RESPONSE OF TURF AND AGRONOMIC CROPS TO NICKEL

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METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Protecting Our Water Environment

ABSTRACT

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A greenhouse study was conducted at the Metropolitan Water Reclamation District of Greater Chicago, Illinois during 2003-2005, to evaluate the phytotoxic threshold concentrations of various crops grown in a Watseka loamy sand (sandy, mixed, mesic Aquic Hapludolls) spiked with 0-50 (L set) and 0-250 (H set) mg kg^{-1} Ni. Each of the two sets was arranged in a randomized complete block design with three replicates. The L set planted with tomato (*Solanum*) and bean (*Phaseolus*) spp., and the H set with Kentucky bluegrass (*Poa*) and fescue (*Festuca*) spp. Nickel profoundly affected seed germination and root development in all species ($p<0.01$). Plant tissue Ni concentrations increased with rate of Ni used to spike soils. In *Solanum*, tissue Ni concentrations were in the order root>leaf>fruit. Dry matter yield, an index of plant performance, generally increased slightly in response to low tissue Ni concentrations (<40 mg kg^{-1}), and then decreased with additional tissue Ni increases. Phytotoxic threshold values (PT_{50}) were estimated for *Solanum, Phaseolus*, and *Festuca* spp. as 47, 125, and 133 mg kg^{-1}, respectively. At 50% relative root length, *Poa* root and leaf Ni were estimated at 110 and 115 mg kg^{-1}, respectively. Together with data from field studies on Ni uptake by these plants from biosolids-amended soil, data generated in this study may be useful in establishing guidelines for safe biosolids applications to agricultural soils.

RATIONALE

- Data on phytotoxic threshold concentrations (PTC) of Ni in edible crops are relatively scarce, but they are important for establishing land application rates of Ni associated with soil amendments such as biosolids.
- Nickel is an essential micronutrient for normal growth and metabolic functions of both plants and animals, but high concentrations can be toxic to both.
- Nickel phytotoxicity affects plant and root growth, resulting in stunted growth, chlorosis, and necrosis which all impact crop productivity.

OBJECTIVES

- To estimate a PTC for Ni in each crop species tested in this study, i.e. a tissue Ni concentration at which relative dry matter yields approach 50% (i.e. PT_{50}).
- To evaluate the effects of various tissue concentrations on root growth of *Poa* sp.
- To observe whether or not a crop may recover from early exposure to higher concentrations of Ni and resume normal growth and production.

MATERIALS AND METHODS

- Year 2003: Watseka loamy fine sand obtained from farm site at Kankakee County, Illinios. Soil air-dried and sieved.
  10 kg weighed into each of 27 pots (L set)
  15 kg placed in each of 24 pots (H set).
- Crushed Ni SO_4 salt applied to:
  L set, to supply 0, 5, 10, 15, 20, 25, 30, 40, and 50 mg kg^{-1} Ni
  H set, to supply 0, 10, 30, 50, 75, 100, 250, and 375 mg kg^{-1} Ni.

  Treatments thoroughly blended with each soil. Pots dampened and allowed to equilibrate for approximately 2 weeks. Initial low dose of NH_4NO_3 applied to assist in establishment of plants.
  Chemical characteristics of untreated Watseka soil included (Table 1).
- L set: 3 replications of 9 treatments arranged in a randomized complete block (RCB) design.
  - *Phaseolus vulgaris* L. cv Contender seeds treated with inoculum, and dried before planting. Harvested 62 days after planting (DAP).
  - *Solanum lycopersicon* L. cv Beefy planted. Harvested 78 DAP.

  H set: 3 replications of 8 treatments also arranged in an RCB design.
  - *Festuca arundinacea* L. cv Titan seeds sown. Harvested 69 DAP.
  - *Poa pratensis* L. cv Merit seeds sown. Harvested 86 DAP.
- Soil sampled from each pot at time of harvest.
  Root length of *Poa* sp. measured to evaluate Ni effect on root growth.
  Plant tissue samples rinsed with deionized water, dried to constant weight to obtain dry matter yields. Conc. HNO_3 digests analyzed for Tissue Ni.
  Mehlich 3 soil extracts analyzed by ICP technique (Methods of Soil Analysis, 1996).

Table 1. Chemical Characterization of Watseka loamy fine sand (from Kankakee County, Illinois) before application of Ni treatments in 2003.

