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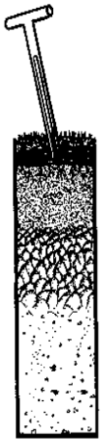


THE SOIL PROFILE

A newsletter providing information on issues relating to soils and plant nutrition in New Jersey

Volume 27 2022

Nickel Nutrition and Soil Fertility Research at Rutgers NJAES

In soil fertility and nutrient management, agronomists and growers are often so focused on the big three – Nitrogen, Phosphorus, and Potassium – such that micronutrients become an afterthought. This seems especially so in the case of Nickel (Ni). It is required in such small amounts by plants it is sometimes called a nano-nutrient.

The classification of Ni as an essential nutrient for plants is relatively recent (Brown et Al., 1987). Essential in this context means that a plant cannot complete it normal lifecycle and reproduce without this specific element. Another criterion for essential is the element is a constituent of an essential plant molecule and is not replaceable by another element.

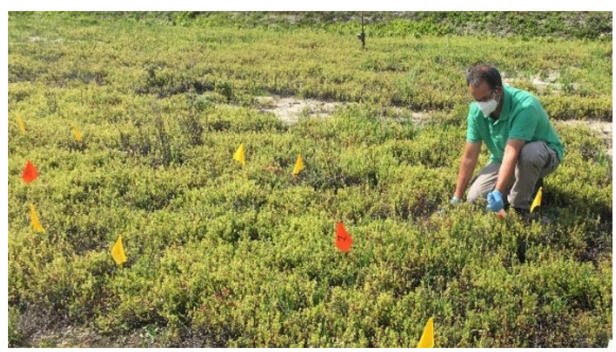
There are eighteen elements (H, C, O, N, P, K, S, Ca, Mg, B, Cl, Cu, Co, Fe, Mn, Mo, Zn, and Ni), out of the approximately hundred elements listed on the periodic table, that are classified as essential for plant nutrition. Certain other elements may be beneficial or only essential to a few plant species. Silicon for example, it is considered quasi-essential because the element benefits plants, but has not been clearly established as essential to all plant species (The Soil Profile 2012, Silicon and Soil Fertility).

The amount of Ni required by plants is very small. A tissue concentration of less than 0.5 ppm on a dry matter basis is regarded as sufficient for most plants. Many soils contain an abundance of Ni (about 5 lb./acre). However, total content of a nutrient in soil often does not translate into availability for plant uptake.

Nickel deficiency was first reported on farms in pecan orchards. Woody plants or tree crops in general appear to have a higher requirement for Ni. Legumes also have a high requirement for Ni. Besides, pecan, the deficiency has been observed on river birch trees, peach, English walnut, citrus trees, and hydrangea.

Nickel Nutrition Research

A new USDA-SARE funded project on Ni nutrition is underway at the Rutgers NJAES Philip E. Marucci Center for Blueberry and Cranberry Research. This study is investigating appropriate levels Ni fertilizers to be applied to soil or cranberry foliage and the potential to suppress plant diseases such as fruit rot.



Dr. Alon Rabinovich, a postdoctoral researcher working in collaboration with Dr. Heckman's Soil Fertility Research & Extension program, is shown above applying Ni as a foliar fertilizer treatment to cranberry plants.

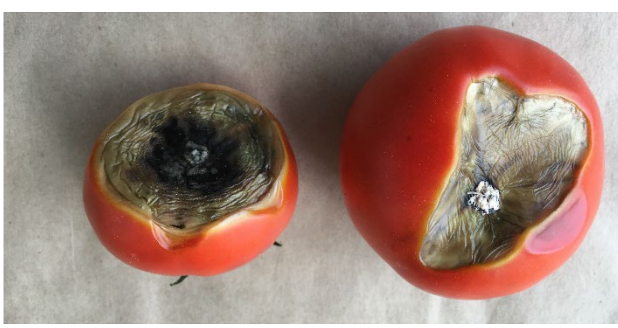
Since little is known about the Ni nutritional status of plants and soils in New Jersey, we decided to conduct a survey. Tree crops in the spring were from several locations in the piedmont and coastal plain (Hunterdon, Middelesex, and Monmouth counties). The young leaf tissue samples were collected from pecan trees May 19, 2022.

Dr. Alon Rabinovich shown (right column) sampling pecan leaves from a step ladder. Six pecan trees were sampled, and soil samples were collected under the drip line of each tree.

Soil and plant tissue testing for Ni was performed using method- EPA 3051 microwave digestion assisted elemental analysis. A 0.1g of sample of each plant or soil was analyzed. The samples were digested in microwave pressure using nitric acid HNO_3 for 1h, then analyzed with ICP-MS for multielement (ICP-MS, Lab Meadowland Environmental Research Institute).

