Salt leaching in pecan orchards of the Southwest

By S. Miyamoto

Pecans, along with almonds and walnuts, are among the most salt-sensitive tree crops currently grown under irrigation. Many growers are not aware that salts are affecting tree growth, nut yields and quality, because symptoms of salt-affected trees are difficult to differentiate from water stress (Fig. 1). Diagnosis of salt problems and general approaches for minimizing soil salinization have been previously discussed (Miyamoto, 2006: Miyamoto et al., 1986). The present article provides additional information on practices of salt leaching during routine irrigation as well as salt leaching irrigation for restoration.

The objective of salt leaching is to keep root zone soil salinity below a level that negatively impacts tree growth and production. The threshold salinity of irrigated pecans is in the range of 2 to 3 dS m^{-1} when measured in the soil saturation extract (Miyamoto et al., 1986), an official method of measuring soil salinity (Rhoades and Miyamoto, 1990). In areas rich in gypsum, trees may tolerate higher levels of soil salinity, probably by 1 or 2 dS m^{-1}. Calcium and sulfate ions are less harmful to pecan trees than sodium and chloride ions (Miyamoto et al., 1985).

There are 2 ways to approach the task of salt leaching. The first approach is to leach following each irrigation as a maintenance practice. The second approach is to let salts accumulate in the orchard during the growing season and correct by flushing during the dormant period. The latter takes into account the reality that; soil salinity levels vary widely even in a small orchard, and it is more convenient to leach during the dormant period. Once any part of the orchard begins to be salinized, growers need to carry out salt leaching irrigation for restoration. Needless to say, the cause of soil salinization has to be identified prior to deciding the method of salt leaching for restoration. This subject is discussed in the second part of this article.

Minimizing Soil Salinization Theories:

Salts are carried into irrigated fields through irrigation water. The quantity amounts to at least several tons per acre annually, depending on the salt content of the water and the irrigation rate. If there is no drainage, salts accumulate in the order of 20 to 50 tons/acre in 10 years. Leaching salts is therefore critical to health of the orchard. There are 2 concepts in orchard salinization; one concept assumes that irrigation management is the key to prevent salinization, and the other assumes that soil type controls soil salinization. Both concepts are correct, depending on circumstances.

Irrigation-Based Approach: This approach is cited in numerous publications under the common name of "leaching equation", and is based on the idea of providing the drainage required to maintain the salt balance in the root zone each time we irrigate (Rhoades, 1974). The leaching equation has several assumptions: a) the site soil is permeable enough to allow necessary water infiltration and drainage, and b) the salt carried into the field is being leached quantitatively, and c) crops respond to the mean salinity of the root zone. The applicable equation to compute the leaching requirement is

$$LR = (D_w - ET) / D_w = EC_w / EC_d \quad (1a)$$

$$= EC_w / [2 (n + 1) EC_e - nEC_w] \quad (1b)$$

where LR is the leaching requirement, D_W the depth of irrigation, ET the consumptive use, EC_w the salinity of irrigation water, EC_e the mean salinity of the root zone measured in the soil saturation extract (Rhoades and Miyamoto, 1990), and n is an empirical coefficient. Typically, n = 2 in sandy soils, and n = 1 in clayey soils (Rhoades, 1974; Miyamoto et al., 1986).

The consumptive use varies with tree sizes, weather conditions (Miyamoto, 1983: Miyamoto, 1985), as well as floor management practices (Prichard et al., 1990). We assumed a typical annual use rate of 40 inches, and the threshold soil salinity (EC_e) of 2.5 dS m^{-1} (Miyamoto, 2006: Miyamoto et al., 1986). The computed leaching requirements and the irrigation needs are shown in Table 1. The leaching requirement increases with increasing salinity of irrigation water, and so does the irrigation water requirements. This type of estimate may be found in many other publications.

