SOIL COPPER THRESHOLDS FOR POTATO PRODUCTION

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BACKGROUND

A rising concern with the application of dairy wastes to agricultural fields is the accumulation of copper (Cu) in the soil. Copper sulfate (CuSO4) from cattle footbaths is washed out of dairy barns and into wastewater lagoons. The addition of CuSO4 baths on dairies can increase Cu concentration significantly in manure slurry. The Cu-enriched dairy waste is then applied to agricultural crops, thus raising concerns about how soils and plants are impacted by these Cu additions. Repeated applications of lagoon water could potentially raise Cu concentrations to toxic levels for agricultural crops, with very limited possibilities for remediation. It has been stated that most crops can only remove 0.1 pound of Cu per acre per year. If a grower waits until Cu plant toxicity symptoms occur (including plant death), they will continue to see Cu toxicities in that field for an indefinite period of time.

Most Cu that is added to soil will strongly adsorb to soil surfaces (also referred to as cation exchange sites). As sandy-textured soils have fewer cation exchange sites than silty-textured soils, the Cu will not tend to bind to sandy soils as strongly as silty soils. For this reason, more Cu will be left in soil solution as plant available Cu, therefore potentially increasing the risk for Cu toxicities on sandy soils.

Potato growers are concerned about this issue, as many of the predominant dairy producing areas in Southern Idaho are also in Idaho's established potato production regions. Specifically, these growers are concerned that fields currently suitable for potato production may no longer be productive after excessive lagoon water applications with high concentrations of copper have been applied. The goal of this project was to evaluate potato growth and copper plant uptake for potatoes grown under low, moderate, and excessively high soil copper concentrations.

METHODS AND MATERIALS

This study was conducted in a greenhouse setting at the USDA ARS Kimberly Research Station. To establish an effective copper response curve, 6 rates of copper sulfate (0, 50, 100, 250, 500, and 1000 mg Cu/ kg soil) were applied to either a Portneuf silt loam or a Quincy sand. Two Russet Burbank potato seeds were planted at a depth of 3 inches in each pots. Plants were thinned down to one surviving plant at the two-leaf stage. Treatments were replicated four times in a complete randomized block design. After 130 days of growth, plants were harvested, separated into shoots, roots, and tubers, and were analyzed for copper concentration. Soils were also analyzed for soil test copper concentration using the commonly used DTPA extractant.

Plant uptake of copper

Potato plants grown on sandy soil textures absorbed copper more readily than silt loam textured soils, as indicated by increased concentrations of copper in plant roots and shoots (Figure1). This finding illustrates that silty textured soils likely bind more Cu than sandy soils, leaving more copper available for plant uptake on sandy soils. Comparing shoots to roots, we also found between 10 and 17 times greater Cu accumulation in roots than shoots for both soil types at varying soil copper levels (Figure 1). This finding validated what is currently known about copper movement in plants, with copper accumulating in roots rather than shoots.

