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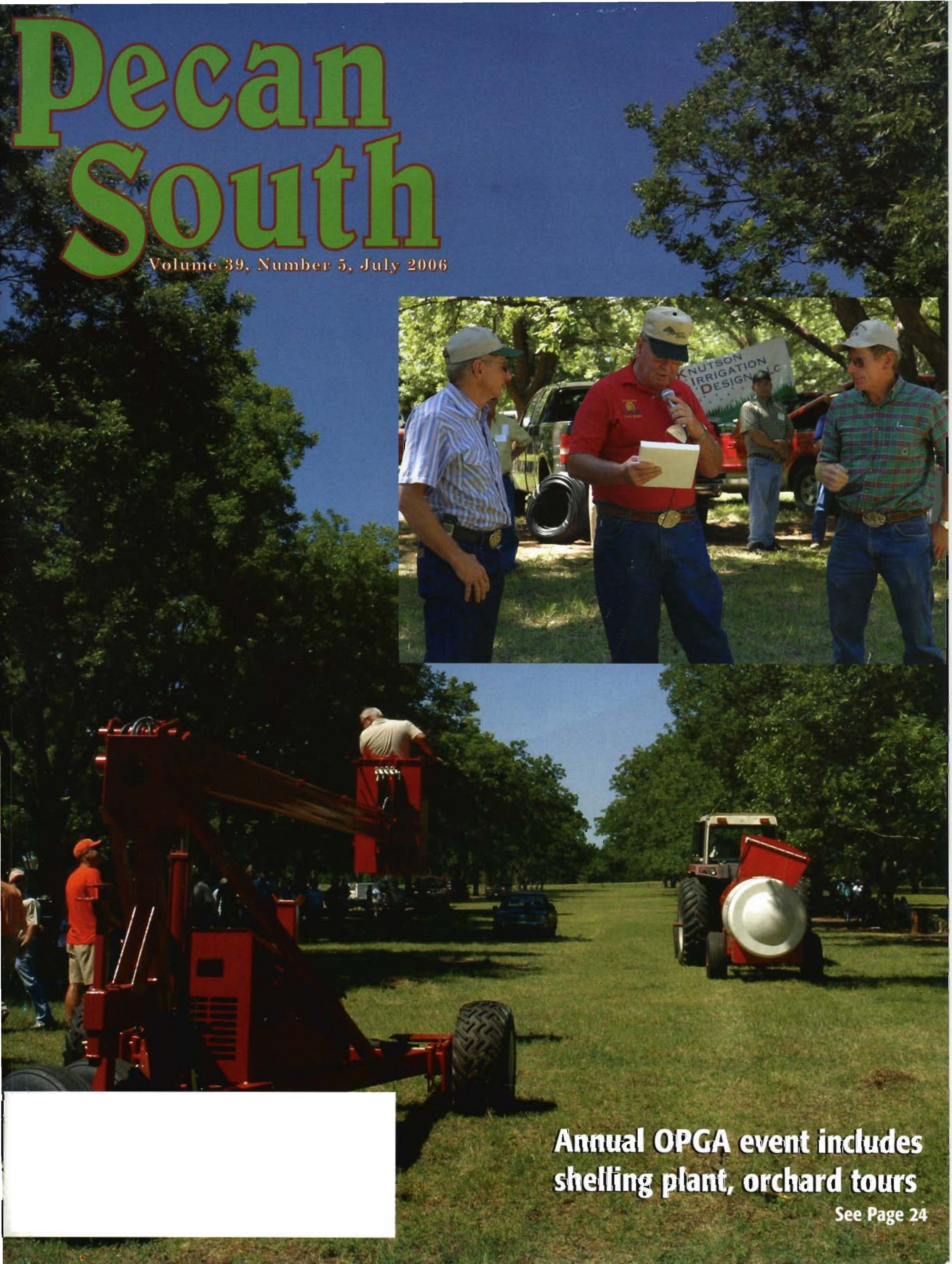

Annual OPGA event includes shelling plant, orchard tours

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Zinc nutrition of pecans growing in alkaline soils

