# Potato Growth Response to High Copper Soils: Addressing Copper-Rich Lagoon Water Applications to Idaho Croplands

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## Introduction

❑A rising concern with the application of dairy wastes to agriculture fields is the accumulation of copper (Cu) in the soil.
❑Spent Copper Sulfate (CuSO4) from cattle footbaths is flushed out of dairy barns and into waste water lagoons.
❑ The addition of CuSO4 baths on dairies can increase Cu concentration significantly in manure slurry, from approximately 5 grams to 90 grams per 1,000 liters, or more.
❑The Cu-enriched dairy waste is then applied to agriculture 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 agriculture crops.
❑ It has been estimated that most crops can only remove 0.1 pounds of Cu per acre per year.
❑Once Cu toxicity symptoms occur it may be too late to remediate the soil.
❑Observed Cu levels in southern Idaho agriculture fields from lagoon water applications range from 7.5 to 36 soil DTPA Cu (mg Cu $kg^{-1}$).

## Objectives

**Objective 1): Evaluate potato growth and copper plant uptake for potatoes grown under low, moderate and excessively high copper concentrations.**

**Objective 2): Develop estimates for soil copper concentration thresholds on silty and sandy soil types.**

## Materials Methods

❑Experimental design
- ❑Greenhouse study at USDA,ARS, Kimberly, Idaho
- ❑Russet Burbank potato seed
- ❑Six rates - 0, 50, 100, 250, 500, and 1000 mg Cu/kg
- ❑Two Soil types- Quincy sand (Mixed, mesic Xeric Torripsamments) and Portneuf silt loam (Coarse-silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids)
- ❑Four replications
- ❑Randomized Complete Block Design

❑Measurable
- ❑ Whole plant, root and tuber* weights
- ❑DTPA extractable soil Cu
- ❑Copper concentrations and uptake in tubers*, roots and shoots

*Greenhouse conditions were restrictive for tuber formation due to high temperatures

## Results - Does soil texture influence copper toxicity?


Quincy sand 1000 mg Cu/kg (left) Portneuf silt loam 1000 mg Cu/kg (right)

❑Potato plants grown on sandy soil textures absorbed copper more readily than silt loam textured soils. (Figure1)
- ❑Soils with more surface area (silty textures) can absorb more copper than soils with less surface area. (sandy texture)
- ❑Copper not absorbed by the soil are left in soil solution, available for plant uptake.

❑Greater Cu accumulation in roots rather than shoots. (Figure 1)
- ❑At 100 ppm soil test Cu, there was 88% more Cu in roots than shoots in the Portneuf silt loam and 94% more Cu in roots than shoots in the Quincy sand.

❑Visual Cu toxicity symptoms were greater in the sandy textured soils than the silt loam soils.
❑More Cu uptake on sand than silt loam, however the soil DTPA copper levels were lower on the sand than the silt loam. (Figure3)
- ❑In **theory**, the more sand in the soil, the higher the potential for copper uptake.
- ❑The DTPA soil Cu test was not designed to handle significantly high levels of Cu concentrations, may not be ideal for relating to Cu uptake at extremely high soil test Cu levels.

❑As Cu concentration increases in roots and shoots, dry weight biomass decreases.(Figure 2)
- ❑ Reduced potato productivity and yield.
- ❑In the silt loam textured soil, Cu concentrations greater than 90 ppm decreased biomass. In the sand textured soil, Cu concentrations greater that 25 ppm decreased biomass. (Figure 2)
  - ❑Again, observed Cu levels in southern Idaho agriculture fields from lagoon water applications typically range from 7.5 to 36 soil DTPA Cu (mg Cu $kg^{-1}$).
  - ❑Therefore, potato growers with sandy soils and soil test Cu levels in this range may already be experiencing yield losses.

## Results

### What does copper toxicity look like in potato plants?

- ❑ Stunted plant growth
- ❑ Chlorosis and necrosis of leaves
- ❑ Leaf wilting
- ❑ Stems are darker in color and hollow
- ❑ Root mass is smaller and darker in color
- ❑ Early plant senescence

Chlorosis throughout the plant

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)


0 mg Cu/kg Quincy Sand 1000 mg Cu/kg

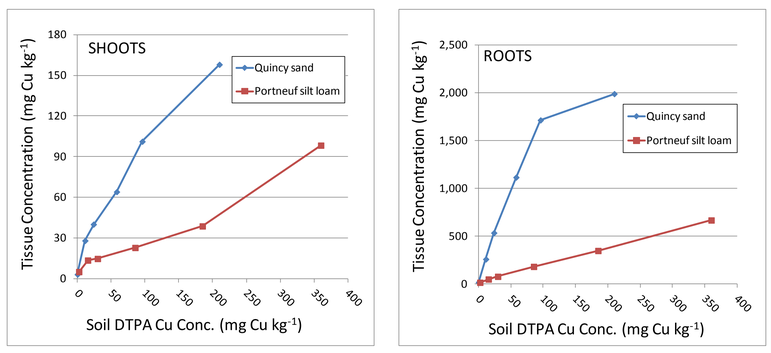


Figure1. Increasing copper concentrations in Russet Burbank potato shoots and roots with increasing soil DTPA copper concentrations, as influenced by soil texture.