The question is how reliable is the estimate? In the New Mexico section of the Middle Rio Grande, salinity of the water ranges typically from 400 to 600 ppm (or 0.6 to 0.8 dS m^{-1}), and we seldom observe soil salinity exceeding 2.5 dS m^{-1}. In the El Paso Valley, it usually ranges from 700 to 850 ppm or 1 to 1.2 dS m^{-1}, and salt problems are increasingincrease downstream, especially in clayey soils. The leaching requirement computed by Eq (1) is small, ranging from 2 to 11 percent for the prevailing salinity of irrigation water used in the region (Table 1). Nonetheless, the equation shows that growers in the El Paso Valley need to better use a greater quantity of water than the folks upstream. This seems to make sense. However, it does not necessarily indicate that Eq (1) is reliable, but simply means that the LR is small when salinity of irrigation water is low. In reality, the errors involved in estimating the consumptive use or measuring the check-in flow are usually larger than the difference in irrigation quantity needed to meet the prescribed leaching fraction at a low salinity range (Miyamoto, 1983). In other words, Eq (1) is essentially a conceptual model, and soil salinity has to be checked through soil salinity monitoring.

There are also some questions about Eq (1) at a high salinity range (>2 dS m^{-1}) where irrigation water

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is rich in Ca and SO_4 (gypseous). In the Pecos Basin of New Mexico and the Tularosa Basin, for example, water with salinity reaching 3 dS m^{-1} is commonly used for irrigating pecans. Calcium and sulfate ions are less harmful to pecans than Na or Cl. In addition, salinity of drainage water when irrigated with gypseous water does not increase linearly with increasing water evaporation, as Ca and SO_4 precipitate as gypsum. Eq (1) should then be rewritten as

$$LR = (D_w - ET) / D_w = EC_w / [(1 - p)\ EC_d] \qquad (2a)$$

$$= EC_w / (1-p)\ [2(n + 1)\ EC_e - nEC_w] \qquad (2b)$$

where p is the portion of salts precipitated, which can be measured by evaporating the gypseous water to the level comparable to 1/LR, and checking the changes in conductivity.

Eq (1) also becomes questionable when water of high salinity has to be used for irrigation. This is a situation that many growers face when the supply of the project water curtails. The leaching requirement becomes so large that it is difficult to implement, because soil permeability is too low or the water table is too high. In other words, soil conditions begin to dictate salt leaching feasibility.

Table 1. The leaching requirements to control soil salinity below 2.5 dS m^{-1} in the soil saturation extract at an annual consumptive use of 40 inches

Irrigation water salinity		Leaching Regiment Sandy	Leaching Regiment Clayey	Water Required Sandy	Water Required Clayey
dS m^{-1}	ppm	-------%-------		---inches/year	
0.5	340-375	1	5	40	42
1.0	680-750	8	11	43	44
1.5	1020-1125	11	18	44	47
2.0	1360-1500	18	25	47	50
2.5	1700-1875	25	33	50	53

Table 2. 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 or irrig. water

Soil-Based Approach: This approach is based on field observations where salt problems seem to occur mainly in certain soil types. In the case of the Middle Rio Grande Basin, for example, salt problems usually appear in clayey soils (clay loam, silty clay and clay), or in areas with high water tables, almost independently of irrigation management (Miyamoto and Cruz, 1987, 1988). Soil salinization is also reported in other areas where irrigation water has elevated sodicity (SAR > 6). Soil permeability becomes low due to adverse effects of Na on soil structure, regardless of how one attempts to water. There are many other cases where soil conditions dictate soil salinization.

There are 3 important practical steps in managing salinity from a soils-based concept. First, detailed soil-mapping to identify structural and chemical changes in an orchard. Soil-mapping is conveniently available on the internet at http://websoilsurvey.nrcs.usda.gov. If an area of interest is not mapped, it may be necessary to create one, relying on seasoned field men. Second, irrigation scheduling must be developed by using the best estimate of consumptive use and soil water holding capacity, first ignoring the salinity control aspect (Miyamoto, 1985). Third, establish soil salinity checking sites covering different soil types. We then compute the following parameter called the salt concentration factor (SCF).

