The Effect of Phosphorus on Nickel and Zinc Uptake in Red Lettuce Leaves

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Abstract

Varying levels of phosphorus were added to separate samples of lettuce plants. In addition to the phosphorus, a controlled amount of nickel and zinc in solution were added to all the samples. The metal concentrations and distribution in the leaves were analyzed using the APS. Since phosphorus is linked to root growth, it was expected that the phosphorus would increase the amount of metal found in the lettuce leaves. Excess levels of Phosphorus have also proven to be a deterrent to metal uptake within a plant. Thus, the effects of adding phosphorus in relation to metal absorption would reach a peak. After this point, increasing the levels of phosphorus would no longer have a positive correlation with the metal absorption. By finding the range of peak metal absorption, it may be possible to determine the optimal amount of phosphorus. It was found that the plants that received the highest level of phosporous absorbed more Zn as well other trace metals in the soil. The results for Ni were inconclusive.

Introduction

Many household fertilizers are composed of varying concentrations of nitrogen, phosphorus, and potassium. Of those three elements, phosphorus is the most limited in plant soil, due to the naturally occurring "phosphorus cycle". The phosphorus cycle is among one of the slowest of all matter cycles thus, absorbing optimal levels of phosphorus naturally is difficult for plants. Phosphorus in phosphate form, is an integral component of nucleotides, that store energy in the cell and thus assists the plant in storing and transferring energy. Phosphorus also promotes root growth, thus plays a major role in the metal uptake in the roots. However, if the concentration is too high, the excess phosphorus will not give any additional assistance and inhibits metal uptake by the plant. This means that for most plants, there is an ideal amount of phosphorus needed to help growth. With this information crop growers are able to determine the desirable amount of phosphorus in their fertilizers for optimal growth.