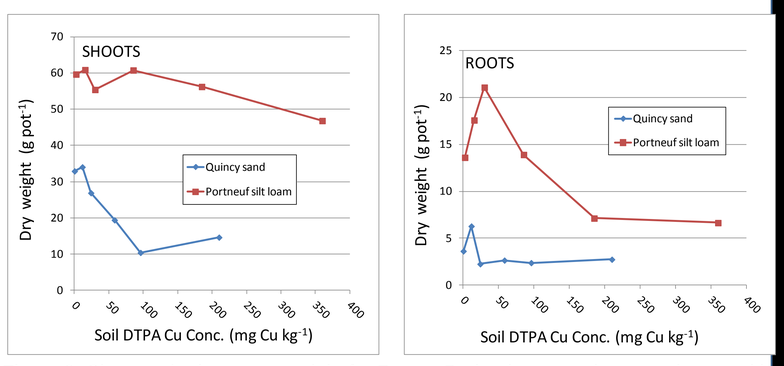


Figure 2. Changes in dry matter weight for Russet Burbank potato shoots and roots with increasing soil DTPA copper concentrations, as influenced by soil texture.

## Results

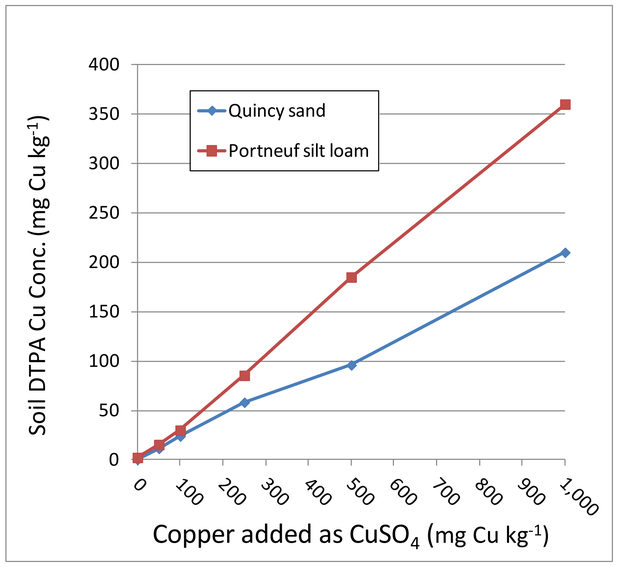


Figure 3. Effect of copper application on soil test DTPA copper on two contrasting soil textures.

❑Greenhouse conditions limited tuber formation on both the sand and silty soil textures.
- ❑ Tuber Cu concentrations ranged from 11-20.4 ppm, or <=0.006 mg Cu/100 g fresh tuber weight.
- ❑ National Academy of Sciences recommendation for Tolerable Upper Intake Levels of Cu for children ages 1-3 is 1 mg Cu/100 g fresh weight.
- ❑At these levels the tubers do not pose any health risks.

❑Tissue Cu concentrations in both roots and shoots increased dramatically with increasing soil DTPA Cu concentration up to 375 ppm in both the silt loam and sand soil textures. (Figure 1)
- ❑Potatoes appear to be luxury consumers of copper.
- ❑Potatoes could **possibly** be used for remediation of Cu saturated soils.

❑Comparison of sensitivity to copper toxicity for potato, corn, and alfalfa, based on greenhouse research studies.
- ❑Two studies conducted by Ippolito et al. with similar silt loam soil.
- ❑At soil DTPA Cu concentrations values of 160, 175 and 180 ppm for corn, alfalfa and potato, respectively, the percent decrease in plant biomass was 0, 7 and 22 for corn, potato and alfalfa, respectively.
- ❑It appears that potatoes are less sensitive to Cu toxicity compared to alfalfa and equally sensitive to Cu toxicity compared to corn.

❑Copper removal potential of potato crops
- ❑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
- ❑At the highest Cu rate of 1000 mg/kg, potatoes removed an equivalent of 2 lbs Cu/acre on the silt loam, and 6.6. lbs Cu/acre on the sand
- ❑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.
❑Cu toxicities are more severe on sandy soil than silty soil, despite the lower soil test DTPA in the sand.

❑Potato plants grown on sandy soil textures absorbed copper more readily than silt loam textured soils.

❑At soil test Cu levels up to 375 ppm, tubers do not appear to pose any health risks.

❑Potatoes could **possibly** be used for remediation of Cu saturated soils.

❑It appears that potatoes are less sensitive to Cu toxicity compared to alfalfa and equally sensitive to Cu toxicity compared to corn.

## References

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