By James L. Walworth and Andrew P. Pond

Abstract

There is a general consensus that for leaf samples collected randomly from branches of the pecan tree, a sufficient level of zinc (Zn) is 50 ppm. Leaves exhibiting deficiency symptoms, on the other hand, typically have Zn levels below 11 to 14 ppm. Because Zn is sparingly available in alkaline soils, soil Zn application is problematic in orchards with high pH soils. Extremely high rates (278 lb $ZnSO_4$ per tree) of soil-applied Zn can overcome limited Zn availability in alkaline soils. Lower rates (200 to 400 lb $ZnSO_4$/acre of broadcast or 20 lb per acre banded) may be effective, but maximum response may require several years. Soil acidification (30 gal per tree of 36N H_2SO_4 with 20 lb $ZnSO_4$) also increased pecan leaf Zn, but trees took four years to respond to the treatment. Direct trunk injection is only successful if a relatively large amount (about 2 gal) of liquid is injected under pressure into the trunk, whereas solid slugs are generally ineffective and can cause damage to the cambium tissue. Foliar Zn fertilization is highly effective, but only directly sprayed leaves benefit from foliar Zn application. Both $ZnSO_4$ and $Zn(NO_3)_2$ are effective, and addition of urea ammonium nitrate improves foliar absorption of both salts. Several studies have used Zn chelates at approximately 10 percent the strength of inorganic salts, but they are not as effective in this mode. Spray timing and placement are critical. Applications should be split, between three and five times, with the first spray taking plaee about one week after bud break, and continuing for about eight weeks in bearing trees.

Providing adequate Zn nutrition is one of the most important aspects of pecan tree management. Fertilizing with Zn is particularly critical, and problematic, in high pH soils where soil Zn availability is limited. This review of Zn nutrition focuses on studies conducted in high pH soils but also includes information from relevant studies conducted in neutral and acidic soil. It is intended to provide a comprehensive review of the current state of knowledge of Zn management in pecan orchards, as it pertains to alkaline soils.

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Leaf zinc levels

There is a wide range in "critical levels" or "sufficient levels" of Zn reported for pecan leaves. Sparks (1976) indicated that critical values have variously been identified as 20 ppm (Lane et al., 1965), 40 ppm (Worley et al., 1972), and noted that other researchers have noted no difference in pecan performance when Zn levels were above 36 to 45 ppm. Storey et al. (1971) suggested a 60 ppm threshold. Sparks (1994) noted that deficiency symptoms were eliminated, and vegetative growth and nut yield were maximized, with leaf Zn greater than 50 ppm. Sparks and Payne (1982) recommended a sufficiency range of 50 to 100 ppm, and Sparks (1993) indicated that a threshold value for leaf Zn was 50 ppm based on visual deficiency symptoms and nut yield.

However, several reports indicate a much lower critical level. Kim et al. (2002) studied pecans grown in sand culture and noted interveinal necrosis in leaves with 7.2 ppm, mottling at 9.8 ppm, and no symptoms in leaves with 11.2 ppm. Deficiency symptoms included interveinal mottling, interveinal chlorosis, and marginal curling. They also observed that low leaf Zn was accompanied by high leaf Mn concentrations. In studies conducted in an orchard at the Southeastem Fruit and Tree Nut Laboratory, in Byron, GA, very severe Zn deficiency symptoms corresponded to leaf Zn levels averaging 4.4 ppm, severe symptoms with 4.9 ppm, moderate symptoms with 6.1 ppm, and normal leaves contained 14.3 ppm Zn (Hu and Sparks, 1990). Zinc deficiency did not affect fruit abortion, but did reduce numbers of fruit per shoot, increased death and dying *in situ*, and delayed and staggered shuck dehiscence. Additionally, leaf chlorophyll content, stomatal conductance, and net photosynthesis were all positively related to leaf Zn concentration (Hu and Sparks, 1991). Hu and Sparks (1990) indicated that a possible reason for the apparent discrepancy in critical levels may be that in the latter studies only affected branches were sampled, and that it is common for some branches to exhibit Zn deficiencies while others on the same tree do not. Therefore, treewide sampling results in a general Zn level, which may be considerably different than a single branch level.

