# SOIL APPLICATION OF ZINC TO PECANS IN CALCAREOUS SOILS

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**Abstract**

Zinc deficiency is common in pecans outside their native range, especially in alkaline soils. Zinc-deficient pecan leaves have interveinal chlorosis or necrosis, decreased leaf thickness, and reduced photosynthetic capacity. Foliar Zn application is routine in Southwestern US pecan orchards. Soil Zn application has not been part of pecan management in high pH, calcareous soils because of the soils' ability to adsorb soluble Zn. We are evaluating efficacy of fertigated chelated ZnEDTA in an Arizona pecan orchard planted in 2011. ZnEDTA was injected into the microsprinkler system throughout the 2011-2014 growing seasons at three Zn rates (0, 2, or 4 lb/ac Zn annually). Foliar Zn levels were elevated in each year, indicating soil-applied Zn was taken up by the trees. The highest foliar Zn level in fertigated trees was 37 ppm versus 7 ppm in untreated trees. Treated trees exhibited slight visible Zn deficiency symptoms which were significantly less severe than those in untreated trees. Trunk diameter was significantly greater in ZnEDTA-treated trees than in control trees in 2013 and 2014. DTPA-extractable Zn levels were elevated from less than 1 ppm in untreated plots to 3-5 ppm in soil 24" from the base of trees treated with 4 lb/ac Zn. Light-saturated leaf photosynthesis was measured on four dates in 2013: 25 June, 7 August, 24 September, and 24 October. On all measurement dates, photosynthesis was significantly increased by soil-applied ZnEDTA compared to the control, but was not different between the two soil-applied Zn treatments. Maximum photosynthesis was achieved with approximately 14 ppm. The 2014 nut yields were more than doubled by ZnEDTA fertigation.

## OBJECTIVES

Pecans are the major tree nut crop grown in the desert southwest of Arizona, New Mexico, and Texas. Growing conditions vary throughout this region, although most of the soils are calcareous, and commonly have pH levels of 8.0 or above.

Among plant nutrients, management of Zn is perhaps the most critical. Zinc deficiency is particularly common in pecans grown on high pH soils (Walworth and Pond, 2006). Fenn et al. (1990) studied the effects of soil pH on Zn availability in a South Texas soil and noted that water extractable soil Zn decreased from 394 to 12 ppm as soil pH increased from pH 4 to pH 8. Providing sufficient Zn is particularly problematic in calcareous soils such as those found in Southern Arizona and other semi-arid regions because of the extremely low solubility of Zn in alkaline conditions, and also because carbonate minerals complex soil Zn (Udo et al., 1970).

Rosetting, a characteristic visual symptom of Zn deficient pecan trees, occurs when leaf and internode size are reduced. Severe deficiency symptoms also include interveinal chlorosis, eventually developing into necrosis. Zinc deficiency can reduce catkin length, number of fruits per shoot, fruit development, and when severe it can inhibit production of inflorescences (Hu and

Sparks, 1990). Young Zn deficient orchards are slow to establish and come into production. In bearing-age orchards, Zn deficiency reduces pistillate flowering and fruit set. Shoot dieback from Zn deficiency can quickly reduce overall productive canopy volume. Reduced chlorophyll content and low stomatal conductance have been measured in severely deficient pecan leaves (Hu and Sparks, 1991). Published literature suggests that pecan leaf Zn concentrations should be greater than 40 to 50 ppm to avoid deficiency (Pond et al., 2006; Sparks, 1993 and 1994; Payne and Sparks, 1982).

It is difficult to supply pecans growing in calcareous soils with Zn through soil fertilization programs because of chemical reactions of Zn in alkaline soils (Walworth and Pond, 2006). Due to the difficulty of supplying Zn via soil applications, foliar Zn application is a standard practice in the desert southwest. Zinc sulfate, oxide, or nitrate is sprayed directly on the pecan foliage beginning early in the season, and continuing until vegetative growth has subsided (Kilby, 1985). A total of 3 to 5 applications are required for mature trees, whereas rapidly growing young trees may require as many as 14 annual applications. Repeated applications are necessary because foliar-applied Zn is not easily translocated within the plant (Wadsworth, 1970). Only leaves actually contacted by spray are affected by foliar treatments. Storey et al. (1971) noted that only 0.2% and 1.0% of applied Zn was absorbed by old leaves and young leaves, respectively.