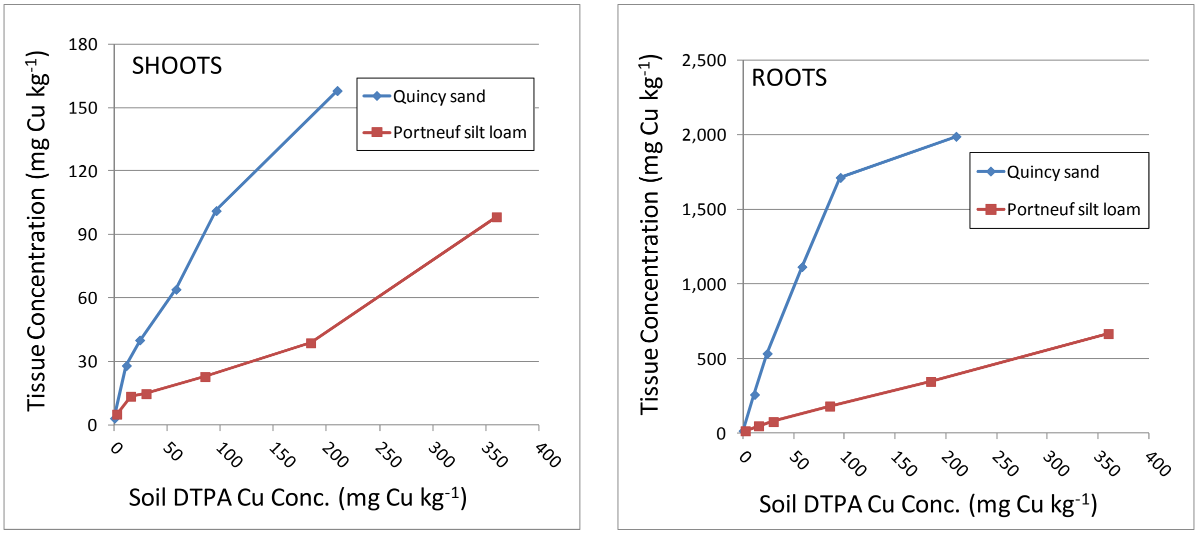

Figure1. Increasing copper concentrations in Russet Burbank potato shoots and roots with increasing soil DTPA copper concentrations, as influenced by soil texture.

Figure 2. Root mass is smaller and darker for the 1000 mg Cu/kg treatment (right) compared to the 0 mg Cu/kg (left) (Photos from Portneuf silt loam soils).

While there was greater Cu uptake by potato plants on sand than silt loam, the soil copper levels were lower on the sand than the silt loam with increasing soil copper concentration (Figure3). The only explanation that we have for this relationship is that the DTPA soil Cu test was not designed to handle significantly high levels of Cu concentrations, and may not be ideal for relating to Cu uptake at extremely high soil test Cu levels. Regardless, this illustrates that different thresholds for copper toxicity need to be established, based on soil texture.

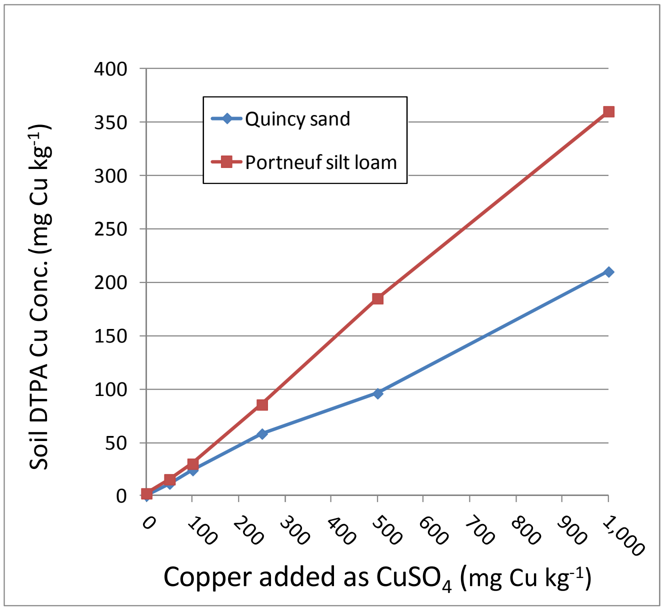

Figure 3. Effect of copper application on soil test DTPA copper on two contrasting soil textures.

Biomass effects

As Cu concentration increases in roots and shoots, dry weight biomass decreased (Figure 4). This finding suggests reduced potato productivity and yield with increasing soil copper levels from 7 to 350 ppm. For the Portneuf silt loam, Cu concentrations greater than 90 ppm appeared to significantly decrease both root and shoot biomass. In the Quincy sand, soil Cu levels above 25 ppm decreased shoot biomass (Figure 4). (Rootballs were relatively small for all Quincy sand treatments, which limited the potential for restricted root growth related to high copper levels). Based on our findings, we would recommend setting limits for potato production at 25 ppm for sandy soils and 90 ppm for silt loam soils.