$$SCF = EC_e / EC_w \qquad (3)$$

where EC_e and EC_w are the measured soil salinity, and salinity of irrigation water, respectively. The measurement of EC_e should be performed at least 3 to 5 sites per soil type as soil salinity readings are highly variable. The typical range of SCF obtained in the El Paso Valley is shown in Table 2 (Miyamoto and Cruz, 1987, 1988). The data shown exclude the area with a water table less than 6 feet. The orchards where we made the observation had been irrigated under the leveled basin using water from the Rio Grande. In practice, soil salinity (EC_e) can be estimated for various salinity of water, using the predetermined SCF values for basin-irrigated fields. For sprinkler irrigated fields, we do not have sufficient data to offer a guideline, but the SCF values should be smaller than listed. If EC_e is to exceed in a given soil type, then the typical course of action is to examine and work on the soils, rather than simply increasing irrigation.

High water tables, especially when charged with salts, are another source of salinization. This problem becomes a concern when the perched water approaches about 6 feet, and becomes very difficult to manage when reaching about 5 feet. The upward capillary flow can bring in excess of 8 to 10 tons of salts per acre per year if the perched table has salinity of 3000 ppm and move up 2 acres-feet per season. Frequent irrigation can help reduce the upward movement only if the drainage water can displace the shallow perched water. Otherwise, the leaching water applied will bounce back. There is no simple way to estimate the leaching requirement to control soil salinity in the presence of saline high water tables. Monitoring of water table levels (or the soil water potential), and

Fig. 1. Symptom of salt-affected trees.

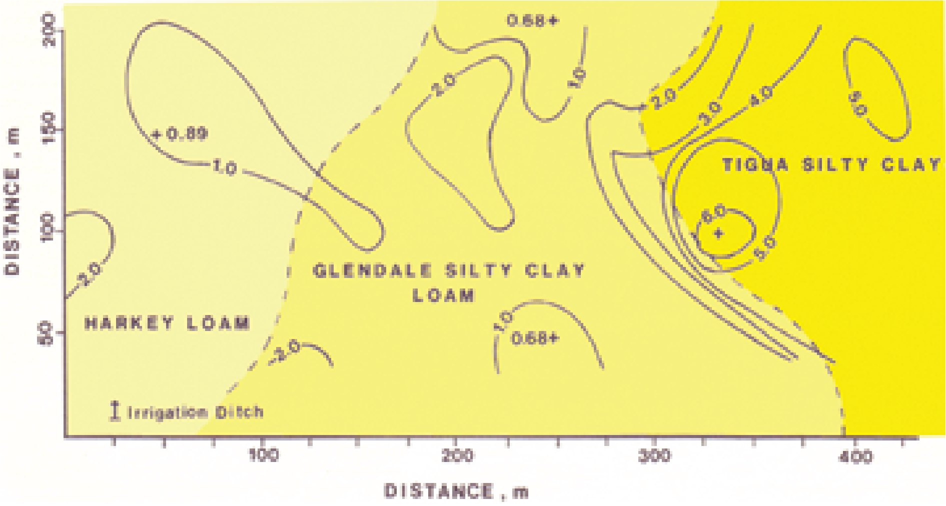

Fig. 2. The distribution of soil salinity in dS m^{-1} at 0 to 2 ft. in a 34-acre border-irrigated pecan orchard consisting of 3 different soil types. Irrigation borders run perpendicular to the horizontal axis.

salinity of soil and the perched water is usually required (Miyamoto, 1989). Field-level monitoring data will help adjust irrigation management appropriately.

The incidences of soil salinization are much less frequent in the orchards established on sandy upland soil, even when it contains a layer of caliche (cemented with $CaCO_3$). The calcic horizon is usually permeable, but it surely limits root developments and the rate of drainage, thus inducing micronutrient deficiency. Soil salinization in orchards developed in gypseous areas has been reported from time to time. Soil pore plugging caused by gypsum precipitation is suspected to be the cause. Annual gypsum loading amounts to 21.5 tons/acre when irrigated with gypsum-saturated water at the depth of 40 inches per year.