For these reasons, there is considerable interest among pecan producers in the potential of soil-applied Zn. However, Storey et al. (1971) found that a soil application of 278 lb/tree of $ZnSO_4$ was needed to provide adequate nutrition to pecans growing in a calcareous soil. Soil application of soluble inorganic Zn salts has low efficiency in high pH soils because Zn rapidly reacts with soil carbonates and hydroxyl groups (Udo et al., 1970). Chelated Zn is less subject to these reactions; in calcareous soils HEDTA, DTPA and EDTA have the greatest stability (Norvell, 1991).

The purpose of this study was to evaluate the efficacy of applying chelated Zn dissolved in irrigation water. This study reports on Zn uptake and plant response to fertigated ZnEDTA.

## METHODS

A field study was initiated in 2011 in a newly-planted pecan orchard, consisting of ZnEDTA applied through the micro-sprinkler irrigation system at rates of 0, 2, or 4 lb/ac Zn, and split across multiple irrigation events throughout the growing season. No other Zn has been applied to these trees. 'Wichita' was the primary variety used in this experiment ('Western Schley' was the pollinizer). Plots were arranged in a randomized complete block design with four replications.

Zinc uptake was measured by analyzing mid-season leaf tissue. Trees were visually rated for Zn deficiency symptoms in mid-season. A 1 to 5 scale was used, where 1 was assigned to trees dying from Zn deficiency and 5 to trees showing no symptoms. Tree growth was measured by trunk diameter 1 ft above the soil surface. It was measured in the dormant season in 2012 and 2013, but 2014 values were recorded in mid-season (June 27, 2014). Nut yield was measured in 2013 and 2014.

On 25 June, 7 August, 24 September, and 24 October, 2013 we measured photosynthesis with a LiCor 6400XT portable photosynthesis system with LED light source (chamber PAR controlled at 1700 μmol·m-2·s-1) and CO2 mixer (reference CO2 maintained at 400 μmol·mol-1) on two representative, sunlight-exposed leaves per tree (four trees per block). On the August measurement date leaf tissue samples were collected from each tree and analyzed for Zn concentration.

Soil sampling was conducted to evaluate effect of treatments on available soil Zn levels and to determine the spatial extent of the impact of treatments on soil Zn levels.

**RESULTS AND DISCUSSION**

Foliar Zn levels increased in response to fertigation with ZnEDTA in all years of the study (Table 1). In general, foliar Zn concentrations corresponded to Zn application rates. Over the four years of the study, the foliar Zn concentrations in the 4 lb/ac Zn application rate have increased from 21.8 to 37.3 ppm.

Table 1. Foliar Zn levels (ppm) in Wichita pecans resulting from fertigated ZnEDTA. Numbers within a column with different letters are significantly different.

| | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|
| No Zn | 14.5b | 9.6c | 6.9b | 12.3b |
| 2 lb/a Zn | 17.7ab | 18.6b | 13.8b | 23.0b |
| 4 lb/a Zn | 21.8a | 25.3a | 24.0a | 37.3a |

The occurrence of visual deficiency symptoms was related to ZnEDTA application (Table 2). In each year, treated trees showed less deficiency than treated trees, however differences between the 2 and 4 lb/ac Zn treatments were not significant.

