Bacteria Inoculation Speeds Zinc Release from Ground Tire Rubber used as Zn Fertilizer in a Calcareous Soil

Hamid Zeinali Behzadan[1], Amir Hossein Khoshgoftarmanesh[1], Azadeh SanaeiOstovar[2], Mojgan Sepehri[1], and Rufus L. Chaney[3]

[1]Department of Soil Sciences and [2]Soilless Culture Research Centre, Isfahan University of Technology, 84156, Isfahan, Iran (sanaeiazadeh@yahoo.com); [3]USDA-Agricultural Research Service, Environmental Management and Byproduct Utilization Laboratory, Building 007, BARC-West, Beltsville, MD 20705, USA

INTRODUCTION

Tire rubber is rich in zinc (Zn) (1-2%) and might be applied as an effective and safe fertilizer source for supplying this nutrient element with no risk of Cd contamination (Taheri et al., 2011). Considering that tire rubber contains around 2 % Zn, a potential Zn fertilizer could be developed from the waste tire byproduct, crumb rubber. In this study, we tested the possibility of using some biological treatments to hasten the degradation of waste tire rubber in soil and thus the release of Zn and sulfur. Both aerobic and anaerobic bacteria can effectively decompose tire rubber polymers (Stevenson et al., 2008). Three bacteria species likely involved in degradation of tire rubber were selected. The *Rhodococcus erythropolis* and *Acinobacter calcoaceticus* were used because these bacteria species are recognized as tire-degrading bacteria. The *Escherichia coli* was used because the ability of this bacterium to break down 2-mercaptobenzothiazole (MBT, a toxic additive in rubber as a vulcanization accelerator).

MATERIALS AND METHODS

A surface soil (0-30 cm) was collected for the experiment from Rudasht research field in Isfahan province. Three rates of ground tire rubber (0, 150, and 300 mg kg^{-1}) as <2 mm diameter particles were incorporated into the soils. Ground rubber contains about 20 g Zn kg^{-1} but very low levels (<0.64 µg g^{-1}) of Cd. The Zn addition from the 150 and 300 mg kg^{-1} rubber was estimated 3.0 and 6.0 mg Zn kg^{-1} soil. Before adding to the soil, ground rubber was exposed to four microbial treatments including no inoculation, inoculation with *R. erythropolis* (R), inoculation with *R. erythropolis* + *E. coli* (R+E), and inoculation with *R. erythropolis* + *Escherichia coli* + *A. calcoaceticus* (R+E+A). The inoculums used on the zero rubber treatment were the same amount (5×10^6 cells ml^{-1}) as added to the rubber before it was mixed with the soil in the rubber treatments. The soils were incubated at 25^0C and their moisture was kept at 70% field capacity using deionized water. Sub-samples of soil were collected from each treatment at 1, 3, 6, and 10 weeks after inoculation and soil pH and DTPA-Zn, Pb, and Cd were measured. The experiment was set up in a quadruplicate completely randomized design with a factorial arrangement.

RESULTS AND DISCUSSION

Application of ground tire rubber and microbial inoculation treatments caused reductions of soil pH (Fig. 1). The magnitude of this reduction was increased over time so that the lowest pH was observed at week 10, although the calcareous soil was well buffered by $CaCO_3$. It seems that the microbial population could adapt to the soil conditions (e.g., the presence of tire ground rubber) over time. Elevated activity of microorganisms resulted in more degradation of tire rubber wastes and further release of sulphur. Addition of ground rubber in combination with microbial inoculants caused an increase in DTPA-extractable soil Zn (Fig. 2). The highest concentration of available Zn was found at week 10. In the rubber-treated soils, the available Zn concentration was higher than the critical level of

Zn (0.5 mg kg^{-1}) determined in the pot experiments for the growth response of wheat. However, the available Zn concentration was still below the critical level of this micronutrient in the soil that is considered for grain production and quality (2 mg kg^{-1}), which suggest that to obtain sufficient Zn concentrations in soil, larger amounts of ground tire rubber should be applied or a longer time is probably needed to release sufficient amount of Zn from tire rubber into the soil (Taheri et al., 2011). The microbial inoculation of soils by itself decreased pH and increased DTPA-Zn (Fig. 2). It seems that increase in soil Zn is partly due to reduction of pH resulted from activity of the microbial population.

