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Diagnosis and Management of Salinity Problems in Irrigated Pecan Production

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Introduction

Pecans, along with Almonds and Walnuts, are among the most salt sensitive tree crops currently grown under irrigation. Yet, many growers are not convinced that salts are affecting yields, partly because symptoms of salt-affected trees are difficult to differentiate from those under other types of stress, such as water stress.

Salt problems usually appear when salinity of water used for irrigation exceeds about 500 mg L^{-1}, and the orchard consists of clayey soils or has a shallow water table. Pecans are especially sensitive to sodium (Na) and chloride (Cl) ions (Miyamoto, et. al., 1985). In other words, salt damage tends to be greater when irrigated with Na-dominated water than with gypsum or Ca and SO_4 rich water (gypseous). Salt problems are not wide-spread, but are common in areas irrigated with water with salinity greater than 700 to 1000 mg L^{-1}.

Recent drought in the Southwest and Northern Mexico has accentuated salt problems as the supply of the fresh project water has dwindled. The shortfall is usually supplemented with groundwater or irrigation returnflow which have elevated salinity. Salt problems also appear when soil and irrigation management practices are out of order.

This short article outlines ways to diagnose and manage salt problems. Readers who are interested in technical details should refer to separate publications listed at the end of this article.

Diagnosis

Symptom

The loss of tree vigor is the first symptom of salt-affected trees. During spring months, budbreak of salt-affected trees is delayed by as much as a week, and leaf and shoots develop slowly. By mid-summer, salt-

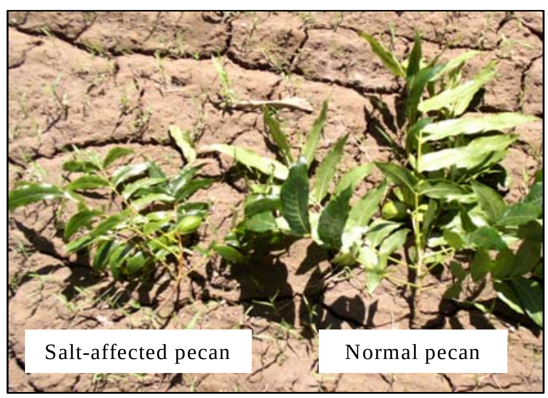

Fig. 1. Symptoms of salt-affected trees.

affected trees have small leaves with slight leaf-tipburn, which often progresses to a length of ¼ to ½ inch by the end of irrigation seasons (Fig. 1). These trees defoliate sooner than others. The second most frequent symptom of salt-affected trees is a smaller nut size and increased sticktight. Typically, salinity has greater impacts on nut size than on percent kernel (Miyamoto et al., 1986).

Pecan trees sustain leaf injury when leaves are wet with sprinklers. In these cases, salts are being absorbed directly through the leaves. This problem is frequently noted with young transplants irrigated with sprinklers, and can be readily corrected through modification of the sprinkler systems (Miyamoto and White, 2002).

Saline Tolerance

As noted earlier, pecan trees are sensitive to salts, especially to Na salts. Tree growth decreases almost linearly with increasing soil salinity or Na concentrations (Fig. 2).

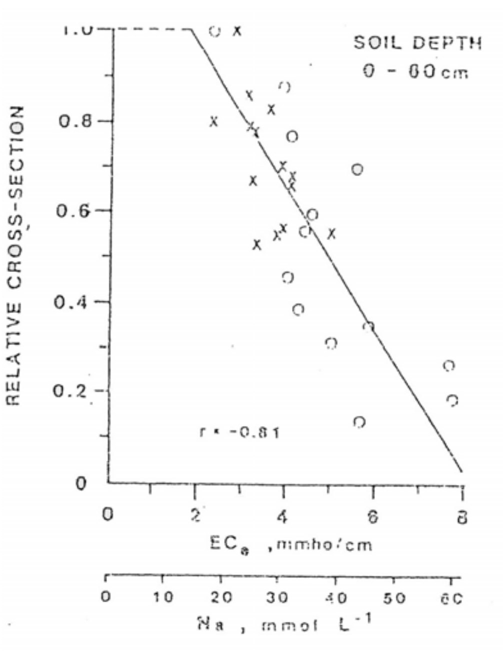

Fig. 2. Trunk cross-section as affected by salinity or Na concentrations in the soil saturation extract (Miyamoto, 1986).

