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Salinity Management and Soil Amendments for Southwestern Pecan Orchards

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Introduction

Managing salts in Southwestern pecan orchards can be a major challenge for growers, due to limited soil permeability and/or low-quality irrigation water. However, effective, long-term salt management is essential for maintaining productivity of pecan orchards. The challenge is to effectively manage soil salinity and sodium (Na) in a cost-effective manner, using appropriate combinations of irrigation management, soil management, and soil amendments.

Formation of Soil Salinity

Many arid region soils naturally contain high concentrations of soluble salts, because soil weathering processes dependent upon precipitation have not been sufficiently intense to leach salts out of soils. Irrigation water and fertilizers contain salts that may contribute further to the problem. Poor soil drainage due to the presence of compacted layers (hardpans, plowpans, caliche, and clay lenses), heavy clay texture, or sodium problems may prevent downward movement of water and salts, making implementation of soil salinity control measures difficult. Adequate soil drainage, needed to allow leaching of water and salts below the root zone of the trees, is absolutely essential for effective management of soil salinity.

The risk of soil salinity formation is always greater in fine-textured (heavy) soils than in coarse-textured soils. This is because sandy soils naturally have larger pores that allow for more rapid drainage. High clay content soil horizons anywhere within the root zone may cause poor drainage and result in soil salt accumulation.

Dangers of Soil Salinity

The most serious problem caused by soil salinity is the decreased osmotic potential of soil water. This has the effect of reducing plant-available water. Therefore, pecan trees grown in salty soils will experience moisture deficits sooner than those in non-salty soils, reflected by reduced growth rate, nut size, and yield. A soil salinity level of 3.5 dS/m (measured in a saturated paste; equivalent to 2200 ppm) can reduce growth by approximately 25% (Figure 1). Branch die-back can occur at soil salinity levels of 5 dS/m (3200 ppm), and trees may die when soil salinity reaches or exceeds 6 dS/m (3800 ppm) (Miyamoto et al., 1986).

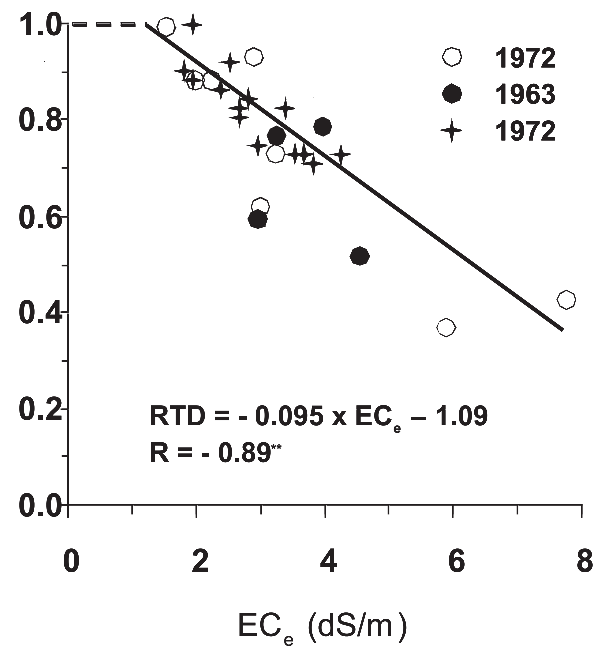

Figure 1. Reduction in pecan relative trunk diameter with increasing soil salt concentrations. After Miyamoto, et al., Irrig. Sci. (1986) 7:83-95.

Additionally, salt-affected soils may contain concentrations of certain ions, such as Na, lithium (Li), boron (B), and chloride (Cl), that can be toxic to plants. Pecan trees are moderately sensitive to Na and B toxicities, so high concentrations of these elements may cause toxicity symptoms, including burning or necrosis (death) of the leaf margins.

Salt-affected pecans typically have leaf burning or marginal necrosis. These symptoms may appear on both older and younger leaves, and are difficult to distinguish from Na or B toxicity (Figure 2). A plant tissue test is the best way to distinguish between these problems.

It is important to remember that while salts cause serious problems for plants, they are actually not detrimental for soils. In fact, high concentrations of soluble salts usually lead to flocculation (aggregation) of soil clays, resulting in good soil structure and permeability. On the other hand, high concentrations of Na, relative to calcium (Ca) and magnesium

Figure 2. Toxic levels of boron (shown here) or other salts cause marginal necrosis on affected leaves.

(Mg), cause dispersion (the opposite of aggregation) which results in soil permeability problems, including slow water infiltration. Unfortunately, while high concentrations of soluble salts may be beneficial for soil structure, salts are detrimental for most plants.

Soil Salinity Control

Salinity is measured by determining the electrical conductivity (EC) of irrigation water (EC_w) or saturated paste extract of soil (EC_e). The EC, directly related to salt content, is expressed in units of dS/m. One dS/m is equivalent to 640 ppm of dissolved salts. Electrical conductivity represents total salt concentration; evaluating Na risk in irrigation water or soil requires calculations involving separate measurements of Na, Ca, and Mg concentrations.

