FARMING PRACTICE
SOIL AMENDMENT WITH BIOCHAR

IMPACT: HEAVY METALS POLLUTION

Reference 28

Peng, X; Deng, YE; Peng, Y; Yue, K 2018 Effects of biochar addition on toxic element concentrations in plants: A meta-analysis Agric For Meteorol. 278:107625. 10.1016/j.scitotenv.2017.10.222

Background and objective

Consuming food contaminated by toxic elements (TEs) could pose a substantial risk to human health. Recently, biochar has been extensively studied as an effective soil ameliorant in situ because of its ability to suppress the phytoavailability of TEs. However, despite the research interest, the effects of biochar applications to soil on different TE concentrations in different plant parts remain unclear. The response of the bioaccumulation of TEs (including As, Cd, Pb, Cr, Co, Cu, Ni, Mn, and Zn) in plants to experimental biochar addition was evaluated. The authors hypothesized that: 1) TE concentrations in plants would be significantly reduced by biochar addition; 2) the ability of biochar to decrease the bioaccumulation of TEs would not be influenced by higher pyrolysis temperatures; and 3) the effects of biochar addition on TE concentrations in plants would be significantly influenced by moderator variables (e.g., experimental conditions).

Search strategy and selection criteria

Peer-reviewed articles evaluating the effects of biochar additions on the bioaccumulation of TEs were identified by searching the Web of Science and Google Scholar on 23 December 2016 using the keywords "biochar", "trace element", "heavy metal", "TE", and "bioaccumulation", and Chinese searches were conducted using CNKI (Chinese National Knowledge Infrastructure). There were no restrictions on the publication year. 1) the treatment and control groups were the same in all aspects except biochar application; 2) experiments used a randomized design; 3) the standard deviation (SD) was provided directly or could be calculated by the standard error (SE); and 4) the culture medium was soil.

Data and analysis

To evaluate the effects of the moderators on the magnitude and direction of the responses of the bioaccumulation of TEs to the biochar addition, we calculated the grouped effect sizes using a categorical random effects model. The significance of each categorical moderator was also evaluated by employing mixed models by comparing the heterogeneity within and between moderator levels. The authors used the meta-analysis software MetaWin 2.1 to calculate the lnRR and its 95% CI.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
97	Pot and field experiments	Soil amendment with biochar	No amendment	Metric: Concentrations of toxic elements (Zn, Cd, As, Ni, Mn, Cr, and Co) in plant tissues; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control	0.75

Results

- In pot studies, the effects of biochar addition on the bioaccumulation of toxic elements (Zn, Cd, Ni, Mn, Cr, and Co) were revealed to be significantly suppressive, except on As (no significant change), and considerable decreases were observed for Cr and Co.
- Compared with the control groups, the Cr and Co concentrations in plants decreased significantly by an average of – 64.13%, which was a substantially greater effect than that observed for Zn, Cd, As, Ni, Mn. Cd decreased significantly in both the pot and field studies by – 30.24% and – 32.54%, respectively, under biochar addition conditions.
- The Cd concentrations in the edible and indirectly edible plant parts significantly decreased by – 33.90% and – 35.42%, respectively, under the biochar treatments.
- Cu and Pb concentrations in the edible plant parts were both significant decreased by – 18.49% and – 48.93%, respectively, after biochar addition.

Factors influencing effect sizes

- Biochar feedstock : The largest number of studies were completed using wood and herbaceous feedstocks for different TEs, and in both cases, the effects were significant for Cd, Ni, and Mn. In particular, the effect of biochar produced from herbaceous feedstocks was more pronounced on Mn (– 44.43%) than the other TEs and biochar produced from wood feedstocks produced the same results on Cr (– 49.43%). Biochar produced from biosolids and lignocellulosic waste produced more significant reductions in Co (– 67.52%) and Cd (– 43.09%) than the other elements. In addition, biochar produced from manures significantly increased the Zn concentration by 91.32%, whereas it decreased the Cd concentration (– 65.37%) in plants. biochar produced from manure significantly decreased the Pb concentrations in plants by – 85.32% [– 92.13% – 72.60%].
- Biochar pyrolysis temperature : Biochar produced at higher temperatures (> 600 °C) had more pronounced effects on Ni (– 83.42%) and Mn (– 81.23%) than biochar produced at different pyrolysis temperatures. The largest number of studies were performed using a temperature range (i.e., 400–500 °C), and the impacts were significant for Zn, Cd, and Ni.
- Type of experiment : The effects of biochar addition on all field studies were scarcely significant, whereas the opposite results were observed for the pot studies
- Soil pH : The responses of Mn and Co to biochar were significantly affected by the soil pH ($P < 0.01$).
- Time scale : Experimental duration affected the response of Zn to biochar.

Conclusion

This integrated study showed that the majority of types of biochar added to soil generally decreased the bioaccumulation concentration of different toxic elements, except for arsenic (As), which showed no change.