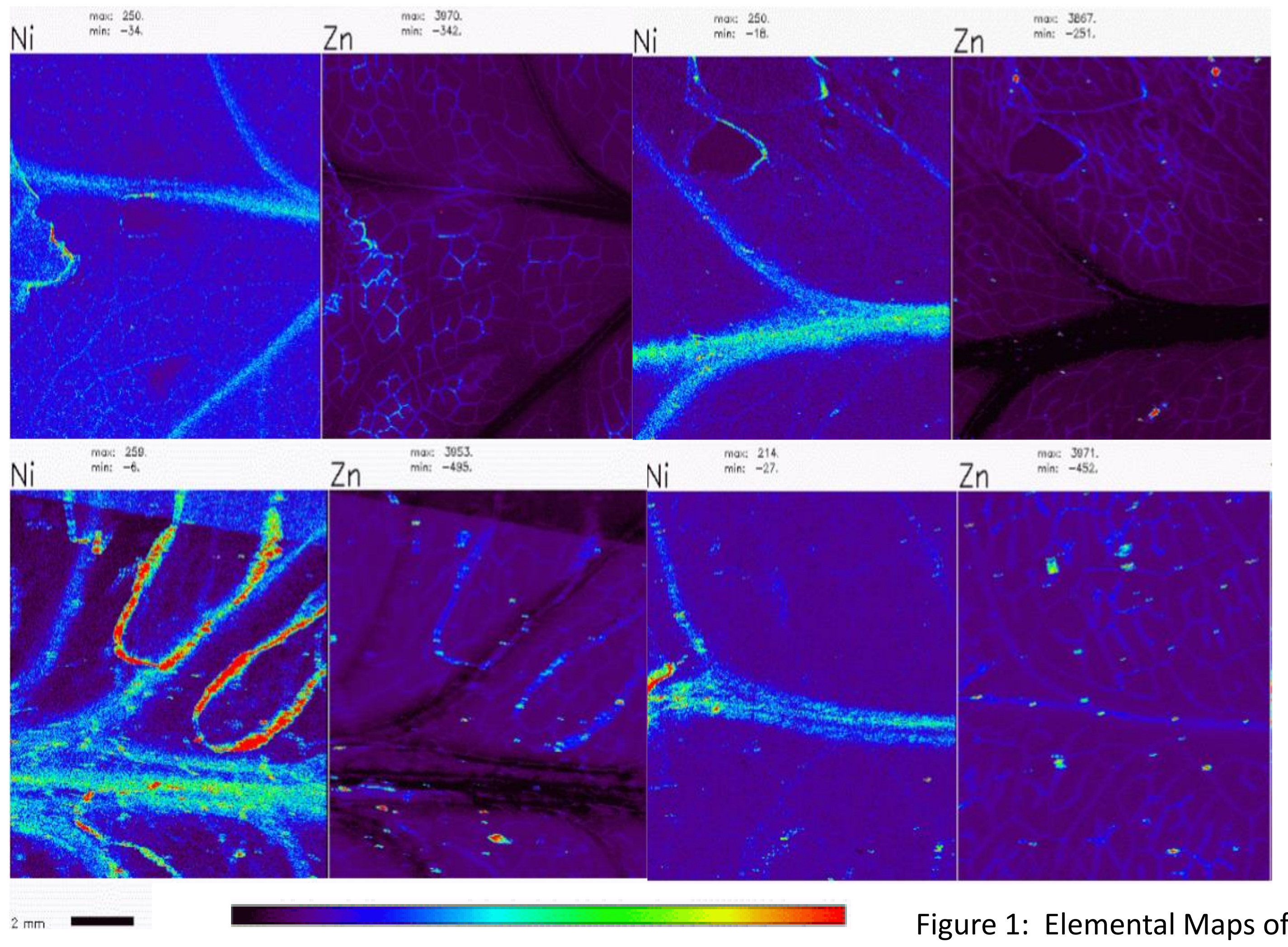
Procedure

A watering system was created through the use of plastic water bottles cut in half with the top half inverted. Equal amounts of the same organic potting soil was added to the top with *Lactuca Sativa* seeds planted inside. A wicking system was created with a string, initially giving the plants water for 23 days. Then, 4 separate solutions were diluted from the stock solutions of .25 M NaH_2PO_4, .25 M $NiSO_4 \bullet 7H_2O$, and .25 M $ZnSO_4 \bullet 7H_2O$ and replaced the water in each reservoir. These solutions had constant concentrations of each metal hydrate at $3x10^{-5}$ M, with the independent variable being NaH_2PO_4 concentrations. There were 3 plants for each varying level of NaH_2PO_4. The different concentrations of NaH_2PO_4 tested were: 0 M, $3x10^{-3}$ M, $6x10^{-3}$ M, and $1.2x10^{-2}$ M. These levels were chosen based on the assumption that the optimal level of Phosphorus is 0.01-0.1 ppm per acre, which was calculated to equate to $6x10^{-3}$ M in our soil. The solution reservoirs were refilled and the plants were watered as necessary for 34 days before being brought into Argonne.

At the Advanced Photon Source at Argonne National Laboratory, the healthiest leaf from a plant of each of the four varying NaH_2PO_4 concentrations was prepared and mounted to the bracket with Kapton Window Film, made of minimally fluorescent material, with the midrib centered. The bracket was then mounted onto the sample stage, which was placed at a 45 degree angle to the beamline. The Double Multilayer Monochromator was used to provide incident x-rays of 11.1 keV to the samples. These x-rays were focused using K-B mirrors to a spot size of 30 microns, through which the samples were raster-scanned in fly-scan mode. The fluorescence emission spectrum was collected at each pixel using a SII Vortex ME4 silicon drift detector, and the data was transformed into images via MAPS software. The data was then fitted and sent for interpretation and analysis to obtain results.

Results

Greater concentrations of phosphorus yielded higher concentrations of heavy metals in the leaf samples generally, even when the levels of phosphorus are well over the recommended levels. The only exception is that a drop in Nickel concentration was observed between the 0.006 M and 0.012 M concentrations. A possible explanation for this is that the excessive concentration of phosphorus may have stunted the uptake of Nickel. The Nickel was found predominantly in the midrib of the leaf, while the Zinc was concentrated in the sublateral veins. It is also important to note that the dense, dark spots represent rips in the leaf samples, and some of the splotches of color near the edges represent the edges of the plant folding over. Due to the 0.006 M and 0.012 M leaf samples having different sized midribs and veins, the ability to generalize metal uptake based on the compositional maps is limited. As the size of the midrib increased, more of each metal was present in the midrib. It is also difficult to make comparisons between Nickel and Zinc uptake--primarily because the count limits were different for each metal, and the hazardous concentration varies. Although none of these substances were added to the watering solution, the Element Distribution Map also showed increased concentrations of Calcium, Sulfur, and Iron as phosphorus content increased.



Row 1: Control (Left) & 0.003 M P (Right)

Row 2: 0.006 M P (Left) & 0.012 M P (Right)

Figure 1: Elemental Maps of Ni & Zn

Figure 2: Experiment Set-up

Conclusion

Metal uptake in the plants increased with increased phosphorus. Nickel and zinc concentrations were observed to be more abundant in plants that were given more phosphorus. Calcium, sulfur, and iron also increased with more phosporous. However, nickel was a possible exception to this, because results were inconclusive. This unbounded increase in metal uptake contradicts the hypothesis that too much phosphorus will inhibit uptake. To better understand this relationship between phosphorus and metal uptake, similar experiments should be run to determine if there is a point at which phosphorus content is high enough to inhibit metal uptake, as it is possible that the phosphorus levels tested in this experiment were not high enough to reach a peak level of uptake. A larger number and range of samples with better image normalization would be required to develop an exact relationship between these variables. Another potential issue with the reliability of our collected data is that the samples dried up over the twelve hour scanning period and the leaves were of different sizes. Drying had a greater effect on the results for higher P concentrations because these were scanned last. In future experiments, cryogenically preparing the samples may prevent them from drying out and leaves should be of a consistent size.

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