The data were obtained in a pecan orchard in the El Paso Valley (Miyamoto et al., 1986). The onset of a significant growth reduction is 2.5 to 3.0 dS m^{-1} in the soil saturation extract or a concentration of Na about 20 meq L^{-1} (460 ppm) in soil samples taken from the main root zone of 0 to 60 cm. When soil salinity increases to a range of 6 to 8 dS m^{-1} (or Na concentrations of 50 to 60 meq L^{-1}), tree branch die-back usually occurs. In the areas with soils or irrigation water rich in Ca and SO_4 (gypseous), trees can tolerate salinity stress better by one or two dS m^{-1} units.

There seem to be a significant difference in salt tolerance among pecan varieties. "Wichita" is, for example, known to be more sensitive to salts and other stresses than "Western Schley". Little is known about the effects of rootstock on salt tolerance. Experiences seem to indicate that 'Riverside' is fairly salt-tolerant, and less adsorptive of Na than 'Burkett' or 'Apache' (Miyamoto et. al., 1985). Salt tolerance of various rootstocks is currently being studied.

Soil Salinity Tests

Testing soils for salinity is among the most reliable methods of diagnosing salt problems. Soil samples should be collected from the main feeder root zone, typically 50 to 80 cm deep. They should be collected on the basis of soil type, if available using a soil map (Miyamoto, 1988). It is important to look for a soil testing laboratory which uses the saturation extract method, an official method of soil salinity testing (Rhoades and Miyamoto, 1990). Make sure to ask for the data on the water content at saturation. The saturation water content provides the valuable information on soil texture and the potential for salt accumulation (Table 1). The potential for soil salinization is expressed by the salt concentration factor (SCF)

$$SCF = C_e / C_w \qquad [1]$$

where C_e is the soil salinity measured in the saturation extract, and C_w salinity of irrigation water. Many commercial soil testing laboratories use a fixed soil to water ratio for preparing the aqueous extract. Tolerance of pecan trees to soil salinity is given by salinity of the saturation extract, and can not be compared with salinity of the aqueous extract made at a fixed soil to water ratio, unless a conversion factor to the saturation extract is provided.

Table 1. Soil textures, the saturation water content, and the typical salt concentration factor in surface-irrigated pecans.

Soil Texture	Saturation Water Content	Salt Concentration Factor[1]-
	ml / 100g	
Sandy loam	< 30	1.0 - 1.2
Loam/Silt loam	30 - 45	1.2 - 2.0
Clay loam	45 - 60	2.0 - 3.0
Silty clay/clay	> 60	3.0 - 5.0

[1]- Salt concentration factor = soil salinity / salinity of irrig. water

Water Testing

Although water quality testing alone is not sufficient to appraise salt problems, the information on salinity, cation and anion concentrations is useful. The cation concentrations can be used to estimate the sodium adsorption ratio (SAR), a measure of sodicity.

$$SAR = Na / (Ca + Mg)^{½} \qquad [2]$$

where the concentrations of Na, Ca and Mg have to be expressed in mmol / liter by dividing mg L^{-1} by their respective molecular weights (Na = 23, Ca = 40, Mg = 24). As noted earlier in Table 1, the extent of soil salinization caused by the use of irrigation water with elevated salinity varies with soil types. The tentative criteria for water quality suitability for irrigation are shown in Table 2 (Miyamoto, 2002). If quality of water approaches or exceeds any of these suggested criteria, a detailed assessment for suitability for irrigation is recommended. Gypseous water can be used for irrigation even when its salinity exceeds the suggested limits. However, it should be understood that water nearly saturated with gypsum can cause gypsum precipitation, pore plugging, and impair drainage unless the field is deep chiseled time to time. These criteria are for the situation of the long-term uses, and water of poor quality may be acceptable for a short-term use, especially when orchard management practices are to be modified accordingly.

