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Effect of Biochar Produced at Different Temperatures on Cadmium Availability in a Calcareous Soil Under Different Moisture Regims Over Time

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Introduction: Cadmium is one of the toxic heavy metals which is highly problematic in today's industrial world. It is essential to study the techniques for removing or reducing its availability, toxicity and consequently its hazardous effects in environment. Biochar is an amendment reported to be efficient in fixing heavy metals. Pyrolysis temperature is among the most important factors affecting biochar's characteristics, such as pH, CEC and specific surface area and generally it's potential to sorb heavy metals. On the other hand, soil moisture regime could affect pH and EC and consequently the Cd availability. Iran is the second producer of pistachio in the world and consequently a large volume of pistachio waste byproducts would be created annually. Converting this byproduct to biochar may be an efficient tool to prevent its accumulation. On the other hand, the produced biochar could be used as a soil amendment. The present study was conducted to evaluate biochar produced from pistachio nutshell under different temperatures for reducing Cd availability under different moisture regimes.

Materials and Methods: The soil texture in the present study was sandy-loam. Raw pistachio nutshell (RPN) was used to produce biochar under different temperatures. RPN was rapped in aluminum foils and heated for 2 h in a muffle furnace under 200, 400 and 600 °C. The pH, EC and concentrations of P, K, Fe, Mn, Zn and Cu of RPN and produced biochars were determined. A completely randomized experimental design with factorial arrangement including nine biochar treatments (control (no amendment), RPN and biochars produced under 200, 400 and 600 °C at 2% and 4% rates), and two moisture regims (20% w/w and waterlogging) was carried out with two replications. The samples were spiked with 25 and 50 mg Cd kg^{-1} and incubated for 90 days under laboratory temperature. Available Cd extracted by DTPA-TEA on 15, 30, 60 and 90 days after incubation. Cadmium concentration determined by Atomic Absorption Spectrometry (Mark and Model: HITACHI- ZCAST 2300). Analysis of variance and compare of means used to evaluate the effects of various treatments on DTPA-Cd.

Results and Discussion: The nutrient concentrations of biochar were increased with increasing the production temperature. The RPN and biochar of 200 ºC had the least nutrient concentrations while the biochar of 600 ºC showed the highest nutrient concentrations. The increases of pH and EC occurred with increasing the biochar production temperature. The pH ranged from 6.36 to 9.36 and EC range was 13.5-31.9 dS m^{-1}. The analysis of variance showed that biochar, moisture regime and their interaction significantly affected DTPA-Cd on all of the studied times ($P< 0.01$) in both Cd levels. The cadmium availability was reduced by incubation times in all of the treatments and 600°C biochar caused the highest decrease of DTPA-Cd. In 25 mg Cd kg^{-1} level, the application of 600°C biochar caused significant decrease of DTPA-Cd by 54.2, 73, 53.5 and 60.5 % in comparison with control on 15, 30, 60 and 90 d, respectively. In 50 mg Cd kg^{-1} level, 600°C biochar in 4% w/w and 20% w/w moisture contents reduced DTPA Cd by 38.6, 43.4, 39.8 and 45.7 mg kg^{-1} on 15, 30, 60 and 90 d, respectively. The DTPA-Cd was reduced by increasing the biochar application rate to 4% w/w, but only for biochar of 600°C, this reduction had a significant difference with 2% application rate. Four percent biochar application rate on waterlogging condition reduced DTPA-Cd by 60.1%, 34.1 % and 53.6 % compared with 2% application rate on 30, 60 and 90 d, respectively. These changes on 50 mg Cd kg^{-1} in 20 % moisture level were 36.8, 43.8, 37.7 and 35.2 % on 15, 30, 60 and 90d, respectively. In 20% moisture level, the application of 600 °C biochar reduced DTPA-Cd compared with waterlogging while raw pistachio nuts and 200 and 400 °C biochars showed a reverse trend and increased DTPA-Cd in 20% moisture level compared with waterlogging.

Conclusion: Generally, regarding the decrease of DTPA-Cd by biochars, especially biochar of 600 °C, it can be concluded that biochar of pistachio nut shell particularly under 600 °C might be considered as an inexpensive and green environmental sorbent for Cd, however its potential to reduce Cd uptake by plants and Cd movement

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in environment requires further studies. Furthermore, the knowledge of the mechanisms that are responsible for Cd retention on biochar and desorption kinetic of sorbed Cd need further investigation.

Keywords: Biochar, Cadmium, Pistachio nutshell, Soil Pollution