EFFECTIVENESS OF SOIL-APPLIED ZINC FOR PECANS

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ABSTRACT

Pecan trees [*Carya illinoinensis* (Wangenh.) K. Koch] are very sensitive to Zn deficiency when grown in alkaline soils due to the formation of insoluble Zn hydroxides and carbonates which have low availability to pecan roots. We tested the efficacy of soil applied Zn-EDTA, Zn-Avail®, and $ZnSO_4$ plus animal manure for supplying Zn to young pecans. Zn-EDTA supplied adequate Zn to potted pecan trees for one season only. The other soil Zn treatments had no appreciable effect. A soil sorption study showed that sorption of Zn-EDTA was negligible. Zn-Avail® reduced soil sorption; animal manure did not. In a field study 2.4 oz/tree of a Zn-EDTA solution containing 9% Zn raised leaf Zn levels to almost 30 ppm and essentially eliminated Zn deficiency symptoms. 1.2 oz/tree of Zn-EDTA reduced, but did not eliminate symptoms. A minimum leaf Zn level of 30 ppm is suggested as adequate for pecans.

INTRODUCTION

Zinc is considered one of the most influential nutrients affecting pecan yield and nut quality (Sparks, 1987). In areas with acidic soils, both soil fertilization and foliar sprays are commonly used to supply Zn to plants (Wood, 2007) whereas foliar sprays are standard in alkaline soils (Smith et al., 1979). During the 1970's and 1980's a program of repeated foliar Zn sprays was developed in Texas (Storey et al., 1974). Foliar spraying has become the standard method to supply Zn, but it requires the use of expensive equipment, and significant time and labor.

Soil Zn application has been evaluated in alkaline soils with inconsistent results and when it is effective, tree response can be delayed several years (Smith et al., 1980; Walworth and Pond, 2006). Soil application of soluble inorganic Zn salts, such as Zn sulfate, has low efficiency in high pH soils because Zn rapidly reacts with carbonates and hydroxyl groups forming compounds with low solubility (Udo et al., 1970). For this reason, high rates of Zn application may be required to attain adequate leaf Zn levels (Wood, 2007). Chelates reduce reactions of the metal with soil ligands such as OH^- and CO_3^{2-}; Zn chelates with the highest stability in calcareous soils are HEDTA, DTPA and EDTA (Norvell, 1991). However, neither band application of 74 lbs/a of Zn as $ZnSO_4$ nor 20 lbs/a as Zn-EDTA increased Zn uptake in established pecans growing in calcareous soil in Arizona (Nunez-Moreno et al., 2009a). Some synthetic resins such as Avail®, a dicarboxylic acid copolymer resin-P complex (J.R. Simplot Company, Boise, ID) can sorb Ca, reducing soil P fixation (Tyndall, 2007). The ability of Avail to adsorb cations might be used to reduce soil Zn sorption, but the effectiveness of such fertilizers has not been studied. Additionally, organic amendments can reduce Zn adsorption, and increase Zn mobility, solubility, and availability in calcareous soils (Ozkutlu et al., 2006; Pinto et al., 2004). Combining application of $ZnSO_4$ and animal manure increased Zn uptake in a pecan orchard in Arizona (Nunez-Moreno et al., 2009b).

The objective of our studies was to evaluate effectiveness of several soil-applied Zn treatments, and inoculation of pecan trees with mycorrhizal fungi, for enhancing Zn uptake.

METHODS

Shade-house Study

One year old ‘Wichita’ trees budded on VC-168 rootstock were planted in 10 gal pots filled with highly calcareous Pima clay loam (loamy, mixed, active, calcareous, thermic, typic torrifluvents) with a soil pH of 7.6. Soil treatments were: an untreated control, Zn sulfate, Zn-EDTA, Zn Avail, manure, manure plus Zn sulfate, and foliar-applied Zn sulfate. All soil Zn treatments were applied at a rate equivalent to 74 lb/a Zn. Manure was applied at 10 ton/a. Soil treatments were applied just once, on April 4, 2008. Manure and manure plus Zn treatments were applied to the surface of the soil and mixed into the top 4 in. Zn sulfate, Zn EDTA, and Zn Avail were applied in the bottom of four 7 in deep holes that were backfilled after fertilizer application. Foliar applications were applied at approximately two week intervals throughout the growing season: seven times in 2008 and ten times in 2009. Each treatment was replicated seven times, with a single tree comprising each experimental plot.