Zinc application to soil

Zinc deficiency is common in pecans grown on high pH soils (Alben and Hammer, 1944). Lane et al. (1965) noted that Zn deficiency symptoms were more severe in a limed soil than in an unlimed soil in Georgia. Fenn et al. (1990) studied the effects of soil pH on Zn availability in a South Texas soil. Water extractable soil Zn increased from 12 to 394 ppm as soil pH was lowered from pH 8 to pH 4.

Sparks (1976) noted that soil Zn treatments are successful in the acidic soils of the southeastern United States, but much less likely to be effective in alkaline soils. Storey et al. (1971) found that an extremely high rate, 278 lb of $ZnSO_4$ per tree, was needed in calcareous soils in Texas to provide adequate Zn to pecan trees. Finch and Kinnison (1934) recommended $ZnSO_4$ applied to soil from January to May in Arizona at rates ranging from 1 to 15 lb $ZnSO_4$ per tree depending on tree diameter, but provided no data evaluating efficacy. However, Smith et al. (1934) reported that $ZnSO_4$ at 4 to 5 lb per tree corrected rosette in the second year after being trenched into a silt loam in Uvalde, Texas.

Placement of Zn fertilizers is an important consideration. Wood and

Payne (1997) applied ZnO and $ZnSO_4$ to a Georgia soil that had been overlimed. The pH in the top inch was 7.3, and 6.2 in the inch below that. A single application of 143 lb Zn/acre was applied in the spring as a broadcast treatment. Use of ZnO increased tissue Zn over 50 ppm in year two when disced into the soil, and in year four when not incorporated. Zinc sulfate was just as effective as ZnO. Payne and Sparks (1982) applied ZnSO4 as banded (0 to 20 lb/acre) or broadcast (0 to 400 lb/acre) treatments to a Georgia soil with pH ranging from 4.8 to 5.2 in a single application. Leaf Zn levels increased for five years. Applications of at least 100 lb/acre broadcast or 20 lb/acre banded Zn increased leaf levels to over 50 ppm. Greater broadcast application rates increased leaf Zn sooner: 400 lb/acre increased Zn above the 50 ppm threshold in the second year, 200 lb/acre in year four to five, and 100 lb/acre in year five. In banded treatments, 20 lb/acre raised leaf Zn to 50 ppm in year five.

Several forms of Zn fertilizer can be soil applied. Worley et al. (1972) studied the effects of $ZnSO_4$, ZnO, and ZnEDTA broadcast or placed in holes (six holes, each 1 inch in diameter x 1 ft deep), in a Georgia soil over-limed to a soil pH of 7.4. Either ZnO (applied at 3 oz/in of trunk cirucumference applied annually over five years) or ZnEDTA (0.3 oz/in) broadcast on the soil increased leaf Zn relative to the untreated control; Zn placed in holes did not. Broadcast ZnEDTA effects were significant in year two, whereas ZnO effects were not significant until year five. $ZnSO_4$ (application rate, 3 oz/in) had no significant effect, regardless of placement.

Additionally, Zn can be applied through appropriate irrigation systems. Lindsey and Condra (undated) conducted field demonstration studies in Texas, applying ZnEDTA to the soil via a drip irrigation system. In Glasscock County in 1974, 0.7, 1.4, and 2.2 lb Zn/acre as ZnEDTA was applied, resulting in leaf levels of 39, 53, and 68 ppm, respectively. In 1975, the corresponding leaf Zn levels were 49, 54, and 70 ppm, respectively. These data suggest that drip irrigation applied ZnEDTA elevated leaf Zn levels, however no unfertilized controls were included, and the data were not statisticaly analyzed.

