A Note on the Effect of Soil Reaction and Zinc Concentration on Peanut Tissue Zinc[1]

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ABSTRACT

Zinc uptake by peanuts (*Arachis hypogaea* L.) is affected by both soil pH and extractable Zn concentration, but the combined effect of these two factors is not well defined. An experiment with lime rates was conducted using NC 7 peanuts that showed an exponential decrease in leaf Zn as the soil pH increased from 4.3 to 6.1. The decrease was very rapid when the soil was more acid, and less rapid as acidity decreased. Plant Zn was also shown to increase quadratically with increasing soil Zn with a data set from Georgia. These two relationships were combined, assuming no interaction exists, to be able to predict peanut tissue Zn as a function of both soil pH and extractable Zn with either the Mehlich-1 or Mehlich-3 solutions. Equations are presented that conform closely with currently assumed values of critical deficient and toxic concentrations in the tissue and soil for peanuts. These should be especially helpful in predicting potential toxicities over a range of pH and soil Zn levels.

Key Words: Soil testing, Zn toxicity, Soil pH, *Arachis hypogaea* L.

Peanuts are more sensitive to high soil Zn than most agronomic crops. The author has observed Zn toxicity symptoms in peanuts grown on soils where corn and cotton have not shown any indication of stress. The high Zn conditions have usually been caused by contamination from a galvanized roof or fence and have been quite localized. These sites have usually been too small for detailed research on factors affecting the Zn content of plant tissue.

Another source of Zn that is being used more extensively is municipal sewage sludge. This material must be disposed of in an environmentally safe fashion and land application is becoming more common. Zinc toxicity also has been observed by the author recently in a field that received a single application of sludge several years before, but the field had become quite acid.

Research has shown that increasing the soil pH will decrease the activity of Zn, hence decrease its uptake by plants (6). Previous regional research with corn and rice did not show a soil pH effect on plant Zn concentration but the pH values were all quite high (2). Current soil tests used in Virginia include the effect of soil pH when evaluating Zn availability (1). Similar results have been shown under North Carolina conditions (4). Most of the research on this subject, however, has been concerned with evaluating Zn deficiency of corn. In order to predict the amount of Zn absorbed by peanuts, the relationships between Zn uptake and both soil pH and extractable Zn must be determined.

In the current report, data will be presented on the effect of soil pH on the Zn concentration of peanut leaves. These data are from a site with a low level of soil Zn. Next, a set of data from Georgia (5) will be re-evaluated to present this author's interpretation of the effect of soil Zn concentration on the Zn content of peanut plants. Finally, soil pH and extractable Zn will be combined in an equation to predict the Zn concentration of peanut tissue.

Materials and Methods

A lime study was initiated on a Goldsboro soil, a fine-loamy, siliceous, thermic Aquic Paleudult, at the Peanut Belt Research Station, Lewiston, North Carolina in 1982. Due to acidification over time, the plots were limed again prior to the 1987 crop. In 1988, NC 7 peanuts were grown. Leaf samples were collected just before landplaster application (June 28) and analyzed for elemental content by ICP. Soil samples were taken to 20 cm at the same time and analyzed by the North Carolina Department of Agriculture Soil Testing Laboratory for pH and soil Zn. Soil reaction was determined, after a 30 min equilibration, in a 1:1 soil:water stirred suspension. Mehlich-3 extractable Zn (7) was determined by atomic absorption.

Keisling *et al.* (5) evaluated the effect of soil Zn concentration on the Zn concentration in the above-ground portion of peanut plants in Georgia. Soil Zn was extracted with the Mehlich-1 solution and reported on a weight basis after assuming that the samples weighed 1.25g/mL (10). They presented data from field experiments and from paired samples from problem field areas. This data was pooled and a new curvilinear relationship between tissue and soil Zn calculated. Their curve was forced through the

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origin.

The prediction equation using Mehlich-1 extractable Zn was multiplied by 1.29 to equal the Mehlich-3 equivalent. This allowed the equation to be used by states that use the Mehlich-3 extractant. The 1.29 factor is an average taken from a report of the 1988 joint meeting between the southern and north-central regional committees on soil testing and plant analysis in which 4 soils were analyzed by the two methods at a number of state soil testing laboratories. Sims (9) also found that the slope of the relationship between Mehlich-3 and Mehlich-1 extractable Zn was 1.29 using four soils from Delaware.

Results and Discussion

The means of the lime treatments in this study resulted in a wide range of pH values, from 4.6 to 5.8. The pH range from individual plots was slightly greater, from 4.3 to 6.1. Mehlich-3 extractable Zn averaged 2.4 mg/L. There was also a wide range in leaf Zn from the individual plots, from 23 to 163 mg/kg.

There was a distinct relationship between leaf Zn and soil pH (Fig. 1). At low pH, tissue Zn was very high. With increasing pH, leaf Zn decreased rapidly at first, then more slowly. This exponential function approached an asymptote of 24.8 mg/kg. A prediction equation effective for soil pH values greater than 4.2 was fit to the data with the NLIN procedure in SAS (8). That equation is

$$Y = 24.8 + 201\exp(-2.36(pH - 4.2)) \quad [1]$$

in which Y is the leaf Zn concentration and pH is the soil pH.

