

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, 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.

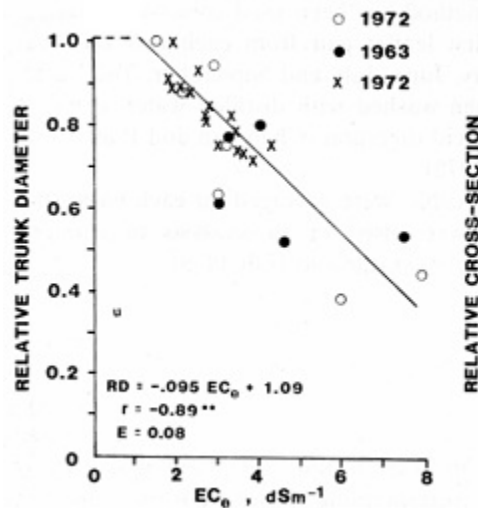
The risk of soil salinity formation is always greater in fine-textured (heavy) soils than in coarse-textured soils. This is because sandy soils naturally have larger pores that allow for more rapid drainage. Soil horizons high in clay content anywhere within the root zone may cause poor

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 a moisture deficit sooner than those in non-salty soils. This will be exhibited 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. From Miyamoto, et al., Irrig. Sci. (1986) 7:83-95.



Additionally, salty 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, which include burning or necrosis (death) of the leaf margins.

Salt-affected pecans typically have leaf burning or marginal necrosis. These symptoms may appear on older or younger leaves, and are difficult to distinguish from Na or B toxicity. 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 permeability. On the other hand, high concentrations of Na, relative to calcium (Ca) and magnesium (Mg), cause dispersion (the opposite of aggregation) which result in soil permeability problems. Unfortunately, while high concentrations of soluble salts may be beneficial for soil structure, salts are detrimental for most plants.

Soil Salinity Control

Salinity is defined by the electrical conductivity (EC) of irrigation water (EC_w) or saturated paste extract of soil (EC_e). The EC is directly related to salt content. The EC is expressed in units of dS/m. One dS/m is equivalent to 640 ppm of dissolved salts. The EC is used to measure salt content, but a measure of Na risk in irrigation water or soil requires separate measurements of Na, Ca, and Mg concentrations.

The key to controlling soil salinity is adequate soil drainage which allows salts to be leached 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 good irrigation

management are the factors under the grower's control that can help control soil salinity.

The irrigation water salinity will help to determine the soil salinity. 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. This is due to evapotranspiration effects. 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 slightly saline (EC_w 1 to 1.5), attention should be paid to the danger of salt buildup.

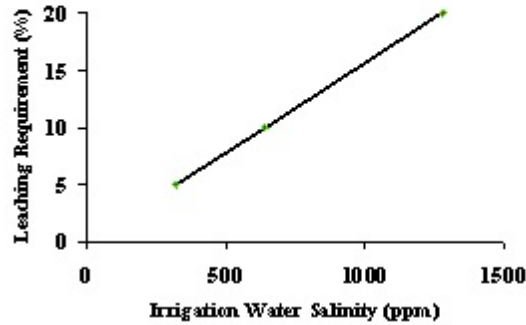
The most effective means of controlling soil salinity at tolerable levels is to leach excess water and salts below the root zone. The leaching requirement is the percent of water applied to the crop (beyond the crop's water requirement) that must leach below the root zone to maintain soil salinity at 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 2 shows the leaching requirement for pecans, depending on irrigation water salinity.

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.

Figure 2 Leaching requirement for pecans.



Tillage for Salinity Control

Unfortunately, poor soil drainage due to low permeability 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 the only effective means of increasing soil permeability. Amendments alone will 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. This sandy material can be mixed with the finer soil particles as the restrictive layer is broken up, thereby increasing soil permeability.