Analyte	Conc	Analyte	Conc
	mg kg^{-1}		mg kg^{-1}
pH	6.3[a]	Cr	0.13
EC	0.09[b]	Cu	1.6
Organic C	0.30[c]	Mn	20
NH_4-N	14	Ni	0.41
Total P	410	Pb	4.8
Avail. P	202	Zn	2.8
CEC of soil	1.8 cmol kg^{-1}	Total Ni	3.2

[a]pH units; [b]Electrical Conductivity (dS/m); [c]Org C (%).
Metals and P extracted with Mehlich-3; Total Ni: HNO_3 digest; NH_4-N:1M KCl-extracted.

RESULTS

- In *Solanum, Phaseolus, and Festuca* spp., relative dry matter yields decreased with increasing tissue concentrations (r=-0.770, -0.916, and -0.986, respectively) (Figures 1, 2, and 3).
- Approximate tissue Ni concentrations associated with 50% relative yield reduction were of the order *Festuca>Phaseolus>Solanum* (Table 2).
- *Poa* sp. root length decreased with increasing root and shoot Ni (r=-0.970 and -0.978, respectively) (Figure 4).
  Approximate root and shoot Ni concentrations associated with 50% relative root length (Table 2) were 110 and 115 mg kg^{-1}, respectively (evaluation of Ni effect on root development, and NOT a PT_{50} index).
- Tissue Ni and Mehlich 3-extractable soil concentrations were all highly positively correlated (r=0.997, 0.963, 0.983, and 0.974 for *Solanum, Phaseolus, Festuca, and Poa spp.*, respectively) (Figures 5-8).

Observations:
- Seed germination was delayed by higher Ni spikes to soil, by as much as two weeks (data not shown).
- Generally, in both H and L sets, all plants in the two highest Ni spikes of each set died. Plants in the lower-dose spikes recovered, some better than others. Plants in the higher spikes of the H set exhibited some degree of resilience in the recovery process. As reported in previous studies, the survival rate of monocot exceeded that of dicot plants in Ni toxicity studies.

Table 2. PTCs for tissue Ni and associated Mehlich 3-soil Ni for *Solanum*, *Phaseolus*, and *Festuca* spp., and *Poa* tissue Ni at 50% relative root length, all grown in a Watseka loamy fine sand during 2004.

Crop sp.	PT_{50}	Mehlich-3 Soil Ni
	mg kg^{-1}	mg kg^{-1}
Solanum	47	5
Phaseolus	125	9
Festuca	133	22
	Tissue Ni	Soil Ni
Poa	110, 115[a]	24, 26[a]

[a]Root, shoot resp.

RESULTS (Continued)

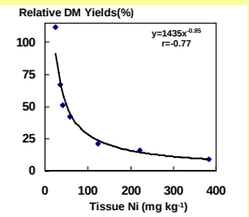

Fig 1. Solanum tissue Ni vs rel. DM ylds

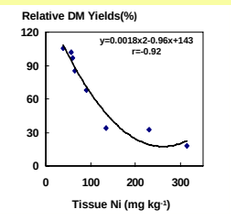

Fig 2. Phaseolus tissue Ni vs rel. DM ylds

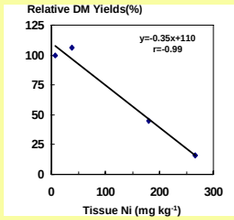

Fig 3. Festuca tissue Ni vs rel. DM ylds

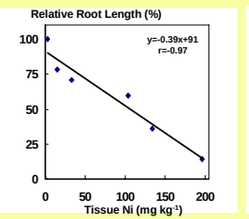

Fig 4. Poa tissue Ni vs rel. root length

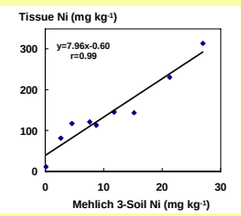

Fig 5. Solanum Tissue Ni vs M-3 soil Ni

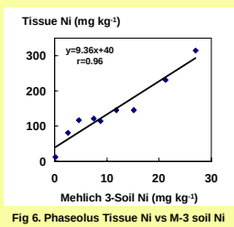

Fig 6. Phaseolus Tissue Ni vs M-3 soil Ni

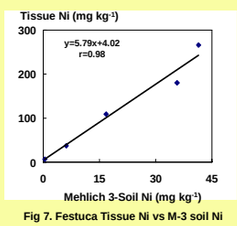

Fig 7. Festuca Tissue Ni vs M-3 soil Ni

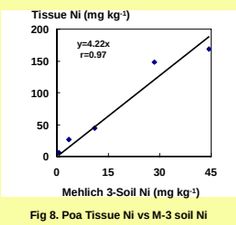

Fig 8. Poa Tissue Ni vs M-3 soil Ni

CONCLUSIONS

PT_{50} values were in the order *Festuca>Phaseolus>Solanum*.

Poa: Root growth affected by extractable soil Ni of approximately 25 mg kg^{-1}.

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