Soil acidification accompanying Zn fertilization may be advantageous, although data are inconsistent. Smith et al. (1980) combined five rates of $ZnSO_4$ (0, 3.1, 14.1, 28.0, and 70.1 lb per tree) and three rates of elemental sulfur (0, 8.8, 11.0, and 25.1 lb per tree) in a Tivoli sand located in the south plains of Texas. Treatments were broadcast below the outer third of the tree canopy in a single soil application in March and tilled in to a depth of 6 inches. In years one, two, and three the highest rate of $ZnSO_4$ resulted in leaf Zn levels of 184, 48, and 31 ppm, respectively, versus about 13 ppm in the untreated control. Sulfur had little or no effect. However, Alben and Hammer (1944) successfully eliminated rosette by applying 50 lb sulfur per tree along with 50 to 75 lb $ZnSO_4$ per tree to a heavy-textured alkaline soil. Fenn et al. (1990) studied the effects of soil acidification with H2SO4 on Zn absorption into pecan trees. Twenty lb of ZnSO4 per tree was trenched into the soil, along with 30 gal of 36 N H2SO4. Leaf tissue Zn did not change for the first three years, but four years after application leaves of the treated trees contained 54 ppm Zn versus 39 ppm in the untreated control. After nine years leaf Zn levels were 68 and 45 ppm for the treated and untreated trees, respectively, and 56 ppm in trees receiving ZnSO4 alone.

Trunk injection

Several studies have investigated the potential for direct Zn injection into the trunks of pecan trees. Finch and Kinnison (1934) recommended application via 0.5 in holes bored 2 to 3 in into the trunk, and packed full of $ZnSO_4$ in May or early June. Worley et al. (1976) found that pressure injection of 2 gallons of solution containing up to 1.4 oz $ZnSO_4$ over a period ranging from 20 minutes to several hours did not cause damage, and rapidly increased leaf Zn levels in Zn deficient trees. Injection of 5 lb $ZnSO_4$ defoliated trees; new foliage contained 565 to 1360 ppm Zn. Worley et al. (1980) reported that $ZnSO_4$ applied as a pressure trunk injection using 2 gal per tree of solution containing 0.04 oz $ZnSO_4$ for every 1 inch of trunk circumference successfully increased leaf Zn. Implants with equivalent amounts of $ZnSO_4$ increased leaf Zn over untreated controls, but did not eliminate Zn deficiency, and caused considerable trunk cambium tissue damage. ZnEDTA applied as pressurized cartridges, with 1 cartridge per 5 inches of trunk circumference each containing 0.14 oz of 2-percent ZnEDTA, were ineffective. Storey et al. (1971) reported that 0.1 oz ZnEDTA injected into the trunk did not provide an adequate supply of Zn to treated pecan trees.

Foliar zinc application

Applying Zn foliarly is the most efficient method of Zn fertilization for pecans grown in alkaline soils. However, coverage may be problematic in large trees. Wadsworth (1970) demonsrated that only leaves actually contacted by spray are affected by foliar treatments. Additionally, timing is critical. Storey et al. (1971) noted that only 0.2 percent of applied Zn was absorbed by older leaves whereas young leaves absorbed 1 percent of $ZnSO_4$ applied without an adjuvant at a rate of 32 oz/100 gal.

A commonly used foliar spray is $ZnSO_4$, often mixed with urea ammonium nitrate (UAN) as an adjuvant. Smith and Storey (1979) found that using UAN as an adjuvant increased Zn uptake from $ZnSO_4$ and $Zn(NO_3)_2$. Storey et al. (1973 and 1979) noted that including UAN at 3 pt/100 gal increased Zn uptake from a spray containing 2 lb $ZnSO_4$/100 gal. UAN can increase absorption from $Zn(NO_3)_2$ as well as from $ZnSO_4$. Storey et al. (1979) noted that 2 lb $ZnSO_4$/100 gal with UAN was as effective as 3 lb $Zn(NO_3)_2$/100 gal without UAN. Five spaced applications of 1.5 lb $Zn(NO_3)_2$/100 gal without UAN, or 0.75 lb $Zn(NO_3)_2$/100 gal with UAN were adequate to maintain leaf Zn levels above 50 ppm (Storey et al., 1974).

