NICKEL AND TURFGRASS GROWTH: ALL YOU NEED TO KNOW

▲ **These two photos** show reduced growth with increasing Ni treatments from Clemson's toxicity study. Each one shows four representative plots of either Diamond zoysiagrass or TifEagle bermudagrass under Control, 400, 800, and 1600 uM Ni treatments. The reduction in clipping yield is significant and easy to see.

Turfgrass managers are always trying to leverage acceptable conditions with minimal inputs (water, nutrients, and pesticides). Maintaining optimal plant nutrition is the foundation of sustaining healthy turfgrasses that require fewer inputs. Liebig's Law of the Minimum states that plant growth is controlled not by the total amount of resources (nutrients) available, but by the most scarce resource (limiting factor). Due to the fertilization of macro and most micronutrients, this principle isn't usually a problem. However, there are trace micronutrients that play critical roles in the plant that we should consider, such as nickel (Ni). Nickel constitutes approximately 3% of the earth's crust and is the 24th most abundant element. Nickel is a trace micronutrient that was discovered to be essential for plants in the 1980s. Typical ranges of Ni in soils range from 5-500 ppm; however, measuring bioavailability in soils is difficult because the plant available form Ni2+ readily oxidizes in the soil rendering it unavailable. Nickel is commonly forgotten in the world of turfgrass nutrition because of the low concentration found in plants (0.05-10 ppm) which is thought to be adequately provided by the soil. However, Liebig should not be disregarded when it comes to Ni and turfgrass.

NICKEL BIOAVAILABILITY

Sports turf grasses are commonly grown in conditions conducive to reduced bioavailability of Ni:

• Dry and/or cool soils in early spring, (Common throughout the Carolinas)

• Soil pH > 7, (Limestone based calcareous sands, which are commonly used for turfgrass root zones typically have pH values in the 8.2 range

• Sandy and or low CEC soils (Putting greens, tees, and frequently top-dressed playing surfaces)

In addition, the following management factors influence Ni bioavailability:

• The presence of root-knot nematodes (Meloidogyne sp.) (Root-knot nematodes are not as damaging to turfgrass as sting or lance nematodes but are still commonly found in soils and can contribute to reduced Ni bioavailability)

•Exceedingly high concentrations of Zn, Cu, Mn, Fe, Ca, and Mg, (Rooney et al., 2007; Wood et al., 2006) (Many constructed root zones are derived from calcareous sands. Additionally, liming materials and other Ca sources (gypsum) are commonly applied in turfgrass management increasing Ca in the root zone)

• Ni deficiency was triggered in pecan with foliar applications of Fe, and heavy early spring application of N. (Turfgrass managers commonly fertilize with both of these nutrients to correct deficiencies and improve turf color.)

Ni TOXICITY, DEFICIENCY, HYPERACCUMULATION, AND PLANT DEFENSE

Minimal information exists on Ni toxicity and deficiency for turfgrasses. However, by way of other plant research, we can make some conclusions about Ni. One of the most well documented Ni deficiency cases has been in pecan trees, in which the deficiency caused a disruption in carbon metabolism resulting in stunted growth leaves termed "mouse ear." Foliar sprays of Ni corrected the deficiency, but only in newly emerged leaf tissue. The diagnosis and management has brought to surface the importance of Ni in plant health and suggests the possibility that many horticulture crops may possess a "hidden hunger" for Ni.

Plants found growing on serpentine soils containing elevated levels of metals (Zn, Cu, Co, Fe, Cr, Mg, and Ni) can hyperaccumulate Ni without deleterious effects. Nickel hyperaccumulator species have been studied for their potential in the phytoremediation of soils contaminated with metals by industrial processes. It is hypothesized that these hyperaccumulators evolved to exploit high soil Ni concentrations to enhance plant defenses from herbivory and disease.