Pecan leaf Ni concentrations ranged from 3.5 to 28.1 and averaged 11.3 ppm. Soils ranged from 3.4 to 9.9 and averaged 6.4 ppm. A few apple, peach, and hazelnut trees were also sampled and had tissue Ni concentrations within a similar range as pecan. At this stage of research there were no clear signs of Ni deficiency. However, the Ni survey data is preliminary and open for further investigation.

A recent publication from scientists in Brazil (Giovannetti Macedo et al., 2021) suggests that Ni may play a role in protecting tomato fruit from a disorder known as blossom end rot.



This is a common physiological disorder on tomato and pepper crops related to Ca nutrition. Drs. Rabinovich and Heckman are beginning an investigation on how Ni nutrition may protect vegetable crops from blossom end rot when grown on New Jersey soils.

Functions of Nickel

In 1975 it was discovered that Ni is a component of the urease enzyme in plants. This enzyme enables plants to metabolize urea. Some species transport N as ureides and plants naturally recycle some N internally with urea as an intermediate. When plants are deficient in Ni, urea may accumulate to toxic levels and cause injury to leaf tissue.

Urea fertilizers are commonly applied to soil or sprayed on foliage to supply N. Crops fertilized with urea may have an increased requirement for Ni.

Nickel is beneficial to legume crops because the element is required by rhizobia bacteria that enabled inoculated plants take N from the atmosphere and convert it into use for plant nutrition.

There is still much to be learned about the role of Ni in plant nutrition and protection against environmental stress and disease. Besides the role of Ni with urease to metabolize urea, Ni activates several other enzymes. Some studies suggest that Ni confers protection against environmental stresses and fungal diseases.

Causes of Nickel Deficiency

Given the essential role of Ni to urease, and that urea has become a widely used fertilizer, there is a potential for Ni deficiency in field environments. Nickel deficiency can occur over a wide range of soil pH conditions (acid or alkaline) but becomes more likely at pH levels above 6.7. A major factor influencing Ni deficiency is competition for uptake with other metal cations. High levels of Zn, Fe, Mn, and Cu compete with uptake of Ni. Heavy and repeated applications of micronutrient fertilizers may induce a Ni deficiency. Calcium and Mg may also compete for uptake. Root damaging nematodes is another factor that my limit Ni uptake.

Nickel Diagnostics

Nickel is a mobile nutrient within plants, and it tends to accumulate in seeds. In tree fruit crops, tissue analysis is normally performed in mid-summer to evaluate mineral nutritional status. But for Ni diagnostics, mid-summer is too late; sampling young leaves in spring is recommended. Possible interactions with other elements should be considered when assessing Ni nutritional status.

Nickel is regarded as deficient when tissue concentrations (ppm or mg/kg dry matter basis) are less than 0.85 in pecan, 0.1 in barley, oats, and wheat, and 0.2 in cowpea.

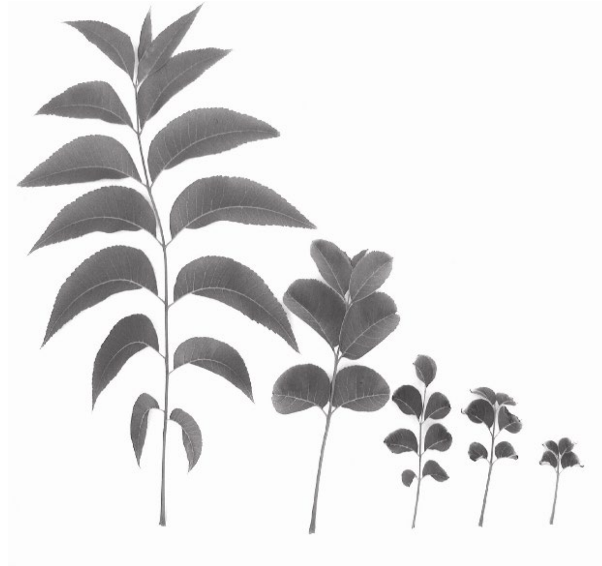
Standards for Ni deficient soils have not been established and most soil test labs do not routinely test for Ni. The Rutgers Soil Test Laboratory uses the Mehlich-3 method to test for several micronutrients (Zn, Cu, Mn, B, and Fe) and does not test for Ni. However, certain soil test parameters may be indirectly useful for diagnostic purposes. For example, a soil pH above 6.7 may suppress Ni availability. Also, exceptionally high soil test levels for other micronutrients may depress Ni uptake.