Practical Options

Increase Irrigation: The most common remedy used to reduce soil salinity is to increase the quantity of irrigation per application. This approach is effective if the soils are permeable enough to accommodate increased irrigation, and that such a practice will not raise the water table to a risky level.

Excessive irrigation of poorly permeable or poorly drained fields can lead to premature defoliation. If a basin or a border method is used, it is essential to have good ground preparation to allow uniform distribution of irrigation water. It is also desirable to have a similar soil type within an irrigation block, especially when the basin method is used. Otherwise, ponded water will percolate through the sandy portion, thus leaving clayey portions poorly leached.

Fig. 2 shows an example of soil salinity distribution in the basin-irrigated pecan orchard consisting of multiple soil types (Miyamoto and Cruz, 1988). The area consisting of clayey soils usually presents low permeability and high soil salinity. If soil salinity does not decrease even when irrigated more than what the leaching equation predicts, one has to examine the soil.

Improve Soil Permeability: Various methods are available for increasing soil permeability and salt leaching, including chiseling, trenching, and chemical amendments (Miyamoto and Storey, 1995; Miyamoto et al., 2002). Sodding can be included as a means to sustain soil permeability (Folorunso et al., 1992; Prichard et al., 1990).

There is ample evidence to indicate that soil permeability decreases with soil compaction (e.g., Shafiq et al., 1994; Sillon et al., 2003). Chiseling is simple and is used most widely. An example of chisels is shown in Fig. 3A. The shank penetration is adjustable up to 7 inches, equipped with coulters to reduce the surface disturbance and damage to the vegetative cover. Some growers remove the coulters in order to obtain weed control and fertilizer incorporation during spring to early summer months. This type of shank neither forms a disk pan nor pulverizes soil clods, both of which adversely affect water infiltration. However, these methods may not adequately improve permeability of deep clayey soils.

Chemical amendments are a supplement to physical measures, and are intended to reduce aggregate disintegration caused by exchangeable sodium (NaX)

Fig. 3. Minimum-till surface chisels used for improving soil permeability.

when salinity of irrigation water is comparatively low, e.g., less than 1 or 2 dS m^{-1} (Shainberg et al., 1982). We previously discussed examples of using sulfuric acid and acid-N fertilizer mix to reduce aggregate destruction (Miyamoto, 1998), and other publications report the use of calcium chloride and other water soluble chemicals and polymers for improving permeability (e.g., Wildman et al., 1988, Wallace et al., 1986).

The effectiveness of chemical amendment depends on physical and chemical properties of soil and water quality. A sodded floor usually reduces the need for chemical amendments as it helps improve soil particle aggregation and infiltration (e.g., Prichard et al, 1990; Florenso et al., 1992). These methods, however, may not adequately improve permeability of deep clayey soils or compacted soils, unless physical measures are used first or concurrently. The use of chemicals for restoration of salt-affected soils is discussed in a later section.

Modify or Change Irrigation Methods: Among the most commonly used methods of irrigation, sprinklers are considered most efficient for leaching salts. The primary reason is that downward movement of soil water flow under sprinklers is unsaturated flow which provides a high level of salt leaching per unit quantity of water applied (Oster et al., 1972). This, however, depends on soil profile configuration. For example, stratified soils prevalent in alluvial basins interfere with soil water movement, and creates saturated flow in clay strata present above the sand or sandy layer. Under such situations, sprinklers may not have the distinct advantage.

Sprinkler irrigation also has the advantage in high water table areas or uneven grounds, as they provide a high degree of water application control. At the same time, it is not uncommon to see an increase in soil salinity upon the conversion to sprinklers, due to arbitrary cut-backs in quantity of irrigation. It can also induce foliar salt damage when sprinkler streams wet leaves.