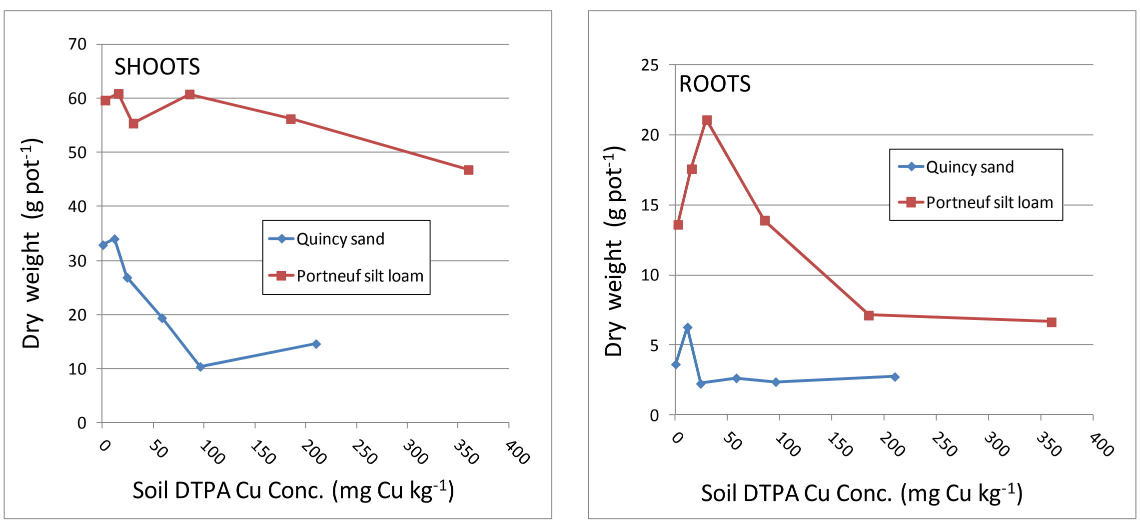

Figure 4. Changes in dry matter weight for Russet Burbank potato shoots and roots with increasing soil DTPA copper concentrations, as influenced by soil texture.

Health concerns

Greenhouse conditions limited tuber formation on both the sand and silty soil textures, although small tubers did form in two pots containing 50 mg Cu/kg treatments, and one pot containing the 1,000 mg Cu/kg treatment. Tuber Cu concentrations among the three treatments ranged from 11 to 20 ppm, which equates to 0.1 to 0.3 mg Cu/100 g fresh tuber weight. National Academy of Sciences (2011) recommendation for tolerable upper intake levels of Cu for children ages 1-3 is 1 mg Cu/100 g fresh weight. At these levels, copper toxicities copper does not appear to be an issue toward humans ingesting potatoes grown on soils containing up to 300 ppm Cu, although further study is needed to confirm this conclusion.

Response to copper in comparison to other crops

Ippolito et al. (2011a; 2011b) conducted a similar study, evaluating the response of corn and alfalfa growth to increasing copper levels in a greenhouse setting in Kimberly, Idaho. At soil DTPA Cu concentration values of 160-180 ppm, the decrease in plant biomass in comparison to non-copper amended controls was 0% for corn, 7% for potato, and 22% for alfalfa. Based on this comparison, it appears that copper sensitivity follows as alfalfa being the most sensitive, an potatoes and corn being the least sensitive.

Copper remediation with potatoes?

It is often stated that a typical crop can only remove 0.1 lb Cu/acre/year. Potatoes grown on the control soils in this study removed an equivalent of 0.06 – 0.1 lb Cu/acre, supporting the commonly made statement. However, at the highest Cu rate of 1000 mg Cu/kg, potatoes removed an equivalent of 2 lbs Cu/acre on the silt loam, and 6.6. lbs Cu/acre on the sand. These findings suggest that potato plants could potentially be used to remove significant amounts of Cu from Cu-affected soils.

SUMMARY

Growers are strongly urged to soil test agriculture land that has received lagoon water applications for DTPA soil test Cu to avoid crop losses related to Cu toxicities. We recommend threshold levels for potato production to be 25 ppm Cu for sandy soils and 90 ppm Cu for silt loams. At soil test Cu levels up to 375 ppm, tubers do not appear to pose any copper toxicity health risks to humans, although this needs to be verified.

REFERENCES

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