Table 2. Tentative water quality criteria for irrigated pecans (Miyamoto, 2002).

Soil Texture	Salinity limit	Sodicity limit	Boron limit
	$dS\ m^{-1}$	SAR	ppm
clay, clay loam	< 1	< 3	< 0.5
loam	1 - 2 [1]-	3 - 8 [1]-	0.5 - 1
sand, loamy sand	2 - 2.5 [1]-	8 - 10 [1]-	1 - 1.5

[1]- Larger numbers apply to Aridisols and smaller numbers to Entisols

Management

The target of on-farm salinity management is to maintain soil salinity at or below the threshold level shown in Fig. 1. This may be achieved by improving water quality and/or improving salt leaching, depending on the given circumstances. Since soil and water properties vary widely with locations, soil and water management to control soil salinity is also site-specific.

Improving Water Quality

Blending or Dilution: Two or more sources of water can be mixed to manipulate irrigation water quality. This strategy is used widely during drought by blending saline well water with fresh project water. Blending is used not only for lowering salinity, but also for lowering sodicity as well as boron concentrations to the permissible levels noted in Table 2.

If a farm operation involves field crops, besides pecans, blending may not be the best strategy. The water of best quality should be allocated to tree crops. Likewise, it may or may not be the best option if an orchard consists of multiple soil types. Water of the best quality should be allocated to orchard blocks consisting of clayey soils. The best quality water may also be set aside for production blocks with high nut loading.

Chemical Additives: Calcium compounds and acidulants have been used to lower sodicity. These practices are usually effective for promoting water infiltration when salinity of water is lower than 1 or 2 dS m^{-1} (Miyamoto, 1998). Water-run application of ammonium fertilizers (but not ammonia) is just as effective as applying Ca compounds for reducing sodicity (Fig. 3). The oxidation of NH_4 at the soil surface to NO_3 at the soil surface provides hydrogen ions (H^+), thus solubilizing Ca from $CaCO_3$ which is usually present in the soils of the arid region (Miyamoto and Ryan, 1976). Ammonium polysulfide is another compound used for many years. The oxidation of NH_4 and elemental S yields H+, and releases Ca. The effectiveness of these measures tends to decrease with increasing salinity of water, and is most consistent and reproducible in alluvial soils under clean cultivation. Sodding reduces the need for sodicity control. Leave check plots for evaluating their effectiveness.

Fig. 3. Simultaneous application of sulfuric acid and ammonia gas to fertilize trees and to condition irrigation.

Desalting: The cost of desalting has declined significantly, but is still not low enough to be economical for pecan production. Desalted water, mostly through reverse osmosis is, however, used for public water supply as well as for watering putting greens in golf courses.

Increasing Salt Leaching

Irrigation Scheduling and Management: The basic equation which describes the salt balance in the root zone is

$$LF = (D_I - ET) / D_I = C_W / [(n + 1)C_c - nC_W] \qquad [3]$$

where LF is the leaching fraction needed to maintain soil salinity below the threshold value of C_c, ET the evapotranspiration, D_I the depth of irrigation, C_W the salinity of irrigation water, and n a matching factor to compute the mean salinity of the feeder root zone; n = 1 for clayey soils and n = 2 for sandy soils. C_c is approximately equal to $2C_e$ of Eq (1).

