Calcium WTR reduces Cu bioavailability in Cu-contaminated soils – a green house study

Jinghua Fan[1], Zhenli He[2], George J. Hochmuth[1], Lena Q. Ma[1], and Peter J. Stoffella[2]

[1] University of Florida, Soil and Water Science Department, Gainesville, FL 32611

[2] University of Florida, IFAS, Indian River Research & Education Center, Fort Pierce, Florida 34945

INTRODUCTION

- Copper (Cu) accumulation in soil from the application of fungicides and pesticides poses a threat to the environment and ecosystem function due to its toxicity (Fan et al., 2011a).
- Calcium water treatment residue (Ca-WTR, pH 9.1, containing mainly $CaCO_3$ and minor CaO), an industrial by-product, was found to be effective in reducing Cu mobility and transport to the environment (Fan et al., 2011b).

OBJECTIVES

A greenhouse study was conducted to determine the effectiveness of Ca-WTR in

(a) reducing Cu accumulation in plants and

(b) improving plant growth.

MATERIALS AND METHODS

- Two representative soils in the Indian River area of south Florida were used in this study: an Alfisol (fine loamy siliceous hyperthermic Typic Glossaqualfs) and a Spodosol (sandy siliceous hyperthermic Alfic Haplaquods) and their related properties are presented in Table 1.
- Ca-WTRs were applied at the rates of 0, 5, 10, 20, 50 g kg^{-1} soil to the Alfisol soil and 0, 5, 10, 50, 100 g kg^{-1} soil to the Spodosol soil based on soil pH determination. There were two levels of soil Cu in this study: the original soil with or without enriched with 1000 mg kg^{-1} Cu in the form of $Cu(NO_3)_2$.
- Ryegrass (Lolium perenne L.) and lettuce (Lactuca sativa L.) were used as indicator crop plants and grown for eight weeks before harvest. Plant biomass yields were recorded.
- Total recoverable and Mehlich 3 extractable Cu in soil and digested plant tissue samples were determined using inductively coupled plasma optical emission spectrometry (ICP-OES, Ultima, J. Y. Horiba, Edison, NJ, USA) following USEPA method 200.7.

Table 1 Properties of tested soils and Ca-WTR used in the study

Property		Alfisol	Spodosol	Ca-WTR
pH	(H_2O)	5.45	4.66	9.05
	(KCl)	4.48	3.5	8.69
EC	(µS cm^{-1})	140	151	659
Total C	(g kg^{-1})	3.29	9.24	112
Total N	(g kg^{-1})	0.29	0.69	0.19
Organic matter	(g kg^{-1})	5.7	15.9	--
CEC	($cmol_c kg^{-1}$)	4.6	11.0	--
KCl extractable N	(mg kg^{-1})			
NO_3^-		7.0	8.9	--
NH_4^+		4.7	11.1	--
Particle distribution	(g kg^{-1})			
Sandy		945	909	12
Silt		43	51	136
Clay		12	40	852
Total Cu	(mg kg^{-1})	84.7	134	0.40
Mehlich 3 extractable Cu	(mg kg^{-1})	44.7	64.1	0.32

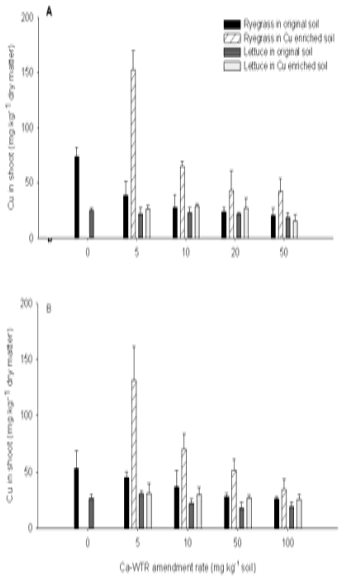


Fig. 1 Relationship between plants (ryegrass and lettuce) shoots Cu concentration and Ca-WTR treatment rates. A) Alfisol. B) Spodosol. Vertical bars represent standard errors

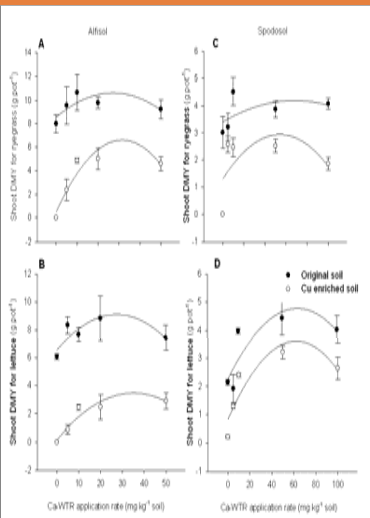
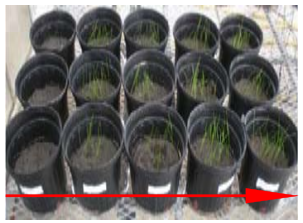


Fig. 2 Relationship between plant shoot dry matter yields after 8 weeks of growth and Ca-WTR treatment rates. A) ryegrass in Alfisol. B) lettuce in Alfisol. C) ryegrass in Spodosol. D) lettuce in Spodosol. Vertical bars represent standard errors

Ryegrass growing in Cu enriched Alfisol (7 days after sown)



Lettuce growing in Cu enriched Alfisol (30 days after sown)

0 5 10 20 50

WTR rates (mg kg^{-1})

RESULTS AND DISCUSSION

- Copper concentrations in ryegrass shoots decreased significantly with increasing Ca-WTR application rates, thus improving plant growth as evidenced by a significant increase in plant biomass yield (P<0.01). For lettuce, plant Cu concentration decreased only at the high Ca-WTR rates (>50 g kg^{-1}) (Fig. 1).
- The growth of plants was inhibited in the slightly Cu-contaminated soils (~100 mg kg-1), but no plant survived in the highly Cu-contaminated soils (added with 1000 mg kg-1). Plant biomass yields increased with WTR application rates at the low levels (5-20 g kg^{-1} for Alfisol, pH 5.45 and 5-50 g kg^{-1} for Spodosol, pH 4.66), and decreased at the high levels (>20 g kg^{-1} for Alfisol and >50 g kg^{-1} for Spodosol) (Fig. 2).
- For the original soils, the maximum dry matter yields for ryegrass was 133% and 149% of the control original Alfisol and Spodosol, respectively, while the corresponding values for lettuce were 145% and 206%. Ca-WTR treatment was critical for both ryegrass and lettuce growth in Cu enriched soils (Fig. 2).

CONCLUSIONS

Application of Ca-WTR at adequate amounts could effectively increase plant growth and reduce plant Cu uptake. In addition, ryegrass had a greater potential for Cu uptake and translocation than lettuce in both soils. Hence, Ca-WTR warrants further testing for its ability to reduce Cu phytotoxicity in Cu-contaminated soils.

Reference

Fan, J., Z. He, L.Q. Ma, and P.J. Stoffell. 2011a. Accumulation and availability of copper in citrus grove soils as affected by fungicide application. J. Soils Sediments 11:639–648.

Fan, J., Z. He, L.Q. Ma, Y. Yang, X. Yang, and P.J. Stoffell. 2011b. Immobilization of copper in contaminated sandy soils using calcium water treatment residue J. Haz. Mat. 189:710–718.