Drip irrigation, especially subsurface drip irrigation, has been shown to provide efficient salt leaching in field crop production (e.g., Hanson and Bendixen, 1995). The flow under drip irrigation is largely unsaturated flow, and the evaporation-driven salinity increase associated with high frequency sprinkler irrigation is minimal with drip systems. This method of irrigation, however, has not been without problems. The ab-sorption of water into soils for example, is soil-dependant, and is low in clay or sodium-affected soils. In coarse sand or gravely soils, water infiltrates straight down with minimal lateral spread.

The conversion from surface or sprinkler irrigation to drip has also been problematic, as the wetting patterns may not be compatible with the existing rooting patterns. This problem can be partly offset by placing large numbers of emitters (Henggeler and Roak, 1992; Henggeler and Word, 1995).

Subsurface drip systems also create salted-surface soils, (unless rainfall is adequate to leach salts into the root zone below the emitter depth), as well as salt accumulation at the wetting front. The accurate prediction of soil salinity under drip irrigation is not easy (e.g., Hanson et al, 2009), thus requiring field-level salinity monitoring.

The efficiency of surface irrigation has been considered to be low. However, introduction of laser leveling and high flow turn-outs improved water distribution efficiency. In terms of salt leaching efficiency, flooding may not provide the best results, as discussed earlier (Fig. 2). It is a challenge to devise borders so as to have a group of similar soil types within a basin. Alternatively, it would be helpful to implement measures to improve soil permeability only in areas consisting of clayey soils.

Table 3. The depth of leaching water required to leach salts from various depth of soils to half of the initial soil salinity

Soil depth	Intermit[1] k = 0.1	Sandy 0.2	Loamy 0.3	Clay 0.4
Inch---	------------------Inch	------------------------		
18	3.6	7.2	11.9	14.4
24	4.8	9.6	14.4	19.2
30	6.0	12.0	18.0	24.0
36	7.2	14.4	21.6	28.8

*we need to add the depth of water required to bring the soil moisture to the field capacity level

[1] intermittent leaching irrigation

Salt Leaching Irrigation for Restoration

Theory of Leaching Water Requirements

The quantity of water required to leach salts from a specified thickness of soil profiles has been an interest of growers, and it varies with soil types and the method of leaching. A simple practical equation was developed by Hoffman (1980), using field data.

$$C / C_o = k / (D_w - D_o) / D_s, D_w > D_o \quad (4a)$$

or

$$D_w = kD_s / (C / C_o) + D_o \quad (4b)$$

where C_o is the initial salt concentration in the soil, C the soil salinity upon initiation of salt leaching, D_o the depth of water required to wet the soil, D_w the depth of leaching water applied, D_s the soil depth to be leached, and k the empirical coefficient; 0.1 for sandy loam, 0.3 for clayey soils (Hoffman, 1980). Under intermittent pondering, k is approximately equal to 0.1, irrespective of soil types. In soil column studies, we found k = 0.23 for silty clay loam, and k = 0.4 for silty clay under ponded leaching (Miyamoto and Enriquez, 1990).

The depth of water required to leach salts from the specified depths to half of the initial value (or $C / C_o = 0.5$) is shown in Table 3. It was assumed for calculation that the soil moisture content is at or near field capacity at the onset of leaching. If not, the quantity needed to bring the soil moisture to the field capacity has to be added.

The quantity of water needed for

salt leaching is highly dependant on soil types as well as the methods of irrigation used. Intermittent leaching provides efficient leaching of salts, as it yields unsaturated flow. The leaching water passing through large soil pores is not nearly as efficient as water flow through small pores. However, intermittent leaching usually takes more time to complete salt leaching, including the rest period between leaching irrigation cycles. Under high evaporative conditions, this adds to the water requirement, which is ignored in the example of the estimate by Eq (4).

This also brings back the same question. How reliable is the estimate? It is somewhat more reliable than Eq (1), mainly because there is little need to account for the evapotranspiration, which is low during the dormant period. However, we have uncertainty with the factor, *k*. The best policy would be to apply the leaching water in 2 or 3 increments, then check soil salinity until soil salinity is reduced to a desirable level, e.g., less than 2 to 3 dS m^{-1}. Since the soil conditions are highly spatially variable, it is normal to use different amounts of water for salt leaching within an orchard.

