diesel contaminated soil because diesel disrupts root cells and other organs. The study by Anoliefo and Edegbai [11] on the anatomy of plants treated with crude oil, revealed the presence of oil films in the epidermal and cortical regions of the root, stem and leaves, causing root stress which reduces leaf growth via stomata conductance.

Growth retardation in diesel contaminated soil may be due to insufficient aeration of the soil because of displacement of air from the spaces between the soil particles [18]. Apart from their indirect effect through the soil [19] hydrocarbons from diesel also affected the germinated rice plants directly, smearing the roots of plants with oily substances and thus limiting transpiration and respiration, reducing permeability of cell membranes, and upsetting metabolic conversions [20].

CONCLUSION AND RECOMMENDATION

Germination is inhibited in diesel contaminated soils and the degree of inhibition is dependent on the level of contamination and the time of planting after contamination. There is a highly positive correlation between the time of planting and percentage germination of rice seeds. The coefficient of correlation increases as the level of contamination increases. Diesel contamination has similar effect on early growth of germinated rice seeds. When seeds were planted eight weeks after contamination, no significant difference was observed in germination percentage but there was, however, significant difference in plant height by week 2. It can therefore be inferred that the germination percentage is not a suitable indicator of when polluted lands could be used for optimum production. The observed trends in rice seed germination and height of plantlets is attributed to the fact that diesel modifies the physicochemical properties of the soil and thereby reduces the biological value of the soil. Further studies should also be carried out and in the open field to be able to ascertain how weather and other environmental parameters can affect the outcome of the study.

ACKNOWLEDGEMENT

The authors acknowledge the support of the research and office staff of the Department of Biotechnology and Dr. Bawa Demuyakor who contributed towards the success of this research.

REFERENCES

1. Michalcewicz, W. 1995, PZH, 46(1), 91.
2. Amadi, A., Abbey, S. D., and Nma, A. 1996, Water, Air and Soil Pollution, 86, 1-11
3. Leahy, J. G. and Colwell, R. R. 1990, Microbiol. Rev., 54, 305-315.
4. Udo, E. J. and Fayemi, A. A. 1995, Journal of Environmental Quality, 4, 537-540.
5. Erute, M. O. 2009, African Journal of Biotechnology, 8(2), 250-253.
6. Ehiagbonare, J. E., Obayuwana, S., Aborisade, W. T., and Asogwa, I. 2011, Scientific Research and Essays, 6(11), 2296-2301.
7. Wyszkowska, J. and Kucharski, J. 2005, Journal of Environmental Studies, 14, No. 3, 347-356.
8. Ogbo, E. M. 2009, African Journal of Biotechnology, 8(2), 250-253.
9. Kirk, J. L., Kironomos, J. N., Lee, H., and Trevors, J. T. 2002, Bioremediation J., 6(1), 57-63.
10. Adam, G. and Duncan, H. 2002, Environmental Pollution, 120, 363-370.
11. Anoliefo, G. O. and Edegbai, B. O. 2000, Journal of Agriculture for Fish, 1, 21-25.
12. Atuanya, E. I. 1987, Nigerian Journal of Applied Science, 5, 155-176.
13. Tyczkowsk, A. 1993, Ekologia Technika, 3, 10.
14. Wang, X., Sun, C., Gao, S. Wang, L., and Shuokui, H. 2001, Chemosphere, 44, 1711-1721.
15. Terge, K. 1984, Oil and Petroleum Journal, 2, 25-30.
16. Kucharski, J. and Wyszkowska, J. 2001, Acta Agrophis, 51, 113-120.
17. Molina-Barahona, L., Vega-Loyo, L., Guerrero, M., Ramirez, S., Romero, I., Vega-Jarquin, C., and Albores, A. 2005, Ecotoxicological Evaluation of Diesel-Contaminated Soil Before and After a Bioremediation Process, Wiley Periodicals, Inc. Wiley Inter Science, pp 100-109.
18. De Jong, E. 1980, Environmental Pollution, 22, 187-307.
19. Rowell, M. J. 1977, The effect of crude oil spills on soils, The Reclamation of Agricultural Soils after Oil Spills, Toogood, J. A. (Ed.), Department of Soil Science, University of Alberta, Edmonton, pp. 1-33.
20. Pezeshki, S. R. and Delaune, R. D. 1992, Water, Air and Soil Pollution, 68, 461-468.