NI NUTRITION AND UREA NITROGEN METABOLISM

Nickel is a highly mobile element in the plant due to chelation with organic molecules and tends to accumulate in newly formed tissue. Several enzymes in biological systems require Ni as a catalyst; however, the most well-known role of Ni in plant metabolism is its function in the activation of the enzyme urease. Urease hydrolyzes (breaks down) urea into ammonia and carbon dioxide. The hydrolysis of urea by the Ni dependent enzyme urease is necessary to make the nitrogen (N) in urea available to plants. Urease cannot work if it is not accompanied by Ni. Urea is the most popular N source in management due to its solubility, high percentage of N, low price, and ease of handling. Urease and Ni are also important for plants being fertilized with other N sources (nitrate and ammonium) because of the need to cycle urea generated as a byproduct of metabolic processes within the plant. Nickel deficiency has been recorded in several species and leads to an accumulation of urea in leaf tissue causing toxicity, foliar burn, and inefficient urea-N use. Research has determined that plants can directly absorb urea through urea specific channels and aquaporins (water channels found in cell membranes), which changes the previously hypothesized view that urea-N was absorbed by the plant only after being hydrolyzed by urease in the soil or plant surface. Soil urease inhibitors have been thoroughly researched and employed to limit gaseous N loss by ammonia volatilization after hydrolysis. However, the directly absorbed urea from leaf surfaces is directly hydrolyzed by urease in the plant tissue before being assimilated into organic N containing compounds.

Nickel nutrition

- Very little is known about Ni nutrition and fertilization of turfgrasses.
- Due to the extensive use of urea and the necessity of Ni in urea N metabolism, further research is required to determine best management practices for foliar urea N fertilization and supplemental Ni fertilization.
- Increased leaf tissue growth due to Ni supplementation was observed in 'Diamond' zoysiagrass and 'TifEagle' ultradwarf bermudagrass during research at Clemson University.
- Nickel is an essential plant micronutrient
- The reduced Ni bioavailability in common turfgrass management scenarios requires further research to determine Ni sufficiency and deficiency ranges
- Nickel is required for functional urease activity in plants
- Urease is a Ni dependent enzyme that hydrolyzes urea making the N available to plants
- Urease and Ni are important in the cycling of urea generated within the plant and can reduce urea toxicity (foliar burn)

CURRENT RESEARCH

Research conducted at Clemson University reported increases in urease activity, amino acid content, and growth of 'Diamond' zoysiagrass and 'TifEagle' bermudagrass fertilized with foliar urea and supplemental Ni. Plants not receiving supplemental Ni contained <1 ppm Ni in leaf tissue, whereas Ni supplemented plants accumulated up to 17 ppm by the conclusion of the study. At this concentration, no toxicity symptoms were observed. In a second study at Clemson University, Ni toxicity was examined in the same species. Symptoms of toxicity progressively increased as Ni concentration reached 100 ppm and resulted in growth reductions up to 32% in 'TifEagle' at the highest Ni concentration supplied. Due to these findings, 'Diamond' and 'TifEagle' are considered moderately tolerate of Ni and further research should be conducted to measure the effects of Ni supplementation and toxicity of other commonly used turf species.

FUTURE PROSPECTS

Not much is known about other roles Ni plays in the plant and current research is lacking in most agricultural crops including turfgrass. However, from the limited research already conducted, increases in growth and plant health with supplemental Ni nutrition have been recorded. Future research is required due to the popularity of urea as an N source in turfgrass management and strong relationship with the Ni containing enzyme urease that makes the N available to the plant. Further, several questions have been raised concerning Ni nutrition and turfgrass management: Can turf be established more quickly (seeding, sprigging) when supplemental Ni is applied? Are there synergistic effects with pesticides to reduce total inputs and improve plant health? What are the long-term ecological impacts of Ni supplementation? Can Ni supplementation improve urea N use efficiency and does it improve foliar uptake? Can increased Ni concentration in foliage inhibit herbivory? Is there enough Ni bioavailable for turfgrasses that supplementation is not necessary?

Currently, no Ni fertilizer sources are marketed for turfgrass, while other micronutrients with similar concentrations within the plant (Mo) are commonly included in liquid micronutrient products. Only one Ni fertilizer is currently marketed (Nickel Plus, Nipan LLC.) for use in pecan. To investigate Ni nutrition and possible turfgrass deficiency, an estimate of Ni input needs to be determined for managed turfgrass surfaces. Additional research determining bioavailability in turfgrass scenarios also needs to be conducted to examine if Ni supplementation would be beneficial. ■

Dr. Nick Menchyk is Postdoctoral Fellow, School of Agricultural, Forest & Environmental Sciences, Clemson University. Dr. Dara Park is Assistant Professor, School of Agricultural, Forest & Environmental Sciences, Clemson University. Dr. Haibo Liu is Professor, School of Agricultural, Forest & Environmental Sciences, Clemson University References for this article can be found on www.sportsturfonline.com.