The key to controlling soil salinity is adequate soil leaching to move salts below the root zone. ***There are no amendments that can directly control soil salinity.*** Some amendments can improve soil drainage, and indirectly help control soil salinity by improving conditions for leaching salts. Maintaining soil drainage and providing adequate irrigation are factors the grower can manage to control soil salinity.

The irrigation water salinity largely determines soil salinity levels. As a rule of thumb, the EC of the soil (EC_e) is at least 1.5 times higher than the EC of the irrigation water (EC_w), except in very sandy soils. If drainage is poor, the EC_e may be several times higher than the EC_w. If the irrigation water quality is very good (EC_w <0.75 dS/m), then there is little need to worry about salt buildup. However, if the water is even moderately saline (EC_w 1 to 1.5), attention should be paid to the danger of salt buildup.

The most effective means of controlling soil salinity at tolerable levels is to leach excess water and salts below the root zone. The leaching requirement is the percent of water applied to the crop (beyond the crop's water requirement) that must leach below the root zone to maintain soil salinity at a desired level:

$$LR = \frac{EC_w}{5(EC_e) - EC_w} \times 100$$

where LR is leaching requirement, EC_w is salinity of the irrigation water in dS/m, and EC_e is the maximum soil salinity which results in no growth or yield reduction. In pecans, the maximum EC_e causing no growth reduction is approximately 2 dS/m (Figure 1). The greater the irrigation water salinity, the greater the leaching requirement, thus it is critical to know the salinity of orchard irrigation water. Figure 3 shows the leaching requirement for pecans, depending on irrigation water salinity.

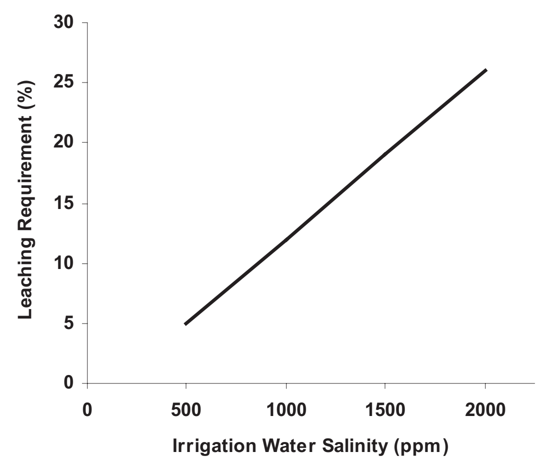

Figure 3. Leaching requirement for pecans.

Leaching can be accomplished by periodic applications of excess water during the growing season, or by irrigation or rainfall during the winter. A regular program of soil sampling should be followed to ensure that salinity is being managed properly and not accumulating in the rooting zone.

Tillage for Salinity Control

Unfortunately, low water permeability and poor soil drainage can limit water infiltration and leaching of salts. If low permeability is due to restrictive layers within the soil profile, such as caliche or hardpans, then tillage may be an effective means of increasing soil permeability. Amendments alone may not correct such problems. Potential tillage methods include ripping, trenching, and slip-plowing. These methods are most effective if there are sandy layers within the plowing depth. The sandy material can be mixed with the finer soil as the restrictive layer is broken up, thereby increasing soil permeability. Incorporation of animal manures or other organic soil amendments may also help increase permeability and water infiltration.

Formation of Soil Sodicity

High levels of Na, frequently found in arid region soils and groundwater, can cause a special set of problems in beyond those discussed for other salts. In fact, many problems of low soil permeability can be traced to the effects of Na on the behavior of soil clay particles. Sodium can cause problems when it replaces Ca and Mg on clay cation exchangeable sites, particularly in fine-textured soils. While Ca and Mg cause soil clays to flocculate and encourage good soil aggregation, Na causes clays to disperse, breaking down aggregates, and leading to surface sealing and slow water infiltration. A soil with an **exchangeable Na percentage** (ESP) greater than 10% (10% of the cation exchange capacity filled with Na) may have permeability problems. Sodium status of soil can also be assessed by determining the **sodium adsorption ratio** (SAR), a measure of the Na to Ca+Mg ratio in soil or water which is roughly equivalent to ESP.

The Na hazard of irrigation water is evaluated by determining the SAR of the water. SAR values of 6 or greater may indicate a potential Na problem, depending on the texture of the soil the water is used to irrigate. The SAR of irrigation water is a critical management parameter because irrigation water is a primary source of soil Na, and soil Na problems can usually be traced back to irrigation water quality.

Controlling and Correcting Sodium Problems

Restrictive soil layers such as caliche, hardpans, or clay lenses can only be corrected by tillage. Sodium problems, on the other hand, may be managed by proper use of soil or irrigation water amendments. Preventing Na accumulation with proper management is often more effective and almost always easier than correcting an existing Na problem, so development of a sound management program is key. Unfortunately, leaching alone may not be sufficient to prevent or correct Na problems.

To prevent Na buildup, high SAR irrigation water can be treated with amendments to lower the SAR, or amendments can be added directly to the soil. Amendments may either contain Ca (such as gypsum), or release Ca from carbonates in calcareous (lime-containing) soils (calcareous soils can be identified by applying a drop of acid, which causes bubbling or effervescence in the presence of calcareous minerals). In general amendments will be applied to and incorporated into the soil at higher rates than are used in irrigation water.