Each pot received 0.4 oz of 36-6-6 each month from May to August. Plants were grown in a shade-house and irrigated with an automated drip system. On 7/28/2008 and 9/8/2009 leaflets were collected from each tree, washed in soapy water, rinsed in tap water, then in 1% HCl, washed twice in deionized water (Smith and Storey, 1976), and dried at 150^{o}F. Leaflets were ground using a mortar and pestle and digested with HNO_3, HCl, and H_2O_2. Zinc concentrations were measured by ICP. In 2008, leaflet area was determined by scanning leaflets on a flat bed scanner and processing the images with Scion Image (Scion Corp., Frederick, Maryland). Chlorophyll index was obtained using a Konica Minolta SPAD 502 meter (Konica Minolta Sensing America Inc., New Jersey).

On 10/15/2008 leaves and leaflets were counted. Five to ten complete leaves were collected to determine leaflet weight, midrib length, and midrib weight and used to calculate total leaf weight per plant. On 9/3/2009 trees were visually evaluated for foliar symptoms of Zn deficiency and individual shoot lengths were measured. Trunk diameter was measured 6 in above the bud union at the beginning and end of each growing season.

Laboratory Sorption Study

Using Pima soil, adsorption isotherms were determined using Zn sulfate, Zn Avail, and Zn EDTA. Additionally, adsorption of Zn sulfate by manure-amended Pima soil that had been incubated for two months was determined. Isotherms were determined using 0.07 oz of soil and adding 0.67 oz of Zn solution containing from 0 to 200 ppm Zn. Suspensions were shaken for 30 minutes, let stand for 24 hours at 77°F, shaken again for 30 minutes, centrifuged at 3000 rpm for 30 minutes, and filtered. Zn in solution was measured using ICP. Freundlich adsorption isotherms were used to calculate the Zn retained by soil.

Field study

‘Wichita’ trees on ‘Bradley’ rootstock were planted in a new orchard in San Simon, AZ on 1/3/2009 in highly calcareous Pima-Grabe silt loam (fine-silty to coarse-loamy, mixed, superactive, calcareous, thermic typic torrifluvents) with a pH of 8.0. Each tree was planted in a hole 2 ft in diameter and 5 ft deep. Each hole was partially back-filled with soil, water added, and treatments mixed into the water. Trees were then planted, and remaining soil placed in the hole. Treatments consisted of a control, 1.2 oz of Zn-EDTA solution (9% Zn), 2.4 oz Zn-EDTA, 0.2 oz *Pisolithus tinctorius* spores, 0.1 oz of *Scleroderma* sp. spores, or 0.2 oz *Pisolithus tinctorius* spores plus 0.1 oz of *Scleroderma* sp. spores. Fungal fruiting bodies were collected from an established pecan orchard in southern AZ. Trees were irrigated with microsprinklers. Trunk diameters were measured on 4/21/2009, 9/24/2009, and 10/8/2010. Leaf samples were collected on 9/24/2009, 7/29/2010, and 10/18/2010. Trees were visually rated for Zn deficiency on 7/29/2010. Shoot lengths and tree heights were measured on 9/24/2009.

RESULTS AND DISCUSSION

Shade-house Study

Shoot growth, leaflet area, leaflet size, and chlorophyll indices measured on 7/29/2008 were not affected by soil Zn treatments or foliar sprays, nor did treatments affect growth measurements made on 10/22/2008 (data not shown). Similarly, 2009 growth measurements were not affected by Zn treatments (data not shown). In 2009, some trees exhibited foliar Zn deficiency symptoms, however differences in visual ratings among treatments were not statistically significant (data not shown). Leaf Zn concentrations were 33 ppm in the untreated control trees in 2008, compared to 244 ppm in the Zn-EDTA treated trees and 140 ppm in the trees that were foliarly sprayed with $ZnSO_4$ (Figure 1).

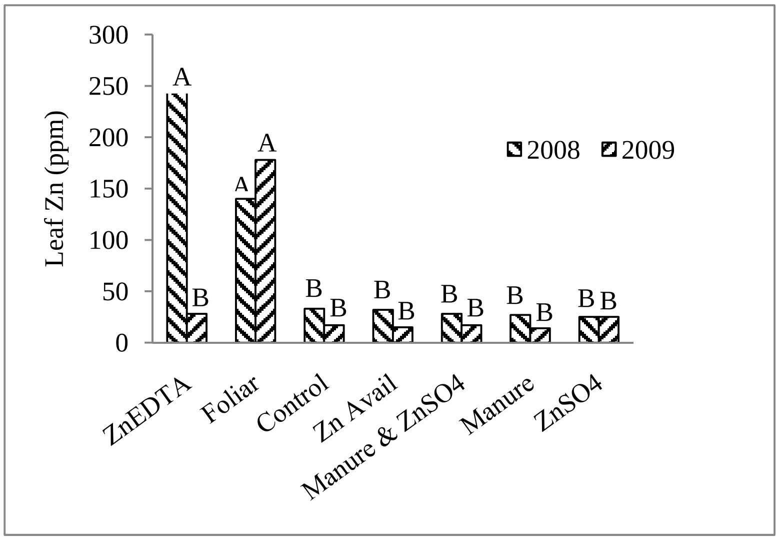

Figure 1. Foliar Zn concentrations in 'Wichita' pecans from shade-house study. Columns for each year are significantly different (at the 5% level) if followed by different letters.