Symptoms of Nickel Deficiency

Visual symptoms of Ni deficiency are not common but there may be "hidden deficiencies" that reduce crop yield without grower awareness.

Deficiency symptoms are well described for pecan trees as "mouse ear little leaf" where it is exhibited as a growth abnormality with reduced leaf size or blunting of leaf tips.

Photos below of Ni deficiency in this newsletter are from Dr. Bruce Wood, USDA, ARS.



Nickel deficiency symptoms are exhibited on pecan as reduced leaflet size as the severity of the deficiency increases.

The photo below is a pecan tree exhibiting Ni deficiency on the right branches (untreated). The branches on the left side were treated at budbreak with a foliar spray of Ni (as nickel sulfate at 100 mg of Ni per L). Photo was taken five weeks after budbreak.

The deficiency tends to be more severe on the upper tree canopy and during the period of rapid leaf growth. Where Ni deficiency is severe, leaves may exhibit necrosis – possibly due to toxic accumulation of urea.

Other symptoms of Ni deficiency that may be exhibited include wrinkling of leaves and brittleness, blunting of leaf tips, chlorosis (which may be mistaken for Fe or Zn deficiency), loss of apical dominance, reduced length of internodes, distortion of bud shape, brittle shoots and limbs, wind breakage, and reduced crop yield.

On leguminous crops Ni deficiency may be exhibited as leaf chlorosis, stunting and reduced leaf expansion.

Prevention of Nickel Deficiency

Under most field conditions, Ni deficiency is probably uncommon. The amount of Ni required by crops is smaller than for any other plant nutrient. However, because Ni has a very important physiological role in urea metabolism, the common use of urea-based fertilizers increases the need for Ni. Tree crops and nitrogen-fixing crops in general have a higher demand for Ni.

Although Ni is relatively abundant in many soils the deficiency might occur if other micronutrients are supplied in excess. Also, excessive application of limestone could raise soil pH to a level that could make Ni deficiency more likely. Thus, be careful when applying Zn, Cu, Mn, or Fe fertilizers and limestone.

Nickel Fertilizers

The amount of Ni fertilizer required to correct or prevent a deficiency is very small. Application of nickel sulfate or other soluble Ni fertilizers such as nickel phosphite, nickel nitrate, or nickel chloride are suitable sources. Organic Ni complexes or chelated forms of Ni, such as nickel EDTA, also may be used. Nickel may be supplied to soil as a blend with other fertilizers or as spray onto plant foliage. When applied as a foliar fertilizer, a concentration of 0.03 to 0.06 ppm of Ni is recommended. When applied to the soil, the application rate should not exceed 0.5 lb./acre of Ni.

Some sewage sludges or biosolids contain high concentrations of Ni and are potentially phytotoxic.

Acknowledgements

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References

Arnon, D. I., and P. R. Scott. 1939. "The Essentiality of Certain Elements in Minute Quantity for Plants with Special Reference to Copper." Plant Physiology 14:371–375.

Bai, C., C. C. Reilly, and B. W. Wood. 2006. "Nickel Deficiency Disrupts Metabolism of Ureides, Amino Acids, and Organic Acids of Young Pecan Foliage." Plant Physiology 140:433–443.

Barker, A. V., & Pilbeam, D. J. (2015). Handbook of plant nutrition. CRC press.

Brown, P. H., R. M. Welch, and E. E. Cary. 1987. "Nickel: A Micronutrient Essential for Higher Plants." Plant Physiology , 85:801-803.

Datnoff , L.E. 2007. Mineral Nutrition and Plant Disease. APS

Eskew, D. L., R. M. Welch, and E. E. Cary. 1983. "Nickel: An Essential Micronutrient for Legumes and Possibly All Higher Plants." Science 222:622–623.

Eskew, D. L., R. M. Welch, and W. A. Norvell. 1984. "Nickel in Higher Plants: Further Evidence for an Essential Role." Plant Physiology 76:691–693.

Fernando Giovannetti Macedo, Wanderley José De Melo, Denise De Lima Delarica, Renata Beatriz Cruz, Elcio Ferreira Santos, Gabriel Maurício Peruca De Melo, Ben Hur Mattiuz, Mara Cristina Pessôa da Cruz & Arthur Bernardes Cecílio Filho (2021): Nickel increases productivity, Ca accumulation and reduces blossom-end rot in tomato, Archives of Agronomy and Soil Science

Wood, B. W., C. C. Reilly, and A. P. Nyczepir. 2004. "Mouseear of Pecan: A Nickel Deficiency." HortScience 39 (6): 1238–1242.

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