In gypseous soils or the soils irrigated with gypseous water, soil salinity may not decrease below 2.2 to 2.4 dS m^{-1}, which is the electrical conductivity of water saturated with gypsum. In such cases, the concentration of Na or Cl may be used as an indicator of leaching completion. The threshold Na or Cl concentration in the soil saturation extract is currently estimated at between 15 and 20 me/liter or 350 to 450 ppm for Na, and 500 to 700 ppm for Cl (Miyamoto, 2006). These numbers are subject to change as new data develop.

Fig. 4. Break up of compacted clay with a ripper.

Practices of Leaching Irrigation for Restoration

The methods of leaching irrigation depend largely upon the existing irrigation system, and the types of soils involved. Several items, however, should be kept in mind. We already mentioned that it is preferable to apply leaching irrigation during the dormant period, and that intermittent leaching does a better job of leaching salts, but takes a longer time. This becomes a constraint when one has to complete the task during a short period, especially in clayey soils having low permeability. Improving soil permeability may become necessary as a pretreatment.

Pretreatments

__Chiseling__: Chiseling is the most popular method, mainly because it is simple and fast to implement as compared to soil profile modification. There are at least two types of chisels; rippers and subsoilers, besides minimum-till surface chisels mentioned earlier (Fig 3). Minimum-till surface chisels are designed primarily to alleviate compaction imposed by ground preparation for harvesting and pruning, and have limitations in improving drainage, especially in deep clayey soils. Rippers are among the most widely used chisels, and have the curved shank to rip soil profiles. The working depth varies from 2 ft down to 6 ft. Deep rippers are used mainly to break up the horizontal orientation of soil profiles (e.g., Kaddah, 1976), including clay pans and calcic pans if present. An example of compacted clay clods broken off with a ripper is shown in Fig. 4. Ideally, this type of shanks should be used prior to tree planting, but is used even in mature orchards. An advantage of rippers is the power requirements which are much lower than that for subsoilers made of straight shanks. The disadvantage is that it tends to bring up large roots to the surface and requires extensive working of ripped soil surface, which usually takes a longer period than the chiseling operation itself. Deep chiseling may be implemented prior to leaching, preferably one side of the tree rows per season prior to an anticipated off-year season. Deep chiseling is also effective in breaking out caliche in gypsic soils.

Fig. 5. Subsoilers used for improving soil permeability.

Subsoilers are basically straight shank (Fig. 5), and are designed to improve permeability and subsoil drainage. It requires a large tractor to pull, about 30 to 40 HP per shank, depending on soil hardness. The advantage is two fold. This operation is fast, and this type of shank does not disturb soil surface (unless it is very dry). In other words, leaching water can be applied as soon as chiseling is completed. Subsoilers cause root damage similarly to deep rippers, but subsoilers cut off the roots, instead of bring them up.

In the case of heavy clay soils, growers experienced slow water infiltration even after deep chiseling. Application of dry sand after or prior to chiseling helps maintain soil permeability, as the sand fills the chiseling cracks. Without the addition of sand, it is uncertain how long the effect of chiseling will last. The sand layer left on the ground also improves trafficability and reduces evaporation. Under certain circumstances, it may be possible to add a substantial amount of sand into the clay layer through several steps of operation. For example, subsoiling may be implemented in one-direction, and then a layer of dry sand can be placed. Thereafter, impose cross-chiseling with a ripper to allow sand incorporation between clay clods. The sand between clay clods acts as the medium for water infiltration, root developments, and salt leaching. This operation can elevate the ground level, which has to be taken into consideration.

Trenching or Excavation: This method of improving soil permeability was initially used to improve surface drainage by trenching the midpoint between two tree rows. Unfortunately, it did not affect tree growth. Subsequently, the location of the trench was moved to the tree dripline, and some growers made the trench wider and deeper. Mixing of an equal amount of sand and clay creates loam which is shown to be good for pecans. However, the sand to be used for mixing should be medium-textured or loamy sand, but not coarse sand.