Table 3 shows the target leaching fraction (LF) required to control soil salinity below 2.5 dS m^{-1} for sandy or clayey soils. The table includes the LF for surface irrigated orchards where soil salinity distribution varies within an irrigation unit. With increasing salinity of irrigation water, the leaching required increases, in many cases to the levels which can not be readily obtained without creating standing water. In the case of gypseous water, the LF can be estimated by subtracting 0.5 to 1.0 dS m^{-1} from the measured conductivity of irrigation water. However, lowering the LF can aggravate gypsum precipitation and subsoil pore plugging.

Table 3. The target leaching fraction (LF) to control soil salinity below 2.5 dS m^{-1} in the saturation extract.

Irrig. Water salinity		LF (Uniform)		LF (30% CV) [1] -	
		sandy	clayey	sandy	clayey
dS m^{-1}	ppm	-------- % -------			
1.0	680	8	11	11	15
1.5	1020	11	18	18	24
2.0	1360	18	25	27	35
2.5	1700	25	33	---	---
3.0	2040	33	43	---	---

[1]- Apply to spatially variable alluvial soils

The target leaching fraction given above is the theoretical value, and it may or may not be achieved, especially in clayey soils which have low permeability. The best time to leach salts is when ET is lowest. In other words, irrigation during the dormant period is most effective for leaching salts. Water treatments mentioned earlier, and improved soil and floor management practices are among the options to maintain or improve water infiltration and drainage.

Soil Management: Chiseling and trenching are two of the most frequently used methods of improving water infiltration. Deep chiseling (up to 60 to 80 cm) helps improve water infiltration and salt leaching in silty clay loam and coarser textured soils (e.g., Helmers and Miyamoto, 1990: Kaddah, 1976) as well as in soils irrigated with gypseous water. Trenching is more suited in clay or silty clay, especially when stratified, as it helps mix soil profile (Miyamoto and Storey, 1995). Feeder roots develop into the trenched area rather quickly. The effect of deep chiseling usually last for many years, and that of trenching is nearly permanent. When trenching is used along a tree row, the area beyond the trench should be deep-chiseled so as to equalize water infiltration between trenched and un-trenched areas.

Sodded floor usually provides better water infiltration than the floor under clean cultivation or treated with herbicides (e.g., Florenso et al., 1992). Table 4 shows an example obtained in a mature almond orchard established on alluvial sandy loam (Prichard et al., 1990). Water infiltration increased by having clover by as much as 26 to 96 % (Growers, however, should be advised that the presence of clover or alfalfa causes severe competition with young pecan trees, especially for satisfying spring nitrogen demands). Resident vegetation (weeds) as well as Bromegrass also helped improve water infiltration toward the end of the season. Bromegrass is a cool season grass. However, both residence vegetation and clover increased water consumption by 14 to 17 %. The water consumption by the floor vegetation could have been greater if the orchard were young. The test orchard had 70 % ground shade. Overall, the improvement in water infiltration exceeded the increase in water consumption, but the effect on soil salinity is unknown as it was not measured. It is also unknown if sodding helps improve infiltration of gypseous water.

Table 4. Consumptive water use and infiltration depth into the floor of almond orchard (Prichard et al., 1990).

	Water use		Infiltration	
	(Apr - Sept)		May	Aug
	inch	%	cm/2 hrs	
Resident Veg.	32	117	5.2	5.5
Clover	31	114	6.7	6.3
Bromegrass	27	100	5.3	6.5
Herbicide	27	100	5.3	3.2

[1]- Mature orchard with 70 % shading

There is no local report on the effect of floor management on water infiltration.

However, several growers have been testing a minimum-till surface chisel to loosen compacted surface soils with minimal disturbance to the soil surface (Fig. 4). This equipment has been marketed to maintain water infiltration into pasture with extensive livestock foot-traffic, and the shank penetrates to 15 to 17.5 cm deep. The passage of the shanks was found to cause extensive cracking of the surface soil if the soil is dry or moist (Fig. 4). This practice reduces growth of resident vegetation, which is probably desirable during summer months. In surface irrigated orchards, this equipment may be used after the completion of spray application at the end of June, then upon nut harvesting. This shallow minimum-till chisel usually does not adequately improve water infiltration into deep clayey soils. Such soils would require a deep chisel as shown later in Fig. 5.