Table 2. Visual Zn deficiency ratings (1=worst; 5=no symptoms) in Wichita pecans fertigated with ZnEDTA. Numbers within a column with different letters are significantly different.

| | 2012 | 2013 | 2014 |
|---|---|---|---|
| No Zn | 3.65b | 3.03b | 2.86b |
| 2 lb/a Zn | 4.38a | 4.80a | 4.91a |
| 4 lb/a Zn | 4.35a | 4.98a | 4.92a |

Trunk diameter growth of Wichita trees was increased by addition of either level of ZnEDTA in 2013 and 2014, but differences between levels were not significant. Note that 2014 measurements were made in mid-season, and do not reflect the entire season’s growth.

Table 3. Trunk diameters (inches) in Wichita pecans resulting from fertigated ZnEDTA. Numbers within a column with different letters are significantly different.

| | 2012 | 2013 | 2014 |
|---|---|---|---|
| No Zn | 1.24 | 1.85b | 2.07b |
| 2 lb/a Zn | 1.34 | 2.12a | 2.33a |
| 4 lb/a Zn | 1.28 | 2.04a | 2.24a |

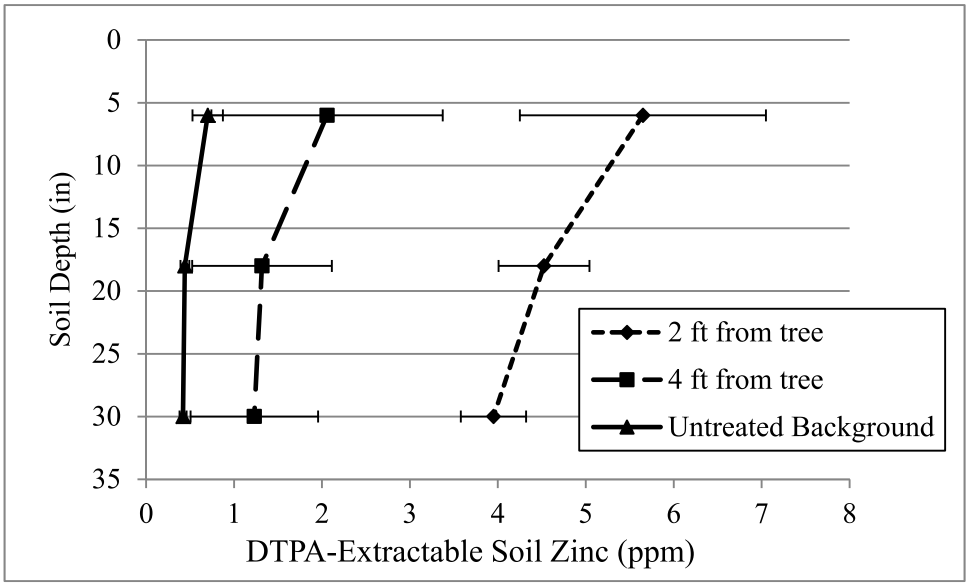


Figure 1. DTPA extractable soil zinc levels following two seasons of ZnEDTA application (with standard error bars).

DTPA-extractable soil Zn levels within the microsprinkler area were elevated above the background level of 0.75 to 0.83 ppm throughout the soil profile (Figure 1). Close to the tree (2 ft from the trunk), soil Zn levels ranged from 4.5 ppm in the upper 1 ft of soil to 3.6 ppm 1 to 2 ft below the surface and 3.2 ppm 2 to 3 ft deep. Further away (4 ft from the trunk) the values were 1.6, 1.1, and 1.0 ppm at these depths. Although critical DTPA-extractable soil Zn levels have not been determined for pecans, for other crops deficiencies are expected when levels are below 0.5 to 0.8 ppm (Alloway, 2008). Responses seen in the current study suggest that this range of values is probably appropriate for pecans.