Some growers dig the trench as deep as the excavator can reach, because of the concern that there might be the second layer of clay. Extra-deep excavation is intended for lowering the water table or improving drainage, rather than modifying root zone soils. The width of the trench also varies, but a rule of thumb is to provide at least the width of the dripline, although this would be affected by the age and size of the trees as well as depth of the rootzone.

There is an indication that thorough mixing of sand and clay is not needed. The sand placed between clay clods serves as a water conductor, and facilitates salt leaching, root developments, and possibly improved aerification. Application of chemical amendments may become necessary once subsoil affected by Na is brought to the surface through trenching or excavation.

Chemical and Water Application

Chemical amendment is to prevent the formation of surface seal during the leaching process, and to lower sodicity of the soil surface where soil particle dispersion takes place (Miyamoto and Enriquez, 1990). Soil sodicity is measured by the exchangeable sodium percentage (ESP) or the sodium absorption ratio of the saturation extract, and can lower water infiltration when exceeds a range of 6 to 9 in some soils (Rhoades and Miyamoto, 1990). The type of chemical amendments needed is the compound which provides calcium at a high concentration enough to keep soil particles flocculated during the leaching process, and helps reduce exchangeable Na at the soil surface. Powdery gypsum is ideally suited for this purpose. In the case of severely Na-affected soils, sulfuric acid usually works better (Miyamoto, 1998).

The application rate of chemical amendment has been calculated based on the quantity of Ca needed to replace the exchangeable sodium percentage to a predetermined value from the root zone. In practice, 5 to 10 tons of powdery gypsum is commonly used per acre, mostly for a budgetary reason. Our observation is that these

conventional rates are acceptable, as long as the powdery gypsum is applied uniformly on the ground surface. Incorporation into the surface layer is not needed. Gypsum is used mainly to prevent soil surface sealing during the leaching process, rather than for lowering ESP to a preset level. Application of gypsum without chiseling or profile modification did not improve salt leaching when tested in the El Paso Valley (Helmers and Miyamoto, 1990), where irrigation water has low sodicity (SAR < 3 - 5). Alternatively, water soluble amendment can be applied to leaching water as mentioned earlier.

Application of leaching water should be completed by bud-break or sooner. We already mentioned that intermittent application is preferred if there is ample time. In the case of basin irrigation, most growers seem to prefer adding 6 to 8 inches of water for the first run, then additional irrigation as field conditions dictate. Trees can tolerate wet soils during the dormant period.

When the water table is high and stagnant, the leaching water applied will bounce back, even when tile drains are installed. The quantity of drainage water which has to be removed under salt leaching irrigation is usually much greater than drain capacity. One method of reducing this problem is to provide dikes on both sides of a tree row so as to pond the water near the trees (Fig. 6). This partial ponding method (Miyamoto, 1989) helps leach salts away from the tree rows, and pushes salts towards the center, which can be handled when the water table recedes.

Similar results can be realized by using driplines placed on both sides of tree rows. However, when the lines are placed a great distance from the tree trunks, they can push salts into the tree rows. When soil profile modification is used in the form of two trenches on both sides of a tree row, salts can also move towards the tree row if they are placed too far from the trees, as irrigation water infiltrates mainly through the trenched areas. Trenching should be implemented when trees are young or at the time of planting. If soil profile modification is implemented on tree rows, salt accumulation in the tree row should not be a significant factor.

Post Leaching Care and Tree Response

If soil profile modification or deep rippers are used as pretreatment, soils are going to settle upon the application of leaching irrigation. Additional ground leveling work has to be scheduled. Sodding of the freshly leveled ground may speed up the development of soil structure. If chiseling with minimum-till surface chisels or subsoilers are to be used as pretreatment, no additional post-leaching care would be required, especially when topdressing with loamy sand. However, leaching irrigation is likely to leach out not only soluble salts, but also nitrate (NO_3). Upon completion of leaching irrigation, nitrogen fertilizer, usually uran through water, should be applied.