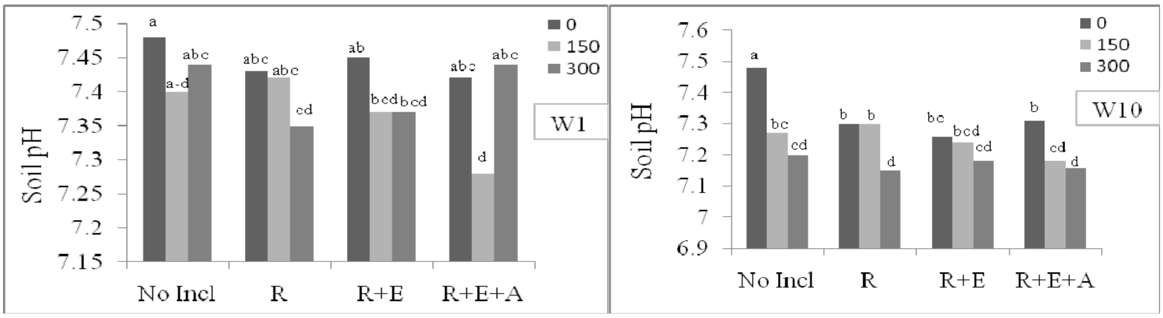

Fig. 1. The effects of ground rubber application and inoculation with three bacterial species on the soil pH at 1, and 10 weeks of incubation.

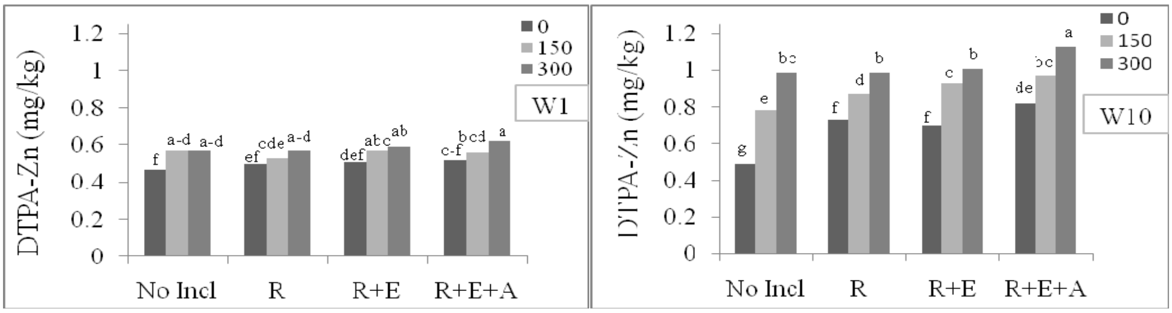

Fig. 2. The effects of ground rubber application and inoculation with three bacterial species on the soil DTPA-extractable Zn at 1 and 10 weeks of incubation.

The tire rubber should also be used a source of carbon for microorganisms and thus stimulate the microbial activity in the soil. After 10 weeks, the extractable-Cd and Pb concentrations in all unamended and rubber-amended soils were below the detection limit of AAS.

CONCLUSIONS

Inoculation of ground rubber with the rubber-biodegrading bacteria species was effective to increase DTPA-extractable Zn in the calcareous soil studied. The highest increase in soil available Zn was achieved by application of 300 mg kg^{-1} ground tire rubber inoculated with *R. erythropolis* + *E. coli* + *A. calcoaceticus*.

REFERENCES

Taheri, S., Khoshgoftarmanesh, A.H., Shariatmadari, H. and Chaney, R.L. (2011) Kinetics of zinc release from ground tire rubber and rubber ash in a calcareous soil as alternatives to Zn fertilizers. *Plant Soil* 341: 89–97.

Stevenson, K., Stallwood, B. and Hart, A.G. (2008) Tire rubber recycling and bioremediation: a review. *Bioremed. J*. 12: 1-11.