AMENDMENTS FOR SODIUM CONTROL

The most common Ca-containing amendment is gypsum ($CaSO_4.2H_2O$). It is inexpensive, abundant, and non-toxic, and can be added to either irrigation water or soil. Gypsum application rates are commonly 1 to 10 tons/acre, depending on soil and irrigation water properties. Gypsum is a neutral amendment, so it has no direct effect on soil pH, but it can slightly lower pH when added to soils with serious Na problems.

Acids or acid-based amendments can be used to prevent or correct Na problems in calcareous soils. Before using these amendments, it is important that soil $CaCO_3$ content be determined as noted above. Sulfuric acid is the most-commonly used acid amendment. Sulfuric acid and other acid-based amendments dissolve soil carbonates and yield gypsum:

$$CaCO_3 + H_2SO_4 \rightarrow Ca^{2+} + SO_4^{2-} + H_2O + CO_2$$

Sulfuric acid can be soil-applied or water-run. Application rates are usually 1-3 tons/acre; gypsum equivalency rates are shown in Table 1. Sulfuric acid added to irrigation water also neutralizes carbonates and bicarbonates, which can negatively affect water infiltration into soil. Note, however, that if irrigation water pH is reduced below 5.5, corrosion of concrete-lined ditches may occur. Elemental sulfur (S) is an acid-based material that is transformed into sulfuric acid by soil microorganisms; this in turn reacts with soil carbonates as shown in the reaction above. A potential disadvantage of using S is its slow reaction time. In warm, moist soils, four to six weeks may be required for the complete transformation of S to sulfuric acid; in cold or dry soils this conversion will take longer.

Acid and acid-forming amendments have the potential to lower soil pH, however it is usually not economical to change the pH of calcareous soils. The main effect of acid application is to dissolve calcium carbonate, and not to change soil pH.

Several other acid-based amendments are available to growers. Many of these contain nitrogen (N), so they can be used as fertilizers as well. Nitro-sul® is an ammonium polysulfide material, which contains 20% NH_4-N and 40-45% sulfur (20 - 0 - 0 - 40S). It causes release of acidity after microbial oxidation. In some, but not all, cases applications can increase the rate of water infiltration. Thio-sul® is an ammonium thiosulfate material containing 12% NH_4-N and 26% S (12 - 0 - 0 - 26S). It also releases small amounts of acidity, but is used mostly as a fertilizer. N-Phuric® is a combination of urea and sulfuric acid that contains 10-28% N and 9-18% S. This amendment releases acidity, is a safer way to use sulfuric acid, and can be safely used in drip or microsprinkler systems as an N fertilizer and to prevent clogging of irrigation lines. In most cases, the prices of these acid-based amendments are higher than those of gypsum or sulfuric acid. Also, the rates of these amendments used to supply N may not be

Table 1. † Value represents S content only; nitro-sul also contains N.

Material	Amount (lbs) equivalent to 1 ton of gypsum
Gypsum	2000
Sulfuric acid	950
Sulfur	380
Nitro-sul	**950 †**

Table 2. Typical infiltration rates for soils of varying textures.

Soil Texture	Infiltration rate (in/hr)
Sand	2
Loam	0.5
Clay loam	0.3
Silty clay loam	0.1

effective for correcting sodium problems. It is recommended that you consult with Cooperative Extension county agents or other qualified persons to determine appropriate rates of these amendments.

GUIDELINES FOR AMENDMENT USE

1. Determine if water infiltration into soil is abnormally slow. Table 2 shows typical infiltration rates for soils of various textures.

2. If infiltration is abnormally slow, determine the cause using soil testing and evaluation. If restrictive layers exist, tillage may be needed. If a Na problem exists, gypsum, sulfuric acid, or acid-forming amendments should be used. Often, a combination of tillage and amendment application will be most effective for eliminating infiltration problems.

3. Determine application method and rates. The appropriate type and rate of amendment depends on soil and water properties, and various management factors. Each situation should be evaluated individually.

4. Practice prevention whenever possible. Manage salts and sodium before they become problems.

Conclusions

Salt in soils comes from natural sources, and also from salts added by fertilizers and irrigation water. Salt buildup is the result of a lack of effective leaching of salts out of soils. This may be caused by poor drainage due to restrictive layers, heavy soils, or sodium, or by lack of a proper leaching requirement. Pecans are sensitive to salts and Na toxicity, so proper salt control is essential for pecan production. Leaching salts through the soil is the only effective way to avoid salt accumulation. Restrictive layers such as caliche, hardpans, or clay lenses can only be corrected by tillage. Sodium occurs naturally in soils and may be present in high concentrations in irrigation water. Sodium causes dispersion of soil clays, crusting, and slow water infiltration and drainage. Sodium problems can be prevented or corrected by the appropriate use of amendments, including gypsum, sulfuric acid, and various acid-forming amendments. Sulfuric acid or acid-forming amendments are effective for correcting Na problems only in soils containing calcium carbonate.

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