Root damage caused by trenching and chiseling has been a concern. In fact, most horticulturists are not in favor of any sort of chiseling or trenching for this reason. This concern is probably justifiable in deep sandy soils where tree roots extend properly and salts rarely accumulate. In reality, root developments in soils which are prone to salinization are usually constrained.

In clayey soils developed over sandy subsoil, for example, pecan roots tend to develop laterally as shown in Fig. 7A, which can best be described as "cable roots" with little branching or vertical penetration. Cutting of these roots, either through deep chiseling or trenching causes development of multiple roots (Fig. 7B) in a manner similar to branching of shoots by cutting off a limb. In a year or two, fibrous roots extend into the soil zones improved through chiseling or trenching (Fig. 7C). This pattern of root regrowth indicates that chiseling or trenching can actually be beneficial for establishing of improved rooting patterns, provided that chiseling with sand application or trenching are implemented adequately and systematically.

If there was no severe root removal, tree response to salt leaching may appear first as uniform budding, then improved shoot and leaf growth as early as May. (High soil salinity slows bud-break, and shoot and leaf growth). When deep chiseling or soil profile modification is used, tree response, mostly consisting of improved foliage may not occur until June or July, as the roots have to regrow first. Salt leaching impacts on nut yields may take a season or longer, depending on the severity of the salt damage. After all, trees must restore roots and leaf growth first. The challenge at present is the lack of understanding how best the roots should be pruned for improved tree performance, especially relative to water and nutrient uptake, and alternate bearings. It is an opinion of author that some attention should be given to tree roots, besides tree tops. At present, guidelines for soil and root maintenance are poorly developed, especially in hedged orchards without tree thinning.

Summary

Salt build-up is a common problem in irrigated pecan production in the wWest. The primary causes include inadequate irrigation, low soil permeability, poor internal drainage, and high salinity of irrigation water. Salinity tests of soil samples collected from different soil types or management units are the first step toward identifying this problem. Soil salinization can be reduced by improving irrigation and soil management practices. When the orchard is already salinized, soil profiles and rooting patterns should be examined. In many cases, pretreatments involving chiseling or trenching may be required for improving soil permeability prior to commencing leaching irrigation. Deep chiseling and/or trenching is ideally suited for improving soils prior to tree planting. When used in established orchards, roots are pruned during these practices, hence they should be implemented carefully after examining soil profiles and rooting patterns. Rooting patterns may actually be improved. The shortcoming at present is the lack of understanding of root pruning effects on water and nutrient uptake, and tree performance. Growers may select a single method of salinity management or integrate multiple methods to improve soil properties and overall tree performance.

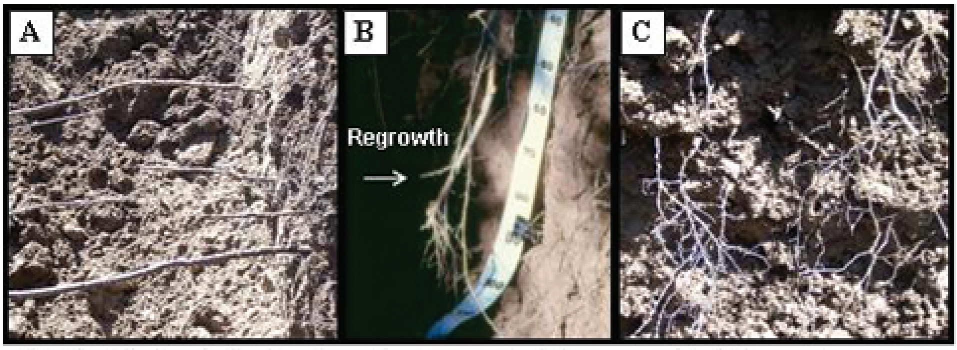

Fig. 7. Horizontal extension of pecan roots (A), regrowth of the root upon cutting (B), and development of new fibrous pecan roots (C).

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