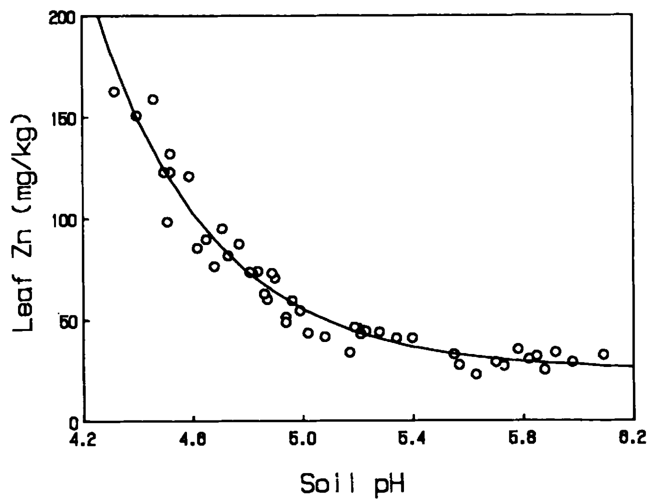

Fig. 1. Effect of soil pH on the leaf Zn concentration of peanuts grown on a Goldsboro soil in North Carolina.

The observations made by Keisling *et al.* (5) relating peanut plant Zn to soil Zn are shown in Fig. 2. There is considerable scatter in the data, which is often observed with very high soil and tissue levels of a nutrient. The highest point shown in Fig. 2 represents the mean of seven samples where plants were showing Zn toxicity. Including this value made it obvious that the relationship was not linear. A prediction equation was first made with a standard quadratic function, but, due to the large variation, it had an unrealistically large intercept term. This term was eliminated by forcing the equation through the origin and the prediction became

$$Y = 26.7M1Zn - 0.565(M1Zn)^2 \quad [2]$$

where Y is plant Zn concentration (mg/kg) and M1Zn is Mehlich-1 extractable Zn (mg/kg).

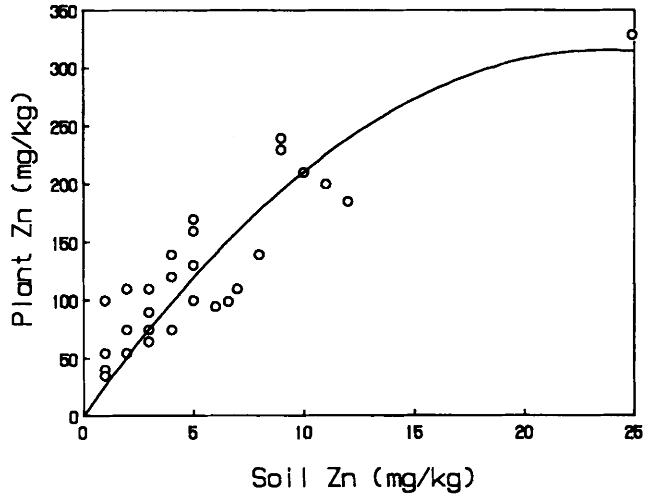

Fig. 2. Effect of Mehlich-1 extractable soil Zn on the plant Zn concentration of peanuts grown in Georgia (data from Keisling *et al.*, 1977).

Although there is considerable scatter in the data shown in Fig. 2, the prediction equation seems to fit fairly well. It would be more reasonable, or logical, to have used an exponential function on the data, but until better relationships are obtained, it did not seem worthwhile to use non-linear statistics.

Equations 1 and 2 can be combined to make peanut tissue Zn a function of both soil pH and Zn concentration., In doing so, the asymptote, 24.8 in this case, must be adjusted. This can be done by setting the tissue Zn at 20 mg/kg for pH 6 and 0.8 mg/kg soil Zn. The latter value is taken from the critical level found in the Southern Regional Study by Cox and Wear (2), and the value of 20 is assumed to be near the plant critical level. This makes the combined equation

$$Y = 201\exp(-2.36(pH-4.2)) + 26.7M1Zn - 0.565(M1Zn)^2 - 4 \quad [3]$$

with the terms as previously defined. At pH 6 and 12 mg/kg M1Zn, the predicted tissue Zn concentration is 238 mg/kg. Keisling *et al.* (5) placed tentative Zn toxicity critical values at 12 and 220 for the soil and plant, respectively. Although they did not give the pH conditions for their data, it must have been near 6, so the current predicted value of 238 is quite close to the 220 mg/kg that they found.

It should be noted, however, that the prediction from the current study was based on leaf analyses, while that of Keisling *et al.* (5) was based on above-ground plant analyses. The relationship between leaf and plant Zn over such a range in Zn concentration is not known. Hallock *et al.* (3) found little difference in the Zn concentrations of main stem portions and leaves from the first lateral branch, but the former tended to be greater. It was assumed valid, therefore, to combine the equations into one that simply refers to the Zn concentration in peanut tissue.

An equation predicting tissue Zn from soil pH and Mehlich-3 extractable Zn can be obtained by taking Equation 3 and converting the terms associated with Mehlich-1 extractable Zn with the factors listed in the Materials and Methods section for assumed sample density and the relationship between the effects of the two extractants. Doing this results in the following prediction equation for peanut tissue Zn:

$$Y = 201\exp(-2.36(pH-4.2)) + 16.6M3Zn - 0.217(M3Zn)^2 - 4 \quad [4]$$

At a pH of 6, Mehlich-3 extractable Zn would have to be slightly over 17 mg/L to reach the predicted tissue toxicity level of 220 mg/kg. If the pH drops to 4.5 , however, that plant concentration would be reached at a soil level of only about 8.5 mg/L.

Combining these equations to assess the effects of soil pH and extractable Zn on plant uptake is the best that can be done with the information currently available. There may be an interaction between these two factors, though. If so, there could be a much more striking effect of pH at high soil Zn levels. With the current equation, the effect of pH is the same regardless of the soil Zn level. Further research is needed to determine an interaction, if one exists, between the effects of soil pH and Zn concentration on the Zn content of peanut tissue. Further research is also needed to relate concentrations of other nutrients, especially Ca (M. B. Parker, 1989, personal communication), to the critical level for Zn toxicity. Until such research is done, however, the equations given above should be especially useful for detecting potentially toxic Zn conditions for peanut production.

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