Formation of Soil Sodicty

Sodium is very common in arid region soils and groundwater. Although Na is a common constituent of irrigation water and soil salts, it causes a special set of problems in addition to those already discussed for 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 as an exchangeable cation on soil clays. Any soil that

has more than 10% exchangeable Na (10% of the cation exchange capacity filled with Na) may have a permeability problem. While Ca and Mg cause soil clays to flocculate and encourages good soil aggregation, Na causes clays to disperse and breaks down aggregation, which can lead to surface sealing and slow water infiltration.

The Na hazard of irrigation water is commonly assessed by the sodium adsorption ratio (SAR) which is a measure of the Na to Ca+Mg ratio in the water. Values of 6 or greater may indicate a potential Na problem, depending on soil texture. 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. The Na status in the soil is expressed either by the SAR, or by the exchangeable sodium percentage (ESP). The risk of Na buildup and resulting low permeability is greatest in fine-textured soils.

Controlling and Correcting Sodium Problems

Restrictive soil layers such as caliche, hardpans, or clay lenses can only be corrected by tillage. Sodium problems, however, can be controlled and corrected by the proper use of soil or irrigation water amendments. Leaching alone is not sufficient to prevent or correct Na problems. It is worth remembering that prevention is usually cheaper and more practical than correction.

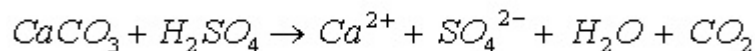
To prevent Na problems, irrigation water can be treated with amendments to lower the irrigation water SAR, or amendments can be added directly to the soil. These amendments can be either those that contain Ca (such as gypsum), or those that release Ca from carbonates in calcareous (lime-containing) soils (calcareous soils can be identified by applying a drop of acid, which causes bubbling or effervescence in the presence of calcareous minerals). The same

amendments can generally applied to irrigation water or to the soil, but in general they will be applied to and incorporated into the soil at higher rates than are used in irrigation water.

Amendments for Sodium Control

Two types of amendments can be used for Na control: Ca-containing amendments and acids or acid-based amendments. By far the most common Ca-containing amendment is gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). It is cheap, 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 known. Sulfuric acid is the most-commonly used acid amendment. Sulfuric acid and most acid-based amendments dissolve soil carbonates and yield gypsum:



Sulfuric acid can be soil-applied or water-run. Rates are commonly 1-3 tons/acre. Sulfuric acid can also be added to irrigation water to neutralize carbonates and bicarbonates, which can negatively affect water infiltration into soil. Elemental sulfur (S) is an acid-based amendment that is 97% sulfur. Soil microorganisms transform sulfur to sulfuric acid, which will react with soil carbonates according to the reaction above. One potential disadvantage of 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 even longer.

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% NH₄-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% NH₄-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, some product literature recommends rates of addition to soils that may not be effective for correcting sodium problems. Therefore, their use should be based on their simultaneous use as amendments and fertilizers, or other special factors. It is recommended that you consult with Cooperative Extension county agents or other qualified persons to determine appropriate rates of these amendments. Rates equivalent to gypsum are shown in Table 1.

Table 1. Comparison of gypsum, sulfuric acid, and acid-forming amendments.

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

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

Regular treatment of irrigation water with appropriate amendments can help to prevent the formation of Na problems. For example, irrigation water can be regularly treated with gypsum to lower the SAR of the water. Typical rates are 100-300 lb of gypsum per acre. The same amendments can also be used to address existing Na problems, although higher rates of application are usually needed. Lowering soil pH is one potential advantage of using acid-forming fertilizer amendments. However, it is usually not economical to change the pH of calcareous soils, and the potential increase in micronutrient availability can usually be more economically achieved by soil or foliar applications of micronutrient fertilizers.

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 will 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.

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

Soil Texture	Infiltration rate (in/hr)
Sand	2
Sandy loam	1
Loam	0.5
Clay loam	0.3
Silty clay loam	0.1

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.

Conclusions

Salt in soils comes from naturally-occurring salts, and from salts added by fertilizers and irrigation water. Salt buildup is the result of a lack of effective leaching of salts through 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 of salts through the soil is the only effective way to control salts. 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. Sodium problems can be prevented or corrected by the use of appropriate amendments. Amendments include 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.