None of the other treatments were significantly different from the control. In 2009, a year after application of soil treatments, leaves from the Zn-EDTA treated trees contained 28 ppm Zn versus 17 ppm in the control trees. Only $ZnSO_4$ sprayed trees, which contained 178 ppm Zn differed significantly from the control.

Laboratory sorption study

Untreated Pima soil adsorbed 1.7 $mg \cdot g^{-1}$ from soil suspensions in equilibrium with 100 ppm $ZnSO_4$ (Figure 2). Zinc Avail® reduced the adsorption of Zn to 1.2 $mg \cdot g^{-1}$ and Zn-EDTA eliminated soil Zn sorption. Pre-treatment of soil with 10 or 20 ton/a manure followed by incubation for two months did not affect Zn^{2+} adsorption from the soil (data not shown).

Field study

Trunk diameter growth during each of the two field seasons was not affected by treatments (data not shown). Similarly, tree height and shoot growth were not related to treatments. On all sampling dates, leaf Zn was significantly higher in trees that were treated with 2.2 oz of Zn-

EDTA per tree than in untreated trees (Figure 3). Trees treated with 1.1 oz of Zn-EDTA appeared to have elevated Zn concentrations relative to untreated trees, but the Zn concentration differences were not significant. Trees inoculated with mycorrhizal fungi did not contain more Zn than the control trees on any sampling date. Visual Zn deficiency symptoms generally mirrored leaf Zn concentrations on 7/29/2010 (Figure 4). On a scale of 1 to 6, where '6' represented no Zn deficiency symptoms and '1' denoted severe symptoms on every leaf, ratings were 5.0 and 4.5 for trees treated with 2.2 and 1.1 oz Zn-EDTA, respectively. Untreated trees had a rating of 3.4.

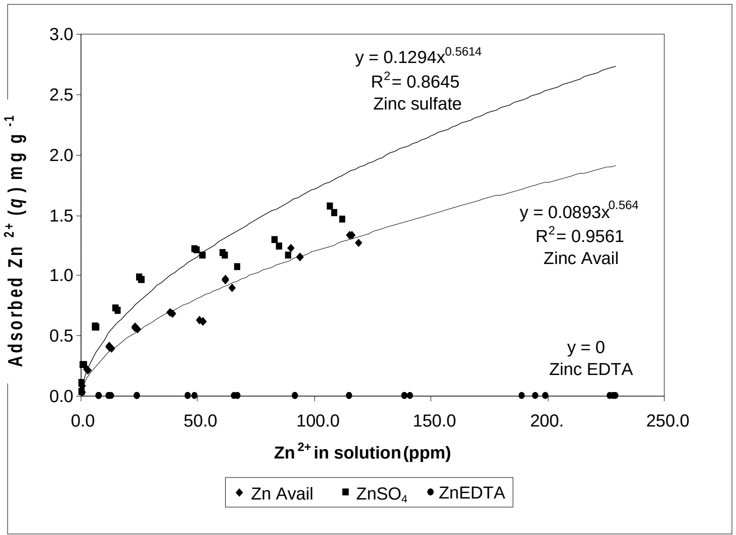

Figure 2. Relationship between sorbed Zn^{2+} and the Zn^{2+} in solution from suspensions in equilibrium with various Zn sources in alkaline, calcareous soil.

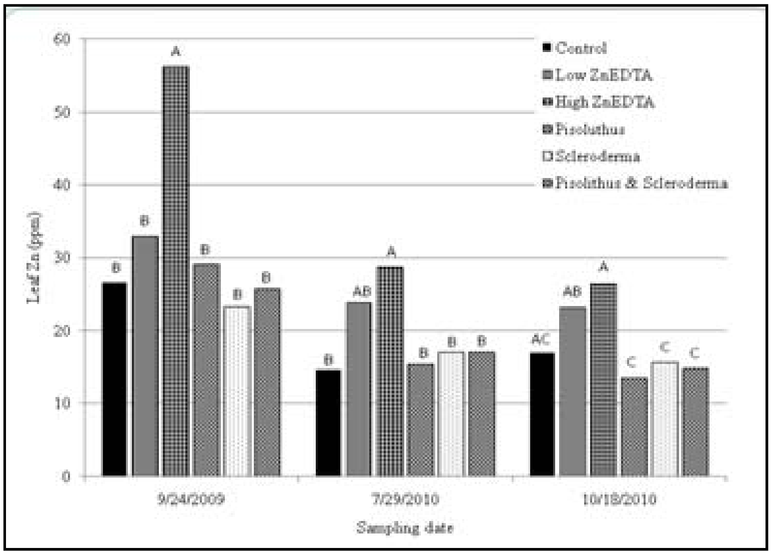

Figure 3. Leaf Zn levels in field study. Columns with different letters are significantly different at 5% level.