Reclamation

If soil salinization continues, it may require more potent measures. The specific measures required depend on site conditions, especially soil texture and water tables, and at times, chemical properties of the soils and water.

Site Investigation

Site investigation for reclamation should include soil texture, profile configuration, the rooting patterns, and the depth to the water table. It is essential to identify the soil horizon which is likely restricting water movement, salt leaching, and root development. Soil samples, along with irrigation water samples, should be collected and be analyzed for salinity and sodicity. The record of irrigation is also useful for assessing irrigation management. If the water table is less than about 150 cm from the ground surface, water table monitoring wells should be installed (Miyamoto, 1989).

Reclaiming Clayey Soils

If the entire orchard consists of silty clay or clay, and salinity of irrigation water can not be lowered below 600 to 800 ppm, it may be an

Fig. 4. A minimum-till surface chisel being tested for alleviating soil surface compaction in pecan orchards.

option to transplant the trees into more suitable sites. If trees are damaged extensively, they should be pruned. If clayey soils appear in small portions, trenching will help (Miyamoto and Storey, 1995). If the orchard consists of silty clay loam or clay loam, deep chiseling improves salt leaching (Helmers and Miyamoto, 1990). Many subsoilers made of high strength steel are capable of subsoil down to 70 to 80 cm with minimal disturbances at the ground surface (Fig. 5 and cover page). Topdressing of subsoiled floor with sand helps sustain permeability.

Fig. 5. Subsoiling shank penetrating 70 cm deep.

If the soil test shows that the exchangeable Na exceeds 10 or higher, and that the soil is dispersed, the use of chemical amendments, such as gypsum and sulfuric acid can help reduce soil sodicity and speeds up reclamation, especially in alluvial soils which have weak soil structure (Miyamoto, 1998). Chemical amendments should be applied after chiseling or trenching, and there is no need to incorporate them into the soil. The uniform application of chemicals improves the effectiveness. Once chemicals are applied, leaching irrigation has to be made in order to leach salts, usually by applying two consecutive deep irrigations during the dormant period to leach salts out of the main root zone. Applications of chemicals without chiseling did not improve salt leaching (Helmers and Miyamoto, 1990).

Reclaiming Soils with High Water Table

There are places where high water tables hinder salt leaching. Even there is a tile drain in such fields, the quantity of water applied to salt leaching can exceed the capability of the drain system. Under such circumstances, a special leaching technique should be considered. One method is to set two borders along the tree rows, then irrigate only within the strips (Fig. 6). This leaching technique helps lower drainage load,

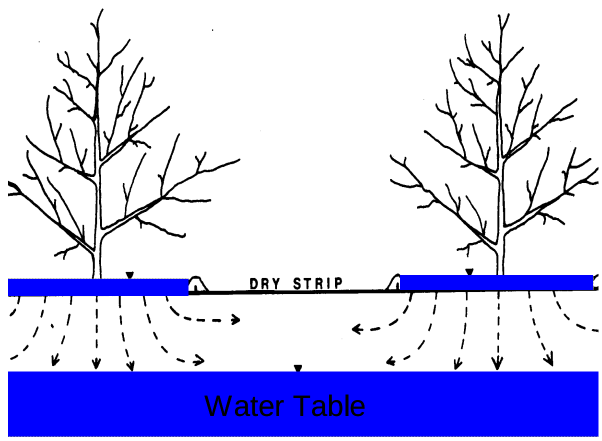

Fig. 6. Strip leaching of salted orchard with a high water table.

and store salts between the tree rows, which can be leached when the water table recedes after an irrigation season (Miyamoto, 1989). However, this method would be less effective in close-spaced mature orchards. The quantities of leaching water required vary with soils and salt levels, and typically 30 to 60 cm. Once salt leaching is completed, sodding may help develop soil structure.

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