Several studies have explored the efficacy of various Zn carriers. Smith and Storey (1979) found that $Zn(NO_3)_2$ was more effective than $ZnSO_4$. Storey et al. (1971) applied $ZnSO_4$ or ZnO at a rate of 1.4 lb Zn/acre in 20 gal/acre and found that ZnO was less effective than $ZnSO_4$. Additionally, ZnEDTA applied at 1.08 lb Zn/acre was less effective than $ZnSO_4$ applied at 10.8 lb Zn/acre. Alben (1962) studied a range of ZnEDTA spray concentrations, and reported that leaf rosette could be treated with ZnEDTA sprays with Zn concentrations of 0.07 to 1.4 lb/100 gal, but that 0.72 lb Zn/100 gal as $ZnSO_4$ provided superior results to all ZnEDTA treatments except the 1.4 lb/100 gal rate.

Finch and Kinnison (1934) recommended 2 lb $ZnSO_4$/100 gal applied foliarly. Sparks (1976) recommended use of $Zn(NO_3)_2$ or $Zn(SO_4)$ at a rate of 2 lb/100 gal with urea or UAN as an adjuvant. Storey et al. (1973) recommended 2 lb $ZnSO_4$/100 gal with 1.5 to 3 pt UAN/100 gal. In a three-year field study, Storey et al. (1979) found that equivalent rates of NZN resulted in lower leaf Zn levels than $ZnSO_4$ with or without UAN, but produced significantly higher nut yields.

Timing of foliar Zn applications is critical, as foliar applied Zn is poorly translocated, and is largely effective only in leaves actually contacted by spray. Storey et al. (1971) recommended application beginning one week after bud break, followed by applications at intervals of 2, 3, 4, and 5 weeks from the previous application. Sparks (1976) recommended foliar application beginning 2 weeks after bud break and continuing for 6 to 7 weeks, and Storey et al. (1973) recommended spraying at green tip, and 1, 3, 6, and 8 weeks after green tip.

Summary

Leaf analysis is the best way to quantify pecan tree nutrient status or to evaluate Zn fertilization management options. In pecans, there is a general consensus that for "whole tree" leaf samples, those taken randomly from branches of the tree, a sufficient level of Zn is 50 ppm. Leaves exhibiting deficiency symptoms, on the other hand, typically have Zn levels below 11 to 14 ppm.

Zn availability decreases with increasing pH, and it is clear that Zn deficiency is a more difficult problem to address in high than in low pH soil.

Soil Zn application is desirable, as it would reduce equipment passes through the orchard and manpower requirements. However, Zn is sparingly available in alkaline soils. It appears that soil applied $ZnSO_4$ can be effective at high enough rates. Just how high is questionable. Storey et al. (1971) used $ZnSO_4$ at a rate of 278 lb per tree to get an adequate response in calcareous soils in Texas. More reasonable rates have been reported elsewhere. For example, Payne and Sparks (1982) had relatively good results with 100 to 400 lb $ZnSO_4$/acre broadcast or 20 lb/acre banded, but several years were required for maximum response. Fenn et al. (1990) reported good longterm results with addition of H2SO4 at 30 gallons per tree along with 20 lbs. ZnSO4, but trees took four years to respond to the treatment.

Direct trunk injection is only successful if a relatively large amount (about 2 gallons) of liquid is injected under pressure into the trunk, which may take from 20 minutes to several hours (Worley et al.., 1976). Solid slugs are generally ineffective and can cause damage to the cambium tissue.

In the southwestern U.S. foliar Zn fertilization is the norm. A typical recommended rate of $ZnSO_4$ for foliar application is 2 lb Zn/100 gal with 3.0 pt UAN applied at 100 gal/acre (M. Kilby, personal communication). Effective $Zn(NO_3)_2$ rates may be somewhat lower, but UAN should still be added at the same rate. NZN may not be as effective at increasing leaf Zn levels, but one study indicated that it's use resulted in superior yields. Several studies have foliarly applied Zn chelates at approximately 10 percent the strength of inorganic salts, but they are not as effective in this mode. Spray timing and placement are critical. Only directly sprayed leaves benefit from foliar Zn application. Applications should be split, between three and five times, with the first spray taking place about one week after bud break, and continuing for about eight weeks in bearing trees.

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