SUMMARY

In the field study Zn-EDTA applied to the soil at planting elevated leaf Zn concentrations, but measured growth parameters were not affected, even though deficiency symptoms were noted and leaf Zn levels were well below the published critical level of 50 ppm (Jones et al., 1991; Robinson et al., 1997). Deficiency symptoms were particularly severe in the second year after Zn application, where use of 2.2 oz of Zn-EDTA per tree raised leaf Zn from 15 to 29 ppm and essentially eliminated deficiency symptoms. In the shade-house study, application of Zn-EDTA raised leaf Zn to 244 compared to 33 ppm in untreated trees in year of application, whereas trees receiving foliar applications of $ZnSO_4$ contained 150 ppm Zn. In the second season of the shade-house study, effects of Zn-EDTA were no longer evident. Zn-EDTA was not sorbed by this soil, as indicated by the laboratory study, and may have been lost via leaching or through degradation. Zn-Avail® was less strongly sorbed to soil than $ZnSO_4$, although its use did not result in increased Zn uptake. Use of animal manure had no effect on Zn sorption.

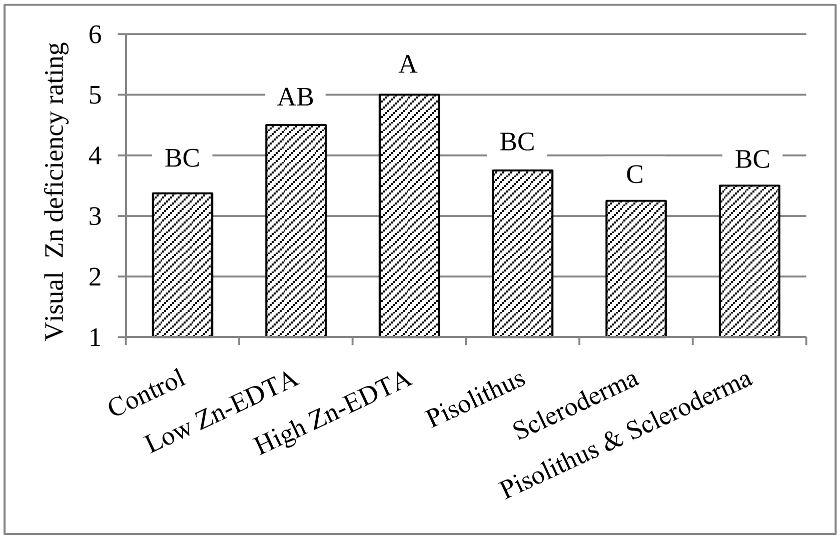

Figure 4. Visual Zn deficiency symptoms in field study, 7/29/2010. 1 = severe symptoms on all leaves; 6 = no symptoms. Columns with different letters are significantly different at 5% level.

In the field study, effectiveness of Zn-EDTA diminished over time. Maximum response was observed in the first season, when application of 2.2 oz of Zn-EDTA resulted in a leaf Zn concentration of 56 ppm, compared to 27 in untreated trees. In the second season, this level of Zn-EDTA resulted in leaf Zn concentrations of 29 and 27 ppm in July and October, respectively. Here, unlike the shade house study, leaching was unlikely, and ETDA degradation is likely responsible for diminished response.

These studies indicate that Zn-EDTA applied at planting can supply Zn for the first two years of growth, but that the response diminishes with time and is unlikely to provide adequate Zn for much longer than this period of time. Our studies also indicate that the 50 ppm critical level suggested by Jones et al. (1991) and Robinson et al. (1997) is probably too high. Critical leaflet levels and sufficiency ranges have been reported to be from 20 to 60 ppm (Lane et al., 1965; Obarr et al., 1978; Sparks, 1976; Worley et al., 1972). We observed that deficiency symptoms were severe in trees with leaf Zn levels in the range of 15 to 20 ppm, moderate where leaf Zn was approximately 25 ppm, and essentially eliminated when leaf levels approached 30 ppm. For ‘Wichita’ pecans grown under the conditions of these studies, 30 ppm is suggested as a minimum adequate leaf Zn concentration.

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