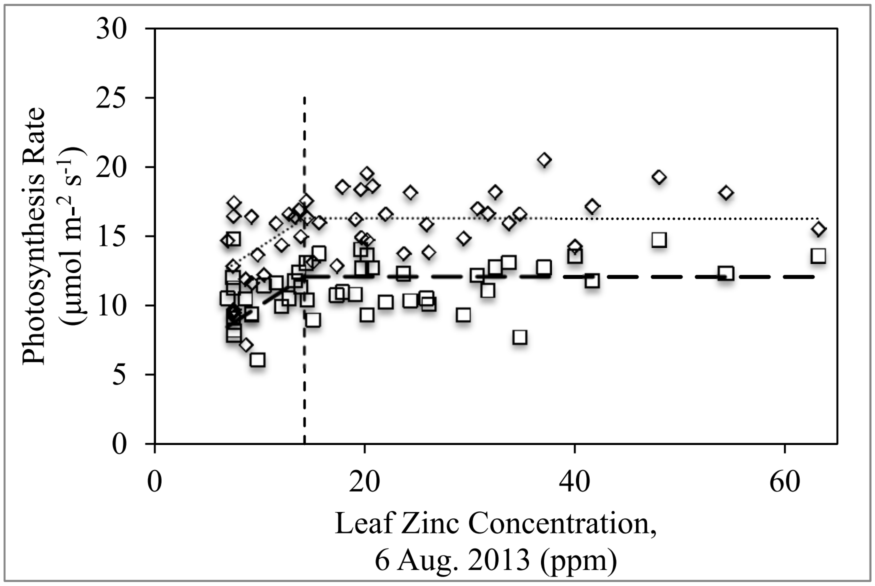


Fig. 2. Broken lines analysis of the relationship of photosynthesis in August (diamonds) and September (squares), 2013 to August, 2013 leaf Zn concentration. The breakpoint occurred at leaf concentration of 14.3 ppm Zn on both dates.

ZnEDTA fertigation significantly increased leaf photosynthesis (averaged across the 4 dates) by 35-40% over the untreated control, but trees receiving the two Zn application rates did not did not have significantly different photosynthesis rates (values for the three Zn treatment levels were 9.86, 13.34, and 13.86 $\mu mol \cdot m^{-2} \cdot sec^{-1}$). Broken lines analyses for August and September further showed that photosynthesis dropped off when leaf tissue Zn concentrations drop below 14 ppm (Fig. 2). Hu and Sparks (1991) showed similar declines in photosynthesis below 14 ppm leaf Zn for 'Stuart' pecan. This is far lower than the currently accepted recommended leaf tissue levels for commercial pecan of about 50 ppm (Heerema, 2013; Jones et al., 1991; Pond et al., 2006; Sparks, 1993). Furthermore, Zn deficiency symptoms were nearly eliminated in trees receiving either 2 or 4 lb/ac Zn, even though foliar Zn levels were only 14 to 23 ppm.

Table 4. Nut yields (lb/ac) of Wichita pecan trees fertigated with ZnEDTA. Values in each column with different letters are significantly different.

| | 2013 | 2014 |
|---|---|---|
| No Zn | 16b | 150b |
| 2 lb/a Zn | 35a | 451a |
| 4 lb/a Zn | 25a | 387a |

Tree nut yields in 2013 and 214 were increased in trees fertigated with ZnEDTA (Table 4). Trees began bearing in their third year (2013) and will increase as the trees mature. 2014 yields were more than doubled in the ZnEDTA treated trees relative to the untreated trees.

## SUMMARY


Fertigation with ZnEDTA can be an effective way to fertilize young pecan trees, even those growing in calcareous, alkaline soils. Soil analyses show elevated DTPA-extractable Zn levels

within the microsprinkler irrigation pattern. Fertigating with ZnEDTA greatly alleviated, and nearly eliminated, visible foliar Zn deficiencies. Annual trunk growth and nut yield were significantly increased by addition of ZnEDTA, although differences between 2 and 4 ppm Zn were not statistically different. Foliar Zn concentrations increases were concurrent with ZnEDTA application rates. Photosynthesis rates were reduced in individual trees when foliar Zn concentrations were below 14 ppm. It appears that the recommended foliar Zn levels of more than 50 ppm are much higher than needed. Our data suggest that, on an orchard block scale, 20 to 30 ppm of foliar Zn